Hydrogeology, Groundwater Chemistry and Land Uses in the Lower Umatilla Basin Groundwater Management Area

Northern Morrow and Umatilla Counties
Oregon

(Final Review Draft)

Gerald H. Grondin
Oregon Department of Environmental Quality

Karl C. Wozniak
Oregon Water Resources Department

Dennis O. Nelson
Oregon Health Division

Ivan Camacho
Oregon Department of Environmental Quality

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Sheri Wadekamper
Gene Kerby
LtC William D. McCune
LtC Larry A. Sparks
Barry Beyeler
Bob Levy
Phil Walchli
Frank Mader
Tom Able, Jr.
Bob Kenny
Duane Neiffer
Chester Prior
Jeff Lyon
Dennis Reisch
Brigitta Lamb
Don Eppenbach
Ron Shoemaker
Rudy Bergstrom

Technical Advisory Committee:

Jerry Anderson
Fred Ziari
Charlie Newhouse
Don Wysocki
Jerald Rea
Tom Darnell
Loren Unruh
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Well Identification and Location Systems

Wells are identified in this report by the well log ID assigned by the Water Resources Department. The ID consists of the first four letters of the county and a six-digit sequentially number. Wells with more than one well log were assigned the ID of the earliest well log of record. Wells without well logs on file are designated by the letters LUB (Lower Umatilla Basin).

Wells sampled by the Department of Environmental Quality are also identified by a three-character project code (UMA) and a sequential number. Cross references are made in the appendices of this report.

Well locations in this report are based on the rectangular system used for the subdivision of public land. Each location is designated by listing land tracts of descending size as shown in Figure 4.1. For example, the well location 4N/28E-20aab indicates a well located within township 4 north, range 28 east (36 square miles), section 20 (1 square mile). The first letter following the section (a) represents the quarter section (160 acres), the second letter (a) the quarter-quarter section (40 acres), and the third letter (b) the quarter-quarter-quarter section (10 acres).

Locations of geographic features are also based on the public land survey system but, following convention, are designated by land tracts of increasing size. For example, the notation NW/NE/NE 20-4N/28E indicates a feature located in the northwest quarter (10 acres) of the northeast quarter (40 acres) of the northeast quarter (160 acres) of section 20 in township 4 north, range 28 east.

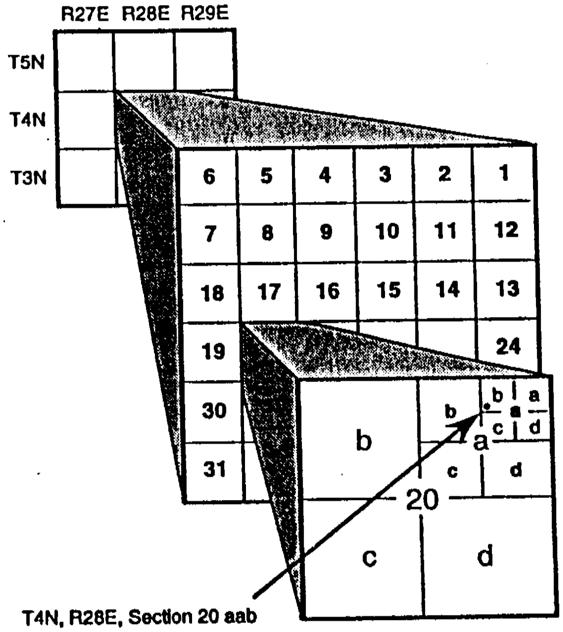

Figure 1 Well location system

EXECUTIVE SUMMARY:

Lower Umatilla Basin Groundwater Investigation

A Groundwater Contamination Problem

In the Lower Umatilla Basin, local activities--such as irrigated agriculture, food processing, livestock operations, domestic sewage and military activities--have contributed to the degradation of area groundwater. The Oregon Department of Environmental Quality (DEQ) declared the Lower Umatilla Basin a "Groundwater Management Area" in 1990 when groundwater sampling during the mid-1980s found high nitrate concentrations in local groundwater.

The Oregon Groundwater Protection Act of 1989 requires Groundwater Management Areas to address confirmed contamination with nonpoint sources once the contaminant concentrations reach certain levels. Nitrate levels above 10 mg/L triggered the series of steps outlined by the legislation.

Nitrate concentrations in Lower Umatilla Basin groundwater exceed 10 and 20 milligrams per liter (mg/L) in many areas. These levels are of greatest concern for infants (less than six months of age), who may develop a blood disorder from ingesting excessive nitrates.

Addressing the Contamination

Five state agencies began coordinating a groundwater quality investigation in July 1990. State natural resource agencies, coordinated by the Oregon Strategic Water Management Group, appointed two local committees to review the investigation results and co-develop an Action Plan. A citizen committee and a technical advisory committee appointed to the Lower Umatilla Basin Groundwater Management Area began meeting in February 1991.

Nitrate contamination of groundwater within the Lower Umatilla Basin has been confirmed and investigated by these agencies:

- Oregon Department of Environmental Quality
- Oregon Water Resources Department
- Oregon Health Division
- Oregon Department of Agriculture
- Oregon State University

The investigation's findings, presented in the Investigative Overview and three technical chapters, are designed to assist in decisions that will address the groundwater contamination problem.

The local committees will co-develop an Action Plan for reducing the area-wide groundwater contamination to below 7 mg/L, the current trigger level. The state agencies will also co-develop the Action Plan, which must be approved by the Strategic Water Management Group.

The Action Plan will need to consider a number of complex factors that make the Lower Umatilla Basin's groundwater vulnerable to contamination. Given enough added moisture, basin soils allow contaminants to reach groundwater within months. Once in the groundwater, nitrate moves slowly, possibly taking decades to be discharged from the groundwater system. Clearly, the Action Plan won't be able to address the groundwater contamination with a "quick fix" solution.

A Thorough Investigation

Area of Investigation

The 550-square-mile investigation site is located in northern Morrow and Umatilla Counties between Willow Creek, Cold Springs Reservoir and the Columbia River. Affected communities include Boardman, Echo, Hermiston, Irrigon, Stanfield and Umatilla. Most of the area occupies a plain that gently slopes toward the Columbia River. The semi-arid area receives about 8 to 10 inches of annual precipitation.

Land Uses

A number of activities in the Lower Umatilla Basin have the potential to contribute nitrate to groundwater.

Irrigated agriculture, which has expanded to nearly 180,000 acres, is the dominant land use in the basin. Estimates indicate that irrigated agriculture releases the most nitrogen to the basin's land surface. Other studies conducted in the basin indicate some nitrogen escapes beyond the root zone at some irrigated fields, even under conservative management strategies.

Food processing facilities in the basin have expanded quickly since the 1970s to meet the economic demand for processed foods, particularly potato products. Wastewater management at food processing facilities has undergone successive adjustments to protect groundwater. Nutrient-rich food processing wastewater is land applied. A first, crop needs, acreage and growing seasons received inadequate consideration. Efforts to protect groundwater by better managing wastewater continues.

Animal feeding operations, particularly those with large numbers of animals confined to a small area, have the potential to release nitrogen to groundwater. The amount of animal waste stockpiled, stored and land applied has varied greatly from year to year, with some waste management problems noted.

Domestic sewage sludge and wastewater, when stored in lagoons or disposed of on or beneath the ground, can contribute nitrates to groundwater. Nitrate from domestic sewage is a concern mainly in areas with a high density of on-site systems.

Extensive military activities, involving metals, nitrogen, explosives and chemicals, have occurred over 180 square miles. Cleanup is the current focus of the military sites, with nitrate and other contaminants a concern at the U.S. Army Umatilla Depot.

Landfills and other disposal sites, particularly those without liners, could contribute nitrogen to groundwater. Electricity producers, facilities handling hazardous waste, area accidents or spills and groundwater recharge projects, were investigated and found to contribute little or no nitrogen.

Natural sources of nitrogen were also investigated. Background levels and a federal study support the finding that the natural contribution is very low.

The Scientific Approach

This investigation set out to determine which activities are responsible for the nitrate contamination.

To understand the distribution and source of nitrate contaminated groundwater in the Lower Umatilla Basin, various state agencies and area facilities participated in four types of groundwater sampling.

- Reconnaissance sampling (1990-1991) improved on existing data and dictated additional sampling locations.

- Bimonthly sampling of the same 35 to 40 wells from 1991 to 1994 offered a view of seasonal and long-term trends.

- Synoptic water level measurements and sampling provided basin-wide results for an understanding of groundwater flow paths and nitrate concentrations.

- Nitrogen-isotope sampling verified and improved on nitrate source information gathered in the other sampling.

The sampling results were evaluated through statistics, chemical constituent maps, graphs, computer modeling, and nitrogen isotopic analyses.

Sampling Results

State agencies collected nearly 850 groundwater samples from 252 sites in the Lower Umatilla Basin study area between June 1990 and March 1993. The sampling results for nitrate could almost be divided into thirds, with about 30 percent containing nitrate concentrations exceeding 10 mg/L, 26 percent less than 2 mg/L, and the remainder somewhere between 2 and 10 mg/L.

The groundwater samples were analyzed for a variety of other constituents to help identify contamination sources. A few samples contained agricultural or industrial chemicals. Eighty-five percent of the project's groundwater samples had sodium exceeding 20 mg/L, the concentration at which individuals on a physician-prescribed sodium-restricted diet should notify their doctors.

Graphs showed a basin-wide relationship between nitrate and total dissolved solids (TDS). Analysis indicate multiple land uses affect groundwater throughout the basin.

Evaluating chemical constituent relationships helped distinguish between potential sources. For example, the influence of septic systems could be distinguished from other potential sources based on potassium-bromide-chloride relationships, while food processors may be distinguished based on magnesium and bromide.

The Role of Geology

In the Lower Umatilla Basin, basalt lavas have been folded into a prominent trough between Arlington and Hermiston. Up to 250 feet of alluvial sediments have been deposited in this trough, mostly by catastrophic floods that swept down the Columbia River during the ice age.

The alluvial aquifer and the two or three upper basalt aquifers serve as the main sources of drinking water. The cities of Hermiston, Irrigon and Boardman draw water from the alluvial aquifer. Irrigation water is pumped from both the alluvial aquifer and the deeper basalt aquifers.

Soils in the alluvial aquifers allow rapid downward movement from excess water on land. Recharge to the alluvial aquifer comes primarily from canals, streams and reservoirs, with some deep percolation of irrigation water (varying with the irrigation practices) and very little from precipitation.

The aquifers generally discharge to the Umatilla and Columbia Rivers. Water in the alluvial and shallow basalt aquifers seem to be connected, based upon hydrogeological and groundwater chemistry evidence. Inadequate well construction allows additional mixing of alluvial and basalt groundwater.

Average groundwater flow velocities in the basin range from 0.0001 miles per year in silts to 0.5 miles per year in sands and gravels. Well pumping and recharge from surface water can affect groundwater movement, altering both the speed and the direction of the flow.

Travel time to groundwater appears short: one to eighteen months with sufficient moisture. The longer travel times were found mostly at sites with fine sediments and wells exceeding 100 feet in depth. Peak nitrate concentrations in the area generally occur from September through June. This possibly represents travel times to groundwater or deep percolation during the non-growing season. The influence of less moisture, crop uptake and evaporation may inhibit deep percolation during the summer months.

Nitrate Sources

Data analysis indicates no single source is responsible for the nitrate contamination in the basin. Nitrate can be attributed to commercial fertilizers, land application of food processing waste water, livestock waste, and lagoons at the U.S. Army Depot. Septic systems were found to influence nitrate in groundwater at lower concentrations, with some exceptions. Natural nitrogen sources are considered small.

This project identified nitrate contamination sources by considering groundwater chemistry, contamination distribution, land use activity distribution and estimated nitrogen use by each local land activity.

Threemile and Sixmile Canyon

This area yielded the highest total dissolved solids levels in the project samples and reported nitrate levels reached 70 mg/L. Analyses identify livestock waste and irrigated agriculture as sources of nitrate contamination. The source of nitrate at PGE's Ash Disposal area, while not from PGE activities, has not been resolved.

Boardman to West Umatilla

The highest nitrate concentrations in project samples came from this area. Project sampling detected nitrate exceeding 70 mg/L in the irrigated crop area between Irrigon and the Port of Morrow. The U.S. Army Depot reported nitrate exceeding 100 mg/L at several sites.

The Depot's explosive washout lagoon area caused the high nitrate concentrations in that area. A Depot source appears responsible for elevated nitrate in the Depot's active landfill area. Nitrate south of the Depot was linked to animal waste and crop irrigation. Nitrate along the west boundary of the Depot was linked to irrigated agriculture. Nitrate north of the Depot appears related to irrigation activity and septic systems.

High nitrates found in groundwater from alluvial and basalt wells south of Boardman are related to irrigated agriculture, livestock waste and septic systems. Nitrate concentrations exceeding 10 mg/L in alluvial groundwater at the Port of Morrow's and Lamb Weston's wastewater land application sites relates to these activities.

Butter Creek to Umatilla

Reported nitrate concentrations reached as high as 100 mg/L in this area. Peak elevated nitrate concentrations were found at the confluence of Butter Creek and the Umatilla River. Past food processing wastewater practices are responsible for elevated nitrates at land application sites. Septic systems affect the groundwater west of the Umatilla River and north of Interstate 84. Livestock and irrigated agriculture also contribute to the elevated nitrate concentrations.

Umatilla to Hat Rock and Echo Meadows Area

Nitrate concentrations did not exceed 31 mg/L and were below 10 mg/L in the Hermiston, Echo, Umatilla Meadows and Hat Rock areas. Nitrate levels for Hermiston's numerous unsewered homes were below 5 mg/L, possibly because of significant canal dilution.

Developing A Solution

Widespread groundwater contamination exists in the Lower Umatilla Basin. Groundwater supplies drinking water to the communities of Boardman, Hermiston, Irrigon, Stanfield, Echo and Umatilla and many rural residents.

Groundwater contamination occurs when water (or another liquid) and nitrate (or another contaminant) exceed what can be removed by vegetation or evaporation. Soil capacity is a factor in preventing deep percolation. Lower Umatilla Basin soils allow nitrate to migrate to groundwater when excess water is available to transport the contaminants.

A wide range of activities introduce water and nutrients to the basin's land surface. The Lower Umatilla Basin Groundwater Management Area Citizen and Technical Committees have the opportunity to address the nitrate sources through the Action Plan.

Steps have already been taken toward preventing nitrate contamination. Some irrigated crop fields already time water and nitrogen application to crop needs.

Food processors have gradually improved their land application techniques for wastewater. The Action Plan can consider if those efforts are sufficient.

Past practices may continue to contribute nitrate to groundwater if too much nitrate is stored in the vadose zone (the zone between groundwater and the land surface). This investigation did not thoroughly explore nitrate in the vadose zone. The committees will need to address the evaluation of different activities for their nitrate contribution to the vadose zone.

The Action Plan may also need to address land uses changes within the Lower Umatilla Basin. For example, septic systems could become a more significant source of nitrate if canal water is no longer available to dilute groundwater in high density areas of individual on-site systems.

Groundwater protection will benefit all Lower Umatilla Basin residents. The challenge lies in coordinating change among diverse land uses for long-term results.

Chapter 1

Investigative Overview

Hydrogeology, Groundwater Chemistry and Land Uses in the Lower Umatilla Basin Groundwater Management Area

Northern Morrow and Umatilla Counties
Oregon

Gerald H. Grondin
Oregon Department of Environmental Quality

Karl C. Wozniak
Oregon Water Resources Department

Dennis O. Nelson
Oregon Health Division

Ivan Camacho
Oregon Department of Environmental Quality

1995

Chapter 1: Investigative Overview

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Introduction

Groundwater Management Area Declaration

The Oregon Department of Environmental Quality (DEQ) established the Lower Umatilla Basin as a Groundwater Management Area (GWMA) in 1990, based upon high nitrate-nitrogen concentrations in groundwater samples.

To be declared a Groundwater Management Area, a location must have confirmed groundwater contamination from multiple widespread sources (nonpoint source activities) at concentrations that meet or exceed specified trigger levels. The trigger level for nitrate-nitrogen in 1990 was 10 mg/L.

Local groundwater samples collected and analyzed for pesticides and other chemicals between 1984 and 1987 confirmed high nitrate concentrations in basin groundwater was common. Nitrate-nitrogen was detected in the Boardman, Irrigon and Umatilla vicinities. Potential nitrate sources included irrigated agriculture, food processing, livestock, domestic sewage and military activities.

Pesticides were detected in samples from four wells (Appendix 1A). Of the 25 wells sampled for nitrate, 11 wells contained concentrations greater than the 10 milligrams per liter (mg/L) nitrate-nitrogen public water supply drinking water standard. Concentrations as high as 80 mg/L nitrate-nitrogen were detected. These results confirmed point source facility monitoring, domestic well testing, public water supplies, and city of Hermiston data, all of which indicated high nitrate concentrations existed in area groundwater.

The 1990 GWMA declaration triggered specific steps outlined in the Oregon Groundwater Protection Act of 1989 (HB3515). An interagency groundwater quality investigation began in July 1990. The Oregon Strategic Water Management Group (SWMG) appointed local citizens to a Lower Umatilla Basin Groundwater Management Area Citizen Committee and a Technical Advisory Committee on November 21, 1990.

Oregon Groundwater Protection Act

The 1989 Oregon legislature passed the Groundwater Protection Act (HB3515) to prevent contamination of Oregon's groundwater resource while striving to conserve, restore, and maintain the high quality of Oregon's groundwater resource for present and future uses. The Act requires a series of activities to address contamination. Those activities include:

- protecting all Oregon groundwater for existing and future beneficial uses;
- conducting public education, research, and demonstration projects;
- identifying and characterizing all Oregon groundwater;
- establishing best practicable management practices to prevent groundwater contamination; and
- establishing areas of concern or groundwater management areas where area-wide groundwater contamination is related to nonpoint sources.

The Act requires implementing those activities by interagency cooperation under the direction of the Oregon Strategic Water Management Group (SWMG).

Groundwater Management Area Process

When a groundwater management area is declared, the Groundwater Protection Act requires SWMG to designate a lead state agency, assign responsibilities to other state agencies, and appoint a local groundwater management committee within 90 days of the declaration. Then, the agencies and the local committee co-develop a draft Action Plan for SWMG approval which will reduce existing groundwater contamination and prevent future contamination.

Implementation in the Lower Umatilla Basin

DEQ currently serves as the lead state agency for the Lower Umatilla Basin Groundwater Management Area (GWMA). State agencies cooperating in the Lower Umatilla Basin GWMA process include:

- Oregon Department of Environmental Quality,
- Oregon Water Resources Department,
- Oregon Health Division,
- Oregon Department of Agriculture, and
- Oregon State University.

SWMG could shift the lead agency role for agricultural water quality management activities to the Oregon Department of Agriculture (ODA) under Oregon Senate Bill 1010. The 1993 Oregon legislature passed SB 1010 which authorizes the ODA to develop and implement water quality management plans in agricultural and rural areas when such a plan is required by state or federal law. A mandatory, rather than voluntary GWMA Action Plan could trigger the shift. ODA Senate Bill 1010 activities in a groundwater management area are subject to SWMG coordination.

SWMG appointed a local 20-member Citizen Committee and a 10-member Technical Advisory Committee to serve the Citizen Committee on November 21, 1990. Committee members are listed in Appendix 1B and 1C. Both committee memberships represent a variety of local interests. The Action Plan will be developed based upon this report after submitting it to the Citizen Committee and state agencies.

Potential Health Effects of Nitrate

The United States Environmental Protection Agency (USEPA) set a 10 mg/L maximum contaminant level (MCL) for nitrate-nitrogen in public water supplies (Oregon Health Division, 1990). Nitrate levels above 10 mg/L nitrate-nitrogen may represent a serious health concern for infants and pregnant or nursing women.

Adults receive more nitrate exposure from food. Infants, however, receive the greatest exposure from drinking water because most of their food is in liquid form. Nitrate can interfere with the ability of the blood to carry oxygen to vital tissues of the body in infants of six months old or younger. The result is called methemoglobinemia, or "blue baby syndrome." Pregnant women may be less able to tolerate nitrate, and nitrate in the milk of nursing mothers may affect infants directly. These persons should not consume water containing more than 10 mg/L nitrate directly, added to food products, or beverages (especially in baby formula). Other domestic use of this water supply is acceptable, including washing or bathing. (Oregon Health Division, 1990).

The 10 mg/L standard of nitrate-nitrogen in public water supplies has been devised to protect a select group of sensitive persons (infants, and pregnant and nursing women). Available health information suggests that non-sensitive persons, including health adults and children older than six months in age, can consume water containing up to 20 mg/L of nitrate-nitrogen without experiencing adverse health effects. At nitrate levels above 20 mg/L, the Oregon Health Division recommends alternate water supplies be used by all persons (Oregon Health Division, 1990).

It has been suggested in preliminary studies that excessive nitrate ingestion may be linked to gastric cancer (Magee and Barnes, 1967, Bogovski, 1972, National Academy of Sciences, 1977, 1980, Ginocchio, 1984). An EPA review of studies investigating the carcinogenicity of nitrate and nitrite found the results inadequate and inconclusive (U.S.E.P.A., 1985, 1989).

Technical Investigation Conducted

Location

The Lower Umatilla Basin study area encompasses about 550 square miles of northern Morrow and Umatilla counties between Willow Creek, Cold Springs Reservoir and the Columbia River. Basin communities include Boardman, Echo, Hermiston, Irrigon, Stanfield, and Umatilla. The area is drained by the Umatilla River, Butter Creek and the Columbia River. Most of the study area occupies an undulating plain that slopes gently to the north.

Technical Investigation Questions

The technical investigation addressed the following questions.

- Where is Lower Umatilla Basin groundwater found and what are its sources?
- Where and how does local groundwater flow?
- Does groundwater in different aquifers interconnect?
- Which current and historic basin land uses potentially contaminate groundwater?
- What is the relative contaminant loading from each source?
- What chemical constituents contaminate groundwater?
- Where does groundwater contamination occur?
- How does groundwater contamination and chemistry vary within an area and over time?
- How does groundwater contamination and chemistry relate to the local hydrogeology and land uses?
- What are the likely groundwater contamination sources?

Identifying the basin's nitrate sources and understanding the groundwater chemistry was complicated by the hydrogeology, varied land uses, and natural water chemistry. An intensive analysis helped to determine likely nitrate sources by investigating the complex and inconsistent relationship between nitrate and other constituents.

This overview summarizes the technical investigation. More details about the investigation can be found in Chapters Two, Three and Four.

Technical Report Supports Action Plan Development

The 1989 Groundwater Protection Act requires state agencies and the local Groundwater Management Area Committee to develop an Action Plan. That plan must include identification of sources and practices contributing to the local groundwater contamination, and consideration of alternatives and recommended actions needed to reduce the groundwater contamination below the trigger levels.

The committee members and state agencies will use this report to explore and identify actions that will successfully reduce groundwater contamination in the basin. This report describes the Lower Umatilla Basin groundwater flow system and quality. It also identifies the nature and the likely sources of groundwater contamination.

Cooperative Interagency Effort

Oregon Water Resources Department

The Oregon Water Resources Department (WRD) characterized groundwater occurrence and flow (hydrogeology) within the alluvial aquifer system and shallow basalt aquifers of the Lower Umatilla Basin.

Oregon Department of Environmental Quality

The Oregon Department of Environmental Quality (DEQ) characterized groundwater quality, land uses, and potential contamination sources of the Lower Umatilla Basin. DEQ's activity included conducting laboratory analyses of inorganic constituents and volatile organic compounds.

Oregon Health Division

The Oregon Health Division (OHD) provided well owners information regarding water analyses and potential health impacts. OHD also analyzed and interpreted how groundwater chemistry relates to contamination sources versus other influences of the Lower Umatilla Basin.

Oregon Department of Agriculture

The Oregon Department of Agriculture (ODA) conducted primary laboratory analyses for pesticides, provided grants for local agricultural research, and provided review, comments and guidance for projects.

Oregon State University

Oregon State University (OSU) conducted agricultural assessments, agricultural field research, and confirmation laboratory analyses for pesticides for the Lower Umatilla Basin. OSU also provided review, comments and guidance related to local agriculture.

Hydrogeology

Climate

The Lower Umatilla Basin has a semiarid climate with hot dry summers and cool moist winters. Annual precipitation varies with elevation and ranges from about 8 inches near the river to about 10 inches near the southern boundary of the groundwater management area. At Hermiston, the average precipitation by water year (October through September) is 8.75 inches (Figure 1.1). About 70% of the annual total falls during the months of October through March. Most of the total falls as rain but snowfall is significant in some years.

Geologic Setting

Large areas of eastern Washington and northeastern Oregon are underlain by a thick sequence of basalt lavas which are collectively known as the Columbia River Basalt Group. In the Umatilla Basin, the lavas have been folded into a prominent east-west trough (the Dalles-Umatilla Syncline) which is roughly coincident with the Columbia River between Arlington and Hermiston. Up to 250 feet of alluvial sediments have accumulated in the trough. Some of the sediments (the Alkali Canyon Formation) were deposited by streams which drained the Blue Mountains to the south but most were deposited by catastrophic floods which swept down the Columbia River drainage during the Pleistocene Epoch (ice age).

Since the end of the Pleistocene (about 12,000 years ago), thin deposits of micaceous silt, sand, and gravel have accumulated in portions of the Butter Creek and Umatilla River drainages. These modern alluvial deposits (Holocene Alluvium) are less than 30 feet thick and are largely composed of reworked catastrophic flood sediments.

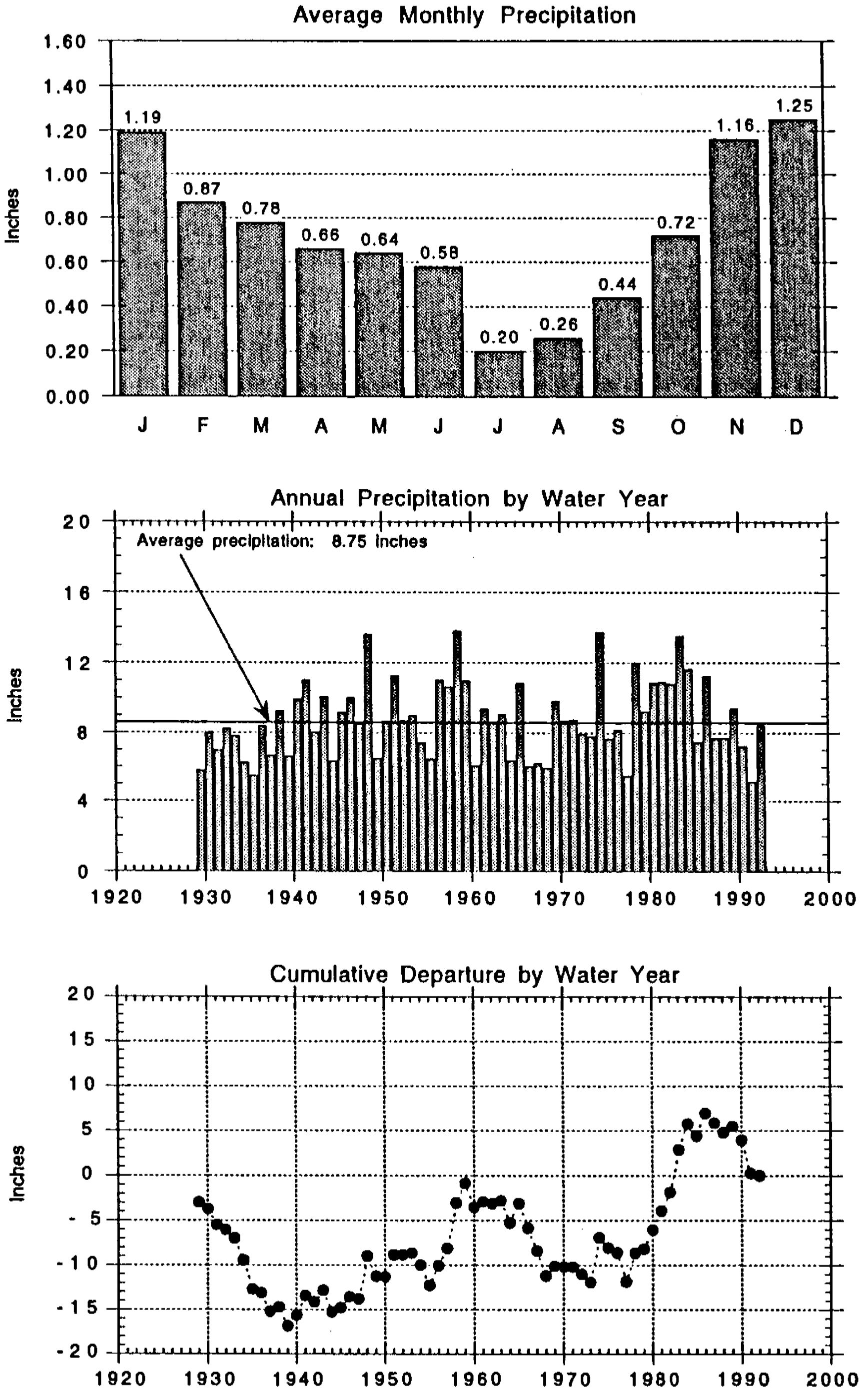

Figure 1.1 Precipitation at the Hermiston airport weather station: average monthly, annual, and cummulative departure (1928-1992).

Groundwater Flow System

The principal aquifers of the Lower Umatilla Basin occur in alluvial sands and gravels which overlie the Columbia River Basalt Group and in porous breccia zones within the basalt flows. The alluvial aquifer and the upper two or three basalt aquifers are the principal sources of domestic groundwater in the basin. The alluvial aquifer is also a source of irrigation water for local farms and, a source of municipal water for the cities of Hermiston, Irrigon, and Boardman. Deeper basalt aquifers are a major source of irrigation water in the basin. The shallow aquifers are the focus of this report.

Figure 1.2 shows a conceptual model of the shallow groundwater system in the basin. Groundwater recharge comes from precipitation, deep percolation of irrigation water (percolation past the root zone), and leakage from canals, streams, and reservoirs. The recharge area for the alluvial aquifer is very broad because porous and permeable sediments overlie the aquifer throughout most of its extent. Recharge areas for the basalt aquifers are narrow because porous and permeable breccia zones in the basalts are generally restricted to the top or bottom of flows (Figure 1.3). Because the breccias typically constitute less than ten percent of a flow's thickness, their exposed surface area is relatively small where the flow margin is exposed at land surface or beneath a cover of sediments.

Groundwater in the shallow aquifers is constantly flowing toward the Columbia and Umatilla rivers where it is discharged from the groundwater system to become stream flow. Discharge from the basalt aquifers to the rivers is probably inefficient except where individual flows are breached in one of the riverbeds. Some alluvial groundwater is discharged to underlying basalt aquifers where updip margins of lava flows are exposed at the base of the alluvial aquifer. Large volumes of groundwater are discharged from the shallow aquifers by wells. Groundwater can also migrate between aquifers in well bores that are open to more than one aquifer or in the annular space behind ungrouted casing.

Alluvial Aquifer

The alluvial aquifer includes all saturated sediments which overlie the Columbia River Basalt Group and saturated breccia zones at the top of the uppermost basalt flow. Water-bearing units include the Alkali Canyon Formation, Pleistocene catastrophic flood deposits, and Holocene Alluvium. The principal water-bearing zones occur in the flood deposits (Plates 2.3 and 2.4).

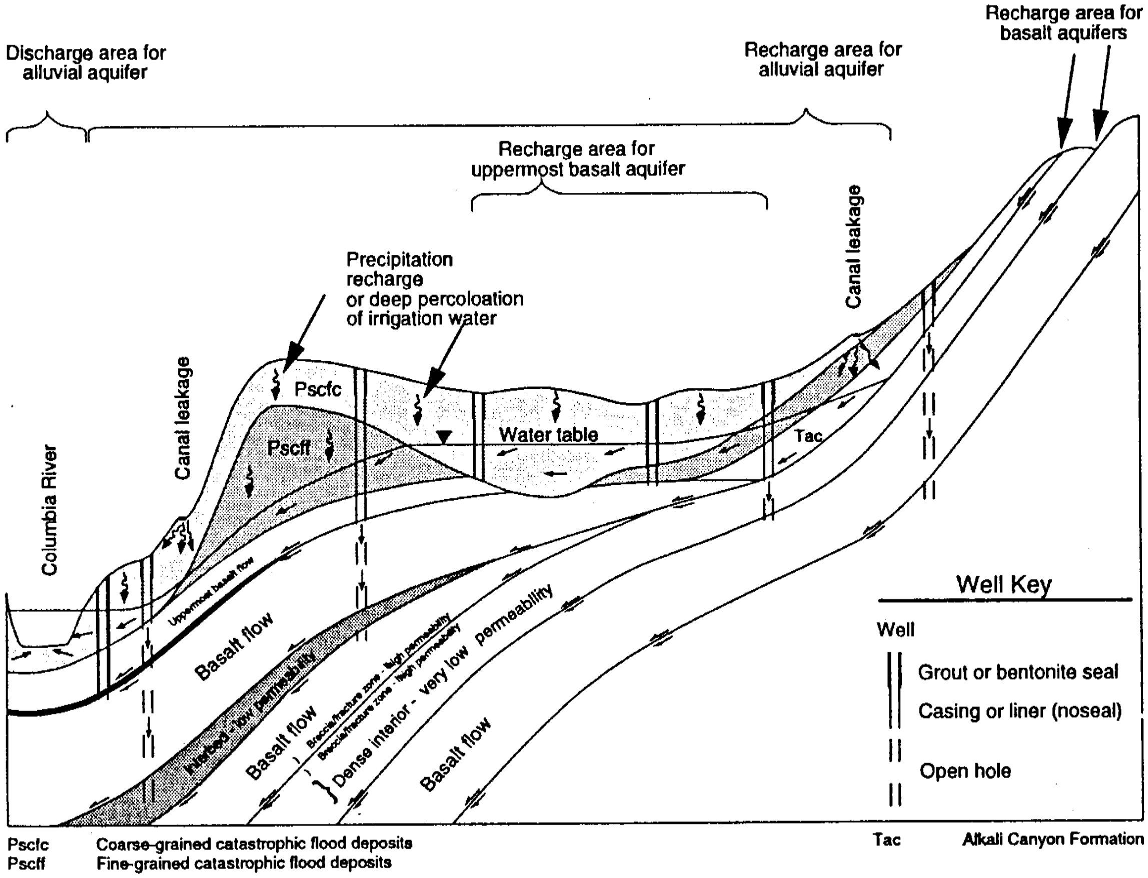

Figure 1.2 Conceptual model of the shallow groundwater flow system

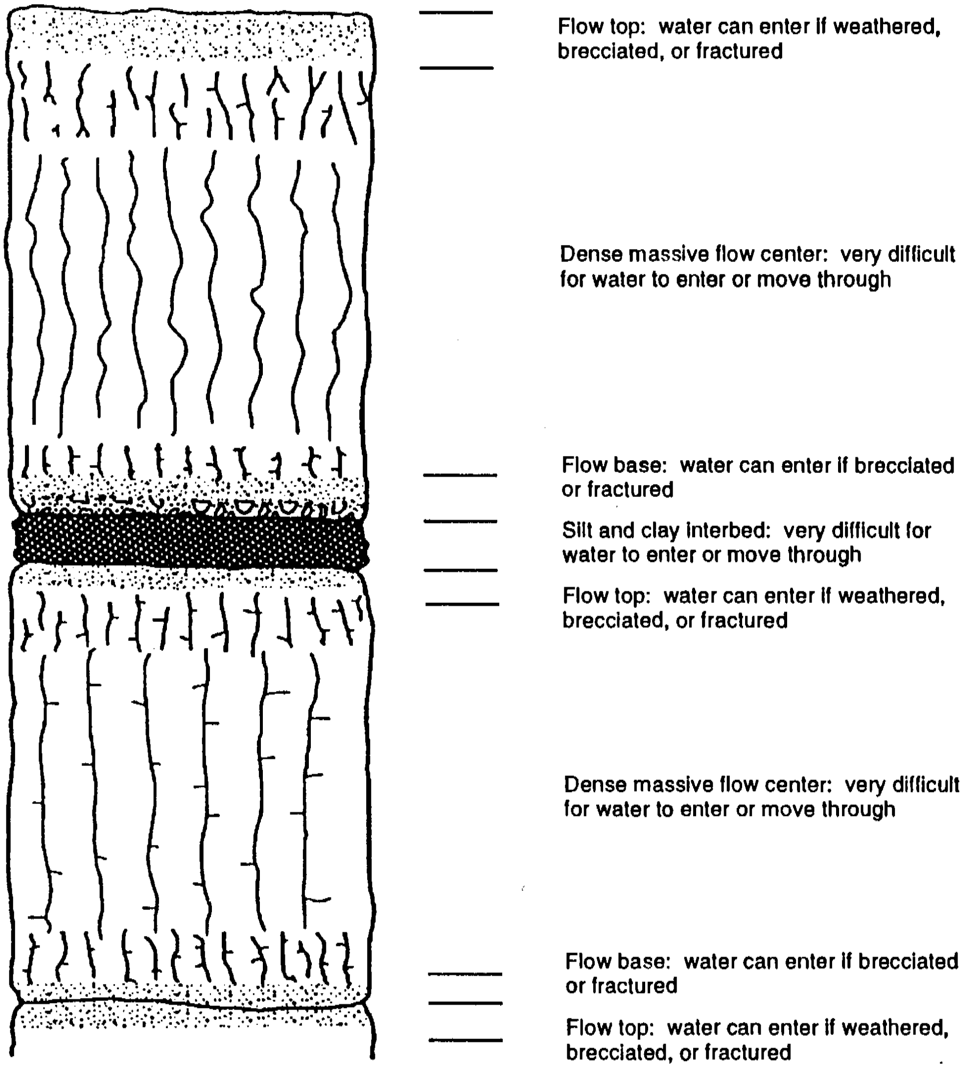

Figure 1.3 Idealized relationship between basalt stratigraphy and groundwater occurrence.

The boundaries of the productive aquifer are approximated by the limits of the water level contours shown on Plate 2.4. The boundaries correspond to areas where the saturated thickness is generally less than 20 feet or where well yields are insufficient for most consumptive uses. Scattered well logs indicate that thin saturated zones occur at considerable distances beyond the limits of the contours. Most of the productive groundwater resource occurs in the area between Boardman, Cold Springs Reservoir, and Echo but an isolated resource occurs in the sediments of Sixmile Canyon between Carty Reservoir and the Columbia River.

The upper surface of the Columbia River Basalt Group defines the approximate base of the alluvial aquifer (Plate 2.2). The subsurface "topography" of the basalt bedrock is the primary factor which controls the thickness of the alluvial aquifer. The aquifer thins above local bedrock highs and thickens above bedrock lows. The aquifer also thins to the south and east as the basalt surface rises to higher elevations.

Aquifer Properties

Hydraulic properties vary geographically within the alluvial aquifer and correlate to the distribution of coarse-grained versus fine-grained sediments. Broad areas of contrasting properties can be differentiated within the catastrophic flood deposits.

Predominantly coarse-grained flood deposits occur as broad tracts of sands and gravels (Pscfc on Plate 2.3). The thickest accumulations occur in three shallow east- to northeast-trending troughs between Boardman and Cold Springs Reservoir. The saturated portions of these sediments (the principal areas are highlighted in yellow on Plate 4) are characterized by low hydraulic gradients (typically less than 10 feet per mile) and high well yields (up to 4000 gallons per minute). Aquifer tests indicate hydraulic conductivities between 1000 and 4000 feet per day.

Predominantly fine-grained flood deposits occur as silty sands, silts, and clays with interbeds of sand and gravel (Pscff on Plate 2.3). Saturated portions are characterized by steep hydraulic gradients (typically 25 to 50 feet per mile) and low to moderate well yields. Where sand and gravel beds are absent, the silts and silty sands are capable of supplying domestic needs only. Where sand and gravel beds are common, wells are capable of yielding up to 250 gallons per minute. Limited data suggest that hydraulic conductivities are less than 50 feet per day in the silts but may be as high as 200 feet per day in the sand and gravel interbeds.

Recharge

Soils in the Lower Umatilla Basin are typically sandy loams with moderate to high permeabilities. In many areas, these soils overlie coarse sands and gravels which are highly permeable. These conditions promote the rapid downward movement of any excess water that occurs at land surface. The timing of water-level rises in wells near recharge sources indicates that recharge water travels from the land surface to the water table in several days to several months.

Although a comprehensive accounting of recharge is beyond the scope of this project, rough estimates of recharge magnitude can be made for the major potential recharge sources in the basin. These estimates are subject to large uncertainties and are presented solely to provide a sense of the relative magnitude of recharge from each source.

Precipitation

Estimates of recharge from precipitation range from 0.2 inches to 2 inches per year (see chapter 2). This is the equivalent of 400 to 4000 acre-feet of recharge per township per year. The conservative estimate is consistent with the behavior of wells near the center of the Umatilla Ordnance Depot, an area remote from other sources of recharge. These wells show flat long-term water-level profiles with no obvious correlation to monthly precipitation trends (Figure 1.4).

Canal Leakage

Approximately 130 miles of primary canals and an unknown length of secondary canals and ditches convey water for four irrigation districts in the basin. Most of the canals are unlined or have older linings which are reported to be in poor repair. The available data suggests that losses from primary canals may range from 2.5 acre-feet per mile per day to 3.7 acre-feet per mile per day. Assuming an average seepage rate of 2.0 acre-feet per mile and a five month operating season, the annual loss for the main delivery canals in the basin is estimated at about 40,000 acre-feet per year (Table 1.1). This estimate does not include losses from lateral canals, ditches, and drains.

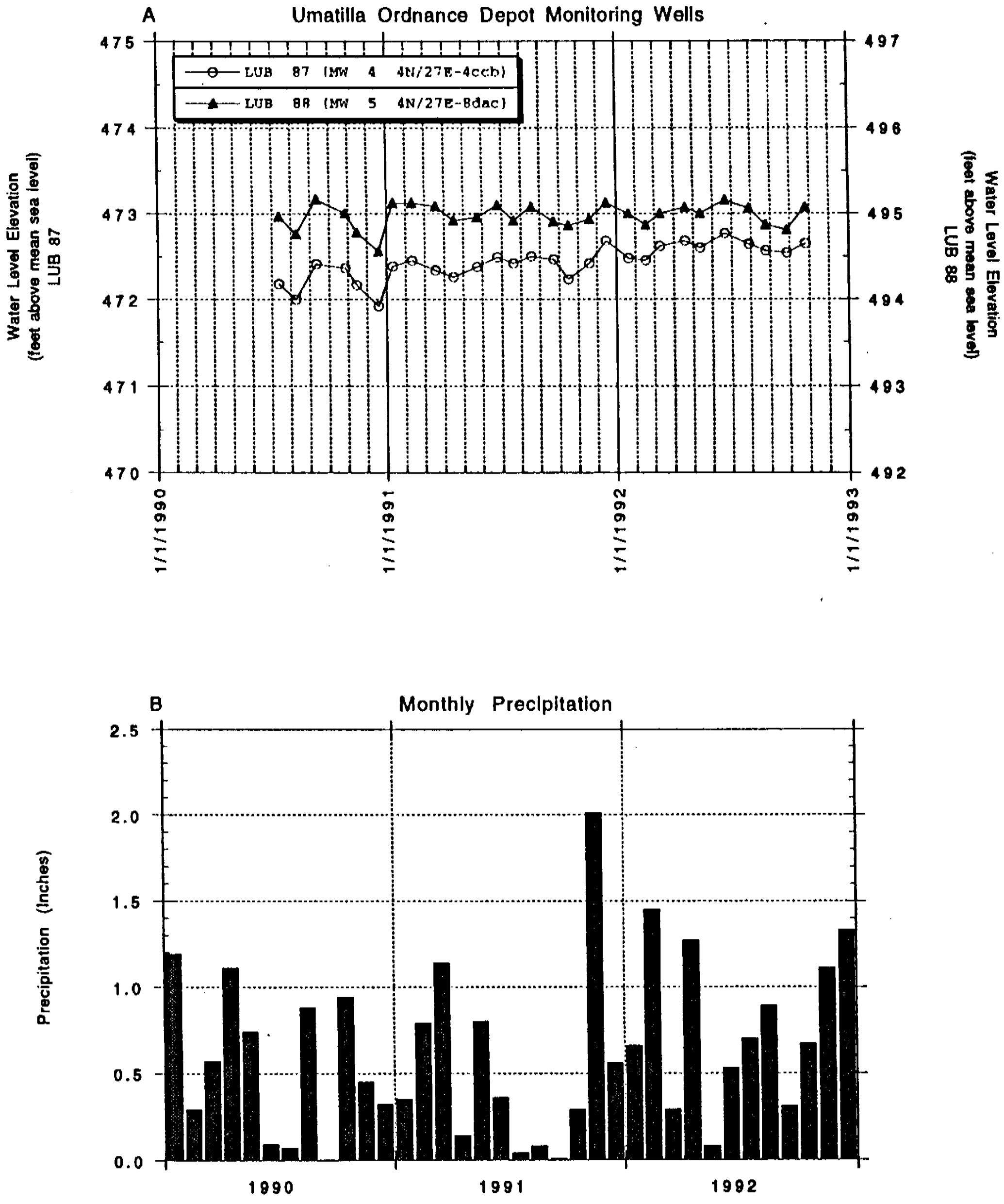

Figure 1.4 Comparison of water-level trends and precipitation in the interior of the Umatilla Ordnance Depot. A, Hydrographs of wells screened in fine-grained flood deposits; B Monthly precipitation at Boardman.

Table 1.1 Estimate of yearly canal losses for main delivery canals.

Irrigation District	Canal	Avg Yrly Diversion * (acre-ft)	Length** (miles)	Estimated Loss (acre-ft/yr)
Hermiston	U S Feed	69,810	25.0	7500
	A Line	50,000	10.0	3000
	Maxwell	18,680	10.0	3000
Stanfield	Furnish	36,550	30.0	9000
Westland	Westland	63,340	20.0	6000
	A***		8.0	2400
West Extension	West Extension	62,360	27.0	8100
Totals		300,740	130	39,000

* Oregon Department of Water Resources, 1988

** Based on digitized lengths from 1:100,000 scale maps

*** Excludes recently lined sections

Deep Percolation

Deep percolation occurs when irrigation water infiltrates beyond the root zone and becomes available for groundwater recharge. The potential for deep percolation exists wherever irrigation water is being applied to the land surface. Factors which control the occurrence of deep percolation include soil permeability, soil moisture content, plant uptake rates, depth of the root zone, and the rate and timing of water application. The rate and timing of water application is controlled by the method of irrigation and by the water management strategies of individual irrigators. All else being equal, the relative potential for deep percolation is high for flood irrigation, less for sprinkler irrigation, and low for drip irrigation. Flood irrigation is still common in the West Extension and Hermiston irrigation districts but rare in the Stanfield and Westland districts. Elsewhere in the districts, hand lines and wheel line systems are common. Center pivots are the dominant sprinkler system used outside of the districts.

Evidence for deep percolation can be seen on the hydrographs (plots of water level versus time) of wells northeast of the Umatilla Ordnance Depot and on the terrace north of the Umatilla River (Figures 1.5 and 1.6). Seasonal water-level rises during the summer and the absence of other potential recharge sources at these localities indicate that applied irrigation water is the most likely source of recharge. Evidence for deep percolation is also seen in the hydrographs of several wells between Butter Creek and Emigrant Buttes. These wells show rising water-level trends during a period of declining annual rainfall (Figure 1.7). All three of these localities are irrigated with effluent water from food processing plants.

Data from the western boundary of the Umatilla Ordnance Depot indicate that deep percolation can also occur in areas irrigated by center pivot systems. Lands west and southwest of the Depot are irrigated by center pivots whereas lands on the Depot are not irrigated. Wells near the boundary show annual water-level rises that range between 0.5 and 2 feet but little or no seasonal fluctuation (Figure 1.8A). Annual rises are greatest near the boundary and decrease toward the interior of the Depot. These trends produce a bending of water-level contours which is coincident with the boundary (Plate 2.4). These phenomena indicate that recharge rates are greater on lands west of the Depot and that groundwater is flowing onto the Depot from the southwest. The only apparent source of recharge that can account for these trends is deep percolation on the irrigated lands. In addition, the coincidence of these trends with a cultural boundary suggests that the underlying cause is cultural.

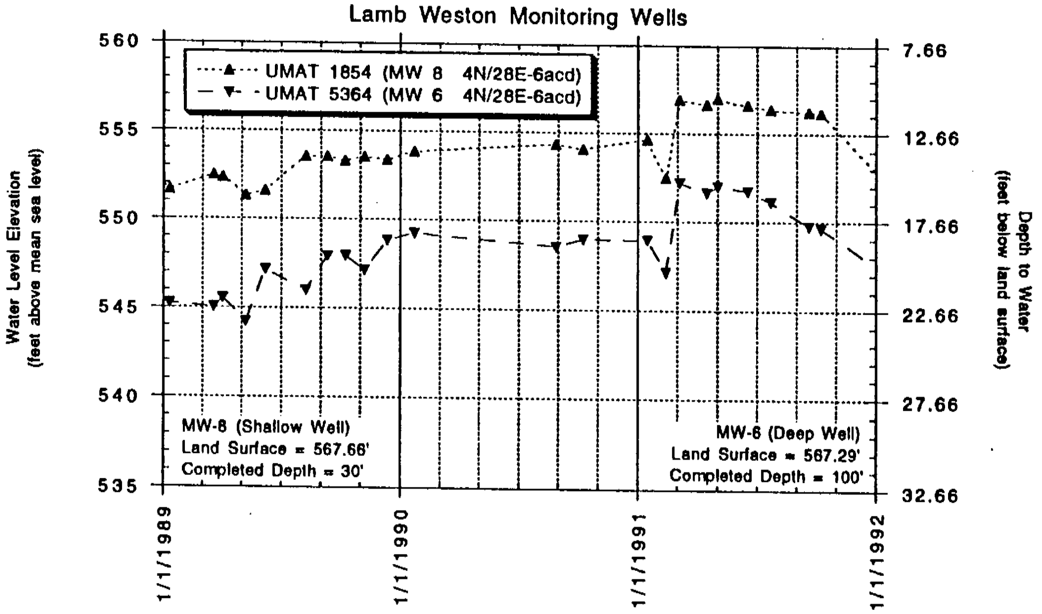

Figure 1.5 Hydrographs of adjacent wells completed in shallow unconfined and deeper confined water-bearing zones within fine-grained catastrophic flood deposits northeast of the Umatilla Ordnance Depot.

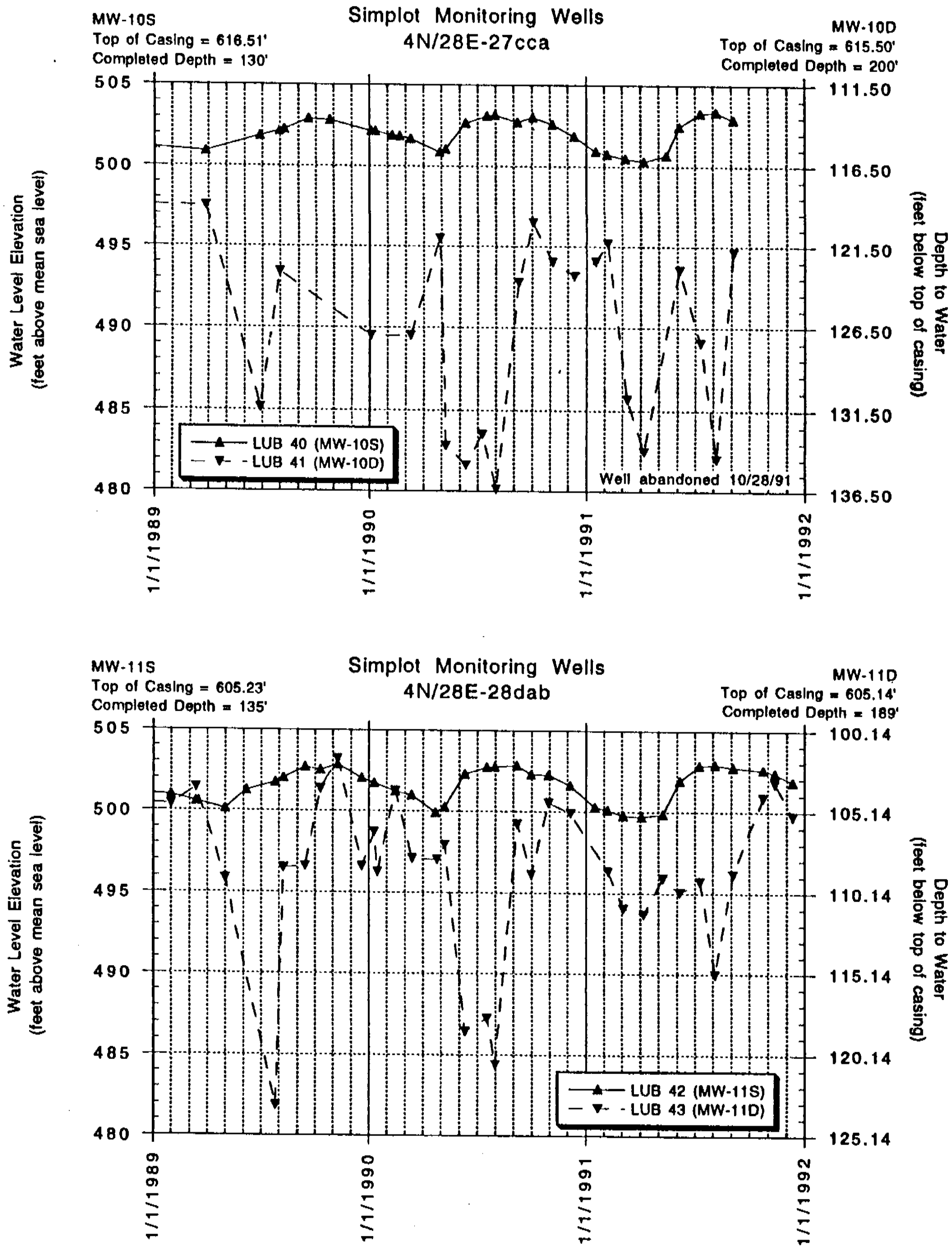

Figure 1.6 Hydrographs of paired wells completed in shallow unconfined and deeper confined water-bearing zones within fine-grained catastrophic flood deposits on the terrace north of the Umatilla River.

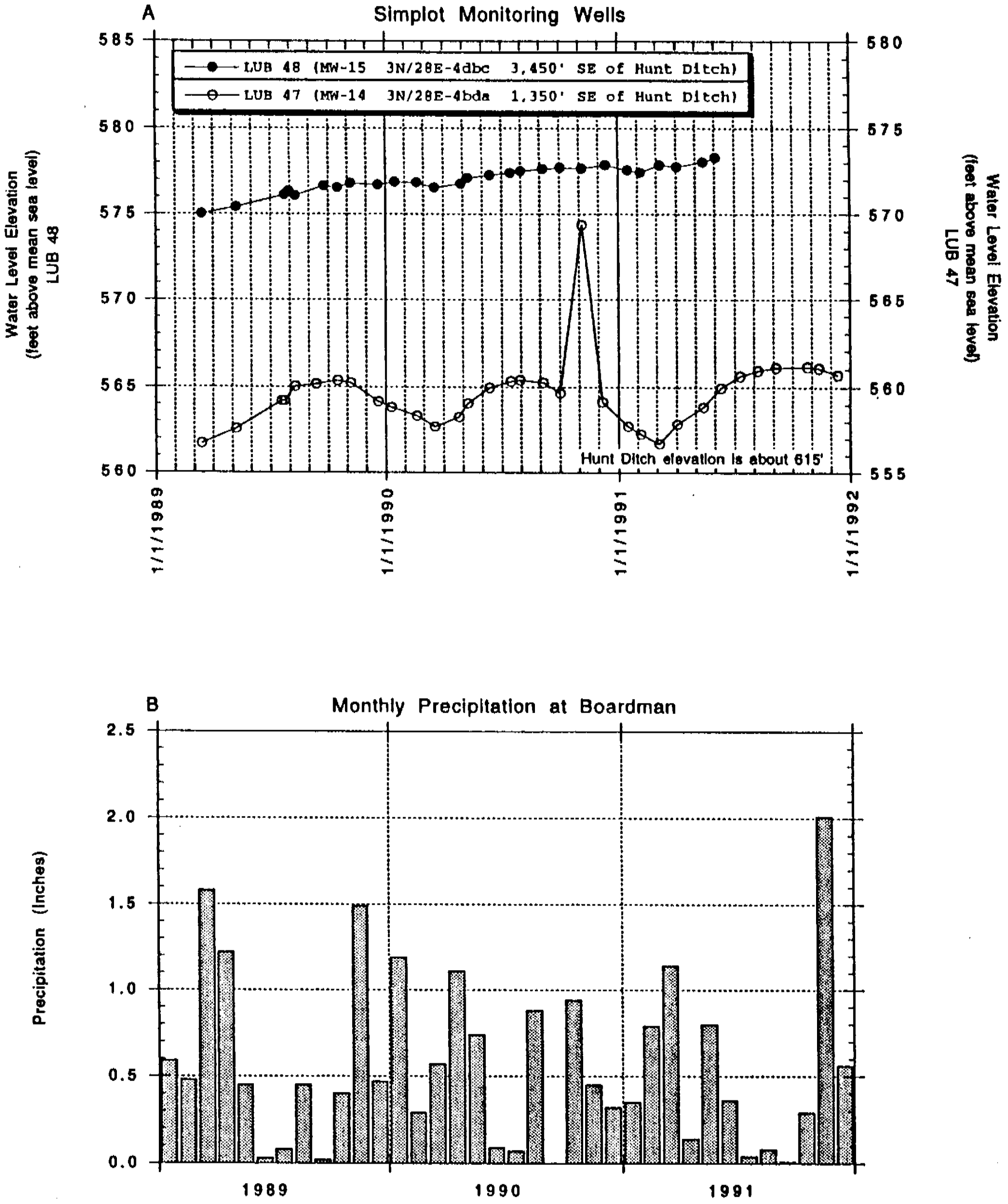

Figure 1.7 Comparison of water-level trends and precipitation in the area between Butter Creek and Emigrant Buttes. A, Hydrographs of wells screened in fine-grained flood deposits; B Monthly precipitation at Boardman.

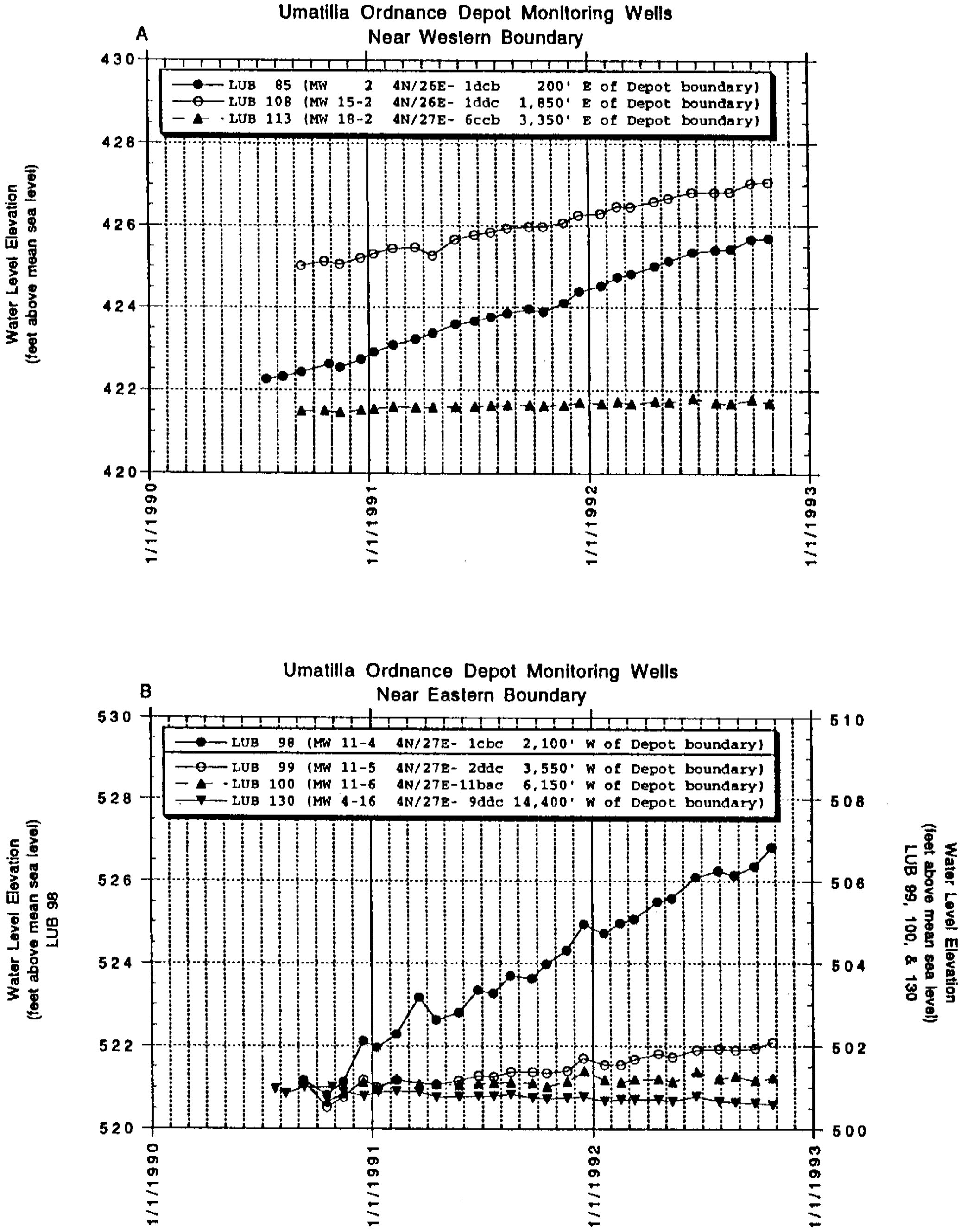

Figure 1.8 Seasonal hydrographs of monitoring wells screened in fine-grained flood deposits on the Umatilla Ordnance Depot. A, Wells near western boundary; B, Wells near eastern boundary.

The available evidence suggests that deep percolation recharge west of the Depot is responsible for groundwater-level rises of about 1.5 feet per year (see chapter 2). Assuming a porosity of 20%, this is equivalent to about 3.6 inches of recharge per year. Assuming an application rate of 36 inches of water per year, this equates to a deep percolation loss of about 10%.

Approximately 180,000 acres of land are irrigated in the Lower Umatilla Basin Groundwater Management area. Percolation recharge of 0.3 inches per year may be typical in areas irrigated by center pivots. Proportionately higher rates are expected in areas irrigated by wheel lines, hand lines, or flooding. If the minimum deep percolation recharge in the basin is assumed to be 2.4 inches per year, the minimum annual recharge from this source would total about 36,000 acre-feet per year.

Reservoir Leakage

Carty and Cold Springs reservoirs are the main water-storage facilities in the Lower Umatilla Basin. Carty Reservoir provides cooling water for Portland General Electric's Boardman Coal-Fired Plant and serves as a sink for some plant effluent. Cold Springs Reservoir is used by the Bureau of Reclamation to store Umatilla River water for the Hermiston Irrigation District. The maximum capacity of Carty Reservoir is 38,300 acre-feet. Cold Springs has a capacity of about 50,000 acre-feet.

Monitoring well hydrographs document leakage to groundwater at both reservoirs (see chapter 2). Wells near Carty indicate that reservoir water recharges the alluvial aquifer in Sixmile Canyon and the uppermost basalt aquifer (Basal Elephant Mountain Aquifer) in a broad area to the north of the reservoir. Prior to the filling of Carty reservoir, saturation in both aquifers was negligible. Wells near Cold Springs Reservoir indicate that the alluvial aquifer is recharged by seepage through the sediments which underlie the southern wing dam.

Leakage from Carty Reservoir to groundwater is estimated by Portland General Electric at about 4000 acre-feet per year, the equivalent of 10% of the total reservoir capacity. Leakage at Cold Springs Reservoir has not been quantified.

Stream Leakage

The potential for recharge from streams exists wherever stream elevations are above the water table. These conditions occur along the Umatilla River between the western part of Umatilla Meadows and Cottonwood Bend. The rate of leakage along this stretch is unknown.

Summary

The available data indicate that canal losses are a major source of recharge to the alluvial aquifer. Basin-wide recharge from deep percolation may be substantial but recharge rates probably vary widely depending upon irrigation practices. Recharge from reservoirs and streams may be significant but is of limited extent. Recharge from precipitation is probably negligible. Projects which reduce or eliminate canal leakage, reservoir leakage, or deep percolation of irrigation water will adversely impact groundwater supplies.

Flow Directions and Velocities

Water-level contours and interpreted flow directions for the alluvial aquifer are shown on Plate 2.4. These features reflect conditions in late winter when pumping withdrawals are minimum.

In a general sense, water-level contours can be thought of as the slope, or gradient, of the water table. In this sense, groundwater flows "downslope", or down gradient, from areas of high to low water levels. Regional water-level highs generally correspond to areas of regional recharge and regional water-level lows correspond to areas of potential discharge. Local water-level mounds indicate areas of local recharge.

Between the Umatilla Ordnance Depot and Boardman, groundwater flow is uniformly to the northwest toward the Columbia River. South and east of the Depot, flow directions are more variable and flow is generally toward the Umatilla River. Radial flow patterns centered near the northeast corner of the Depot and on the terrace between Hermiston and Stanfield indicate areas of local recharge. In much of the area east of the Depot, the topography of the basalt surface controls groundwater flow directions. For example, between Emigrant Buttes and Umatilla Butte, groundwater flow is restricted to east-west pathways between bedrock (basalt) highs along the Service Anticline.

Average groundwater flow velocity along a given flow path can be estimated by multiplying the hydraulic gradient (slope of the water table) times the hydraulic conductivity and dividing by the effective porosity of the aquifer. Based on a probable range of parameter values encountered in the study area (Table 1.2) groundwater velocities in the coarse-grained flood deposits are estimated to range from 2 to 8 feet per day or 0.13 to 0.52 miles per year. Velocities in the fine-grained flood deposits are estimated to range from 0.0002 to 2 feet per day or 0.0001 to 0.13 miles per year.

Table 1.2 Estimated flow velocities in the alluvial aquifer

Water-bearing Unit	Hydraulic Conductivity ft/day	Hydraulic Gradient ft/mile	Effective Porosity	Average Linear Velocity		
				ft/day	ft/year	mi/yr
Pscfc	1000	2	0.2	1.8939	691.8	0.1310
	4000	2	0.2	7.5758	2767.0	0.5241
Pscff	0.01	50	0.05	0.0019	0.7	0.0001
	0.1	50	0.05	0.0189	6.9	0.0013
	1	50	0.05	0.1894	69.2	0.0131
	10	50	0.05	1.8939	691.8	0.1310
	100	50	0.2	4.7348	1729.4	0.3275

These rough estimates are presented only to give the reader a sense of relative flow velocities through the various aquifer materials. Actual flow velocities may vary greatly because of local variations in hydraulic conductivity and porosity. In addition, pumping and recharge can locally alter hydraulic gradients and flow directions during the year, especially in the vicinity of aquifer boundaries. This is well documented in the coarse-grained flood deposits near the Umatilla Ordnance Depot. For example, the above estimates suggest that groundwater will travel from the center of the Depot to the Umatilla River within a period of 10 to 40 years. However, seasonal water-level measurements in Depot wells indicate that flow directions vary by up to 180 degrees during the year in response to off-site pumping and recharge. The net direction of water movement in this system is difficult to predict but the net displacement of a given particle of water is likely to be much less than the range of 0.13 to 0.52 miles per year.

Discharge

Water exits the alluvial aquifer by discharge to streams, discharge to underlying basalt aquifers, and withdrawal from wells. Not enough data is available to determine discharge rates to streams and basalt aquifers but it is possible to outline areas where such discharge is likely to occur.

To Streams

Regional discharge from the alluvial aquifer is to the Columbia and Umatilla rivers. Between Boardman and McNary Dam, the Columbia River fully penetrates the alluvial aquifer. Under natural conditions, groundwater flow in this reach is to the north and the aquifer discharges to the river.

Well hydrographs and water table contours indicate that the alluvial aquifer discharges to the Umatilla River between Echo and the Columbia River except for the stretch between Umatilla Meadows and Cottonwood Bend, as noted in the above section on stream recharge. North of Bridge Road, the Umatilla River cuts progressively through the alluvial aquifer until it exposes the top of the underlying Pomona flow at Three Mile Dam. This geometry indicates that most of the alluvial groundwater that is funnelled down the Umatilla drainage must be discharged to the river in areas south of Three Mile Dam. Between Cottonwood Bend and Bridge Road, discharge to the Umatilla River is manifested by perennial seeps and springs. Measurable spring flows at Minnehaha and Bridge Road range from 3 to 5 cfs in the winter months, the equivalent of 2200 to 3650 acre-feet per year. Additional seepage is likely in the bed and banks of the river.

To Shallow Basalt Aquifers

The potential for discharge to shallow basalt aquifers exists wherever the updip margins of basalt flows are exposed beneath saturated sediments of the alluvial aquifer. All else being equal, discharge is likely to be greatest in areas where high permeability sediments overlie flow margins.

Updip flow margins are common in the study area for the upper two or three basalt flows (Saddle Mountains Basalt). Approximate locations for the principal margins are shown on Plates 2.2 and 2.3. Areas of potential discharge can be determined by comparing the location of flow margins with mapped features of the alluvial aquifer on Plate 2.4.

Additional discharge to basalt aquifers occurs where inadequate well construction provides a conduit between the alluvial aquifer and basalt aquifers. Many basalt wells in the basin do not have a seal which extends into the dense interior of the first basalt flow. Under these conditions, groundwater from the alluvial aquifer can migrate into the well bore through breccia zones at the top of the basalt flow. The volume of water that enters a borehole this way will probably vary depending on local conditions at the surface of the basalt. If the Alluvial aquifer is contaminated, a small rate of inflow may degrade only the water in and near the well bore. A large rate of inflow may produce a contaminant plume in the basalt aquifers tapped by the well. One driller has reported some success in cleaning up domestic water wells in the Boardman area by placing a grout seal completely through the dense interior of the first basalt flow. This suggests that, in some cases, contamination of the basalt aquifers is limited to the vicinity of the well bore.

To Wells

Table 1.3 summarizes well withdrawals from the alluvial aquifer. Total withdrawal is estimated between 65,000 and 98,000 acre-feet per year. Irrigation accounts for 80 to 90% of the total yearly withdrawal.

Groundwater Supply

Under natural conditions, the average annual discharge from an aquifer is in equilibrium with the average annual recharge, the volume of water in storage is constant, and water levels in the aquifer are stable. Artificial recharge or discharge can disrupt this stability and lead to changes in storage. Under favorable conditions, a new equilibrium will be reached and water levels will stabilize at a different level. If artificial discharge is too great, equilibrium may not possible and water levels (and storage) will decline until the aquifer is depleted.

Table 1.3 Summary of well withdrawals from the alluvial aquifer.

Category	Discharge acre-ft/yr			Comments
Domestic Wells	1750*		1,750	Assumes 500 gallons per day per well
Irrigation - Primary	36,000	-	54,000	Assumes 2-3 acre-ft/yr/acre
Irrigation - Supplemental	15,500**	-	31,000	Assumes 1-2 acre-ft/yr/acre
Miscellaneous	9,332		9,332	Mostly commercial and industrial use permits
City of Hermiston	1,811		1,811	City well #5
City of Irrigon	291		291	City well #2
Total	64,684	-	98,184	
City of Boardman	1,108		1,108	Ranney collector adjacent to Columbia River
Umatilla Fish Hatchery	8,881		8,881	Wells and collectors adjacent to Columbia River

* Includes all wells less than 200 feet deep

** Includes County Line Water Improvement District recharge permit for 5339 acres

The principal productive areas of the alluvial aquifer occur within three shallow troughs that are filled with coarse-grained flood deposits (Plate 2.4). Groundwater supply conditions vary in each of the troughs.

In the Ordnance trough, water-level declines indicate that discharge exceeded recharge between 1960 and 1976 and between 1986 and 1993. If this imbalance continues, water levels will continue to decline.

In the Boardman-Umatilla trough the alluvial aquifer is hydraulically connected to the Columbia River and the river determines the base level of the water table. If river levels are maintained over time, long-term storage will remain stable. Large increases in annual pumpage from the aquifer will induce water to flow from the river into the aquifer. In this sense, groundwater supplies in the Boardman-Umatilla strip are relatively unlimited but are developed at the expense of the Columbia River.

The Hermiston trough is similar in size to the Ordnance trough but has a greater density of canals and a lower volume of well discharge. The existing data indicate that groundwater levels are stable and that annual recharge is in balance with annual discharge. Additional pumping capacity is probably available in this area but future conservation measures by the Hermiston Irrigation District and decreased use of the Feed Canal to deliver water to Cold Springs Reservoir may adversely impact groundwater supplies.

Shallow Basalt Aquifers

Water-bearing zones in the Columbia River basalts are largely limited to thin breccia or fracture zones at the top or base of individual flows. The dense interiors of flows are relatively impermeable and confine groundwater to discrete tabular aquifers.

Three shallow aquifers occur within flows of the Saddle Mountains Basalt (the youngest flows of the Columbia River Basalt Group). Each aquifer includes water-bearing zones at the base of a flow and water-bearing zones at the top of the underlying flow. A thin interbed of silt and clay separates the two zones in many areas.

Aquifer Properties

Estimates of hydraulic conductivities for the shallow basalt aquifers range up to 18 feet per day. Estimates of storativity range up to .003. These values are considerably less than their counterparts for the productive parts of the alluvial aquifer.

Recharge

Because the interiors of the basalt flows are relatively impermeable, effective recharge to the shallow basalt aquifers is probably limited to areas where the updip margins of the basalt flows are exposed to recharge waters. Recharge rates cannot be determined from the present data but recharge locales and the relative contributions of the various sources can be established.

Within the study area, updip margins of the upper two basalt flows generally occur beneath a cover of alluvial sediments. Effective recharge to the basalts is probably limited to areas where these sediments are saturated. This is supported by the observation that in areas updip from the Columbia River, saturated portions of the shallow basalt aquifers are generally limited to areas which are overlain by the alluvial aquifer. These factors suggest that most of the recharge to these aquifers comes from groundwater that is discharged from the alluvial aquifer.

The updip margin of the uppermost basalt flow is also exposed beneath Carty Reservoir and in the bed of the Umatilla River between Three Mile Dam and the Columbia River. Leakage from Carty Reservoir to the uppermost basalt aquifer is well documented. Leakage from the Umatilla River is highly probable.

As discussed above, some recharge to the shallow basalt aquifers also comes from alluvial groundwater which migrates through the bores of wells which are inadequately sealed.

Flow Directions and Velocities

Although not enough data was collected from each of the shallow basalt aquifers to contour flow directions, the available data indicate that flow is generally parallel to the regional dip of the basalt flows. Throughout most of the study area, regional dips are to the north and groundwater flow is toward the Columbia River. Hydraulic gradients appear to range from 25 to 50 feet per mile.

Assuming a hydraulic conductivity of 18 feet per day and an effective porosity of 10%, the average groundwater flow velocity in the shallow basalt aquifers is estimated to range between about 1 and 2 feet per day, or 350 to 700 feet per year. These estimates are subject to considerable uncertainty.

Discharge

Water exits the shallow basalt aquifers by discharge to the Columbia River, by withdrawal from wells, and by discharge through well bores to other basalt aquifers. Pumpage discharge was not estimated for the current study.

Although shallow basalt groundwater flow is toward the Columbia River, effective discharge to the river is probably limited to areas where basalt flows are breached by the river. Because the three shallowest basalt flows are breached at various localities within the study area, efficient hydraulic connections probably exist between the shallow aquifers and the river. Discharge rates cannot be calculated using available data.

Many wells in the study are completed in more than one basalt aquifer. Because hydraulic heads are commonly different in the various aquifers, this practice causes groundwater to migrate between the aquifers. The magnitude of discharge by this mechanism is unknown but may be significant in areas of high well density because of the limited storage capacity of the shallow basalt aquifers. The commingling of aquifers in wells also provides a pathway for contaminants to travel between aquifers.

Groundwater Supply

In general, breccia and fracture zones account for less than 10% of the thickness of a Columbia River Basalt flow. Assuming an average porosity of 10%, this equates to a storage capacity of about 1% of the total flow volume. Because of this low capacity for storage, Columbia River basalt aquifers are particularly vulnerable to overdraft, a common condition in many of the deeper basalt aquifers of the Umatilla Basin. Low hydraulic conductivities and storativities in the basalt aquifers also increase the likelihood of interference between wells. These factors and the limited extent of the shallow basalt flows suggest that the development potential of the shallow basalt aquifers is somewhat limited.

Water levels in the shallow basalt aquifers appear to be stable in most parts of the study area, but excessive pumpage may be causing some declines in a small area between Hermiston and the Umatilla Ordnance Depot. Declines may be exacerbated when wells are deepened without sealing off the upper aquifer, a common practice in the area.

Land Use and Nitrogen Loading

Land Use History

Diversity, growth and an evolution to intensive use best describe land use in the Lower Umatilla Basin. A wide variety of land uses were considered as potential sources of groundwater contamination. Both recent and historical uses were investigated. A summary of basin land use history and practices follows.

Before 1945

Lower Umatilla Basin activities before 1945 centered around agriculture. Early basin settlers raised livestock and produced limited crops on small farms. Local farmers organized ditch companies and irrigation districts. Shortly after 1900, the West Extension, Hermiston, Stanfield, and Westland districts existed, and U.S. Bureau of Reclamation began constructing the Umatilla Project for irrigation water. Wheat farming expanded when many dryland acres were developed into irrigated wheat farms after water became available. Flood irrigation was the standard method used at the time.

By the 1920s, Umatilla River water for summer irrigation was fully appropriated. Although the Lower Umatilla Basin had large wheat producing areas, alfalfa remained the major crop. Some grains, vegetables and fruit were also grown. Dairy, sheep and poultry became important commodities. Livestock manure was used as a soil amendment and nutrient source for local crops.

Development of local irrigation water sources resumed after the 1920s. Groundwater development began as a limited irrigation source during the 1930s and 1940s. Drought conditions during the 1930s prompted U.S. Government incentives for well drilling. McKay Creek water was also allocated for irrigation during this critical water period. Despite these water developments, limited agricultural land development occurred during the 1930s and 1940s due to the full appropriation of Umatilla River water.

Early in the 1940s, the basin became a site for military activities related to World War II. The U.S. War Department used 150 square miles for a precision bombing range. The U.S. Army established the 31-square-mile Umatilla Depot to store munitions.

1945-1960s

After World War II ended, military activity continued. The military continued to practice at the bombing range. Army activity included ammunition maintenance, renovation and demolition. Explosive washout wastewater was discharged into two lagoons. The Army began storing missile fuels and chemical agents.

Basin farmers introduced many changes after World War II. Farmers began using commercial fertilizers and introduced sprinkler irrigation. Small acreage farmers began rotating crops of alfalfa, wheat and field corn. Other crops included peas, beans, carrots and fruits. Livestock businesses included a strong dairy industry, large poultry farms and hog operations.

Sewage treatment expanded beyond individual on-site systems as cities began operating municipal sewage treatment facilities.

1960s-1970s

With increasing population growth, residents started to manage disposal of solid waste and domestic sewage. Separate unlined landfills served the Army and local residents. Municipal sewage treatment plants were introduced in some cities.

After the 1950s, beef cattle operations grew in importance while dairy and hog operations declined. At least two large poultry facilities remained active until the late 1960s.

The Basin experienced an irrigation expansion "boom." During the 1960s and 1970s, more irrigation and more efficient use of irrigation water accompanied this boom. Wheeled and center pivot irrigation systems were introduced to the basin. Columbia River water became available via pumping and lift stations. Groundwater (including water from basalt aquifers) became available for irrigation. Corporate farming increased as did the conversion of undeveloped dryland to irrigated cropland. Dryland wheat farming yielded to irrigated wheat and row crops during this period. Watermelon production began on a large-scale.

Economics and limited water eventually slowed the boom. In some areas, groundwater use exceeded groundwater recharge, prompting the Oregon Water Resources Department to restrict or reduce groundwater use to sustainable levels by declaring Critical Groundwater Areas within the basin.

1970s-1980s

The basin served as a major regional wheat producer and expanded into intensive potato production. An increased demand for potatoes and use of center pivot irrigation facilitated the potato production expansion. Irrigation scheduling for efficient water management was introduced to the basin during this period. Potato production used more fertilizer and pesticide per acre and in total quantity than other basin crops.

Large-scale potato processing for fast food and other uses settled near Boardman and Hermiston. These facilities generated large volumes of nutrient rich wastewater, which was land applied to limited acreages.

The Depot and the former bombing range were investigated for contamination from past military use, with some cleanups initiated. The Army applied for a permit to incinerate chemical agents stored at the Depot.

Early 1990s

Total irrigated crop acreage in the Lower Umatilla Basin reached approximately 180,000 acres (281 square miles) by 1992. Of this total acreage, about half produced irrigated wheat and potatoes. Center pivots--which were also used for fertilizer applications--irrigated nearly 90 percent of the total irrigated area (IRZ Consulting, 1993). Many of the farms using center pivots employed some form of irrigation scheduling service (IRZ Consulting, 1993).

About 11 percent (20,000 acres) of the total irrigated area was gravity irrigated. Soils--sands and coarse silt loams--at these sites permit rapid infiltration and make efficient water distribution in the fields difficult.

Irrigated agriculture in the Lower Umatilla Basin continues to change. At least two large farms have been purchased to grow poplar trees for paper production. Drip irrigation has begun at some of these farms.

Land application of domestic sewage, sludge and food processing waste has required careful management. All land application sites must comply with environmental regulations for meeting agronomic rates of crops. Food processors have increased land application acreages.

Cleanup of the various military sites continue, with the Depot's explosives washout lagoon and the incineration of stored chemicals being the key concerns.

Nitrogen Loading

Loading Relationship to Groundwater Contamination

The Lower Umatilla Basin's soil conditions and hydrogeological properties make local groundwater very vulnerable to contamination from many different land uses. For example, this project and/or other investigations have detected nitrate, metals, organic compounds, pesticides, and explosives contaminating groundwater. As land uses continue to expand and evolve, other contaminants may potentially leach through basin soils and contaminate groundwater.

This investigation focused on nitrate, which exceeded levels that triggered state action. Project sampling confirmed extensive areas of the basin have nitrate-nitrogen groundwater concentrations near or exceeding the U.S.E.P.A. drinking water standard of 10 mg/L (see Plates 4.2 and 4.3).

The potential for a land use to contaminate groundwater with nitrate or another constituent relates to loading. Groundwater contamination can occur whenever water (or another liquid) and nitrate (or another contaminant) is released and exceeds or bypasses:

- removal by crops or other vegetation
- removal by evaporation
- soil capacity to prevent deep percolation

Management can reduce or prevent nitrate or other contaminant loss to groundwater. This investigation reviewed the nitrogen loading history for all of the basin's land uses. The following discussion and estimates come from available information.

Local Soils

Soil surveys for the Umatilla and Morrow Counties indicate that basin soils consist of well-drained, fine sandy, and sandy loams. The soils are low in clay and nutrients, contain little organic matter, with a pH range from 6.5 to 7.8 in near surface soil and up to 9.0 in deeper soil. The soil permeability rates from moderate to high, and the available water holding capacity ranges from approximately 0.7 to 3 inches of water per foot of soil.

This investigation assessed nitrate contamination risks of Lower Umatilla Basin soils by using the Oregon Water Quality Decision Aid publication (Oregon State University Extension, 1993). The assessment considered local soil characteristics, available moisture, and the depth of groundwater. Nitrate leaching from basin soils and contaminating groundwater rated primarily as a moderate to high risk with sufficient moisture, and a low to very low risk under dryland conditions. Table 1.4 presents the assessed risk for groundwater contamination from local soils.

Table 1.4 Assessed risk of groundwater contamination from potential nitrate leaching of local soil.

Soil	Leaching Potential		Groundwater Contamination Risk	
	Dryland	Irrigated	Dryland	Irrigated
Adkins WET	Very Low	High	Very Low	High
Koehler	Very Low	High	Low	High
Pedigo	Very Low	Moderate	Very Low	Moderate
Powder	Very Low	Moderate	Very Low	Moderate
Quincy	Very Low	High	Low	Very High
Quinton	Very Low	High	High to Very High	
Sagehill	Very Low	Low to Moderate	Low	Low to Moderate
Shano	Very Low	Low	Low	Low
Winchester	Very Low	High	Low	Very High

Extracted from Oregon Water Quality Decision Aid, H. Huddleston, and others (1993) and used in Oregon HOME*A*SYST, Worksheet #10, Site Evaluation, Oregon State University Extension Service (1993).

Nitrogen Loading Summary

Irrigated Agriculture

Nitrogen fertilizer has been identified as a major source of groundwater nitrate contamination in many areas of the U.S., including the Burbank-Wallula, Washington and Northern Malheur County, Oregon areas. By the early 1980s, nitrate leaching was identified as a problem in most sandy soils. Researchers found nitrate leaching to groundwater depends upon the amount of nitrogen applied, and the method, amount and timing of irrigation. Investigators also found precipitation contributes to residual nitrate leaching from crop soils during the non-growing season.

Irrigated agriculture is the dominant land use in the basin with approximately 180,000 acres (51 percent of the project area) under cultivation in 1992. Information about irrigated agriculture's nitrogen use is limited. Estimates range between a minimum of 7 million pounds of nitrogen used per year since 1975 (141,243 acres, 50 lbs per acre) to 20.5 million pounds of nitrogen used in 1990 (132,500 acres). Any estimate within this range indicates irrigated agriculture releases the most nitrogen to the basin's land surface. Potential nitrate leaching to groundwater depends upon fertilizer and water management.

Food Processing

Nitrogen loading information exists for nutrient and salt-rich food processing wastewater. The local industry has annually produced more than one million pounds of nitrogen since the early 1980s. The potential for nitrate leaching to groundwater depends upon nutrient and water management at the land application sites and possible seepage at wastewater ponds/lagoons.

The industry's waste management has improved, with generally no more year-round land application, expanded application acreage and decreased application rates at those sites. The use of lined storage ponds/lagoons has increased.

Livestock

Nitrogen information for basin animal waste is limited and land application area varied. Project analysis indicates livestock at two large beef, one large hog and one dairy operation, on average, annually produced more than 3.4 million pounds of nitrogen during the 1980s. Assuming nitrogen losses during storage, nitrogen available for land application may have been reduced, probably exceeding 780,000 pounds per year. The potential for nitrate leaching to groundwater depends upon nutrient and water management at land application sites and possible seepage at lagoons, stockpiles and animal pens.

Domestic Sewage

Nitrogen loading information for domestic sewage exists. A high potential for nitrate leaching exists at most large on-site systems and individual systems using drainfields. Most local municipal systems discharge to surface water and/or land apply treated waste. The City of Irrigon's system directly discharges to the subsurface through infiltration beds. Municipal sludge is imported from Portland's metropolitan area and land applied. The potential for nitrate leaching to groundwater depends upon nutrient and water management at land application sites and possible seepage at lagoons.

Military Activities

Nitrogen loading information related to military activity in the basin is limited. Significant loading to groundwater apparently occurred at the U.S. Army Umatilla Depot Activity Washout Lagoons. Approximately 85 million gallons of explosives washout water discharged to the lagoons (0.09 acres total) from the mid-1950s to the mid-1960s, but project information is insufficient for estimating the amount of nitrogen in the washout water. The Depot's unlined landfill received an undetermined amount of nitrogen in dried sewage sludge.

Other Land Uses

Other land uses investigated for nitrogen loading included environmental cleanup sites, accidents, underground storage tanks, landfills, electricity generation, and groundwater recharge. Nitrogen loading information is limited. Except for a landfill, these land uses contribute little or no nitrogen.

Natural Sources

Natural nitrogen loading sources include igneous rocks, lightning, decomposing organic matter and nitrogen fixation by bacteria. Available information was not sufficient to determine local loading from these sources. However, loading is considered small relative to other basin sources. Upgradient groundwater samples with low nitrogen concentrations and USGS statewide groundwater quality statistics support this assumption.

Irrigated Agriculture

Background

Existing literature identifies nitrogen fertilizer as a major source of groundwater nitrate contamination in the U.S. including Burbank-Wallula, Washington (Spalding and others, 1982) and northern Malheur County (Malheur County Groundwater Management Committee, 1991). By the early 1990s, nitrate leaching was identified as a problem in most irrigated sandy soils (Lembke and Thorne, 1980; Watts and Martin, 1981).

Research shows nitrate leaching to groundwater correlates to the amount of nitrogen applied, and the method, amount and timing of irrigation. Spalding and Kitchen (1988) found increasing the amount of applied nitrogen fertilizer beyond 100 pounds per acre correlated to an increased amount of extractable nitrate in the unsaturated zone sampled 6 to 60 feet below irrigated farm land. Hergert (1986) noted that matching nitrogen fertilizer rates more closely to crop yield requirements could substantially reduce nitrate leaching from sprinkler irrigated sandy soil to groundwater. McNeal (1976) and Wendt (1976) found irrigation methods using less water (sprinkler versus furrow and subirrigation versus furrow and sprinkler) caused less nitrate leaching. Watts and Martin (1981) noted irrigation scheduling minimized deep percolation and nitrate leaching. They concluded that irrigation based upon soil moisture requirements or evapotranspiration was the most practical water management method for controlling nitrate leaching.

Research also found precipitation leaching residual nitrate from crop soils during the non-growing season (Hergert, 1986; Detroy and others, 1988, 1990).

Basin History

Irrigated agriculture entered the Lower Umatilla Basin before the 1920s when local farmers organized ditch companies and irrigation districts, and the U.S. Bureau of Reclamation constructed the Umatilla Project (Kopecz, 1994). Many dryland acres developed into irrigated wheat farms after water became available. Flood and furrow irrigation were the standard methods used (Fitch, 1994).

Total irrigated agriculture acreage in the basin apparently increased from approximately 85,500 acres (134 square miles) in 1965 to nearly 180,000 acres (281 square miles) by 1992 (Table 1.5) due to available water, technologic improvements, and market demands (Kopecz, 1994; Pumphrey, 1994). About half of the total acreage produced irrigated wheat and potatoes. Other irrigated crops included field corn, watermelon, alfalfa hay and pasture (Anderson, 1993; Fitch, 1994). Center pivots irrigated nearly 90 percent of the total irrigated area, and they were also used for fertilizer applications. Many farms using these center pivots employed some form of irrigation scheduling service (IRZ Consulting, 1993).

Table 1.5 Total irrigated crop agriculture acreage estimates for the Lower Umatilla Basin.

Period	OWRD Primary Irrigation Water Rights[a] (total acres)	Adjusted OWRD Primary Irrigation Water Rights[b] (total acres)	LANDSAT Photo/GIS Derived (total acres)
1986 - 1992	260,255	233,695	179,880[d]
1976 - 1985	251,556	224,996	171,181[e]
1966 - 1975	200,178	195,058	141,243[f]
1956 - 1965	85,488	85,488[c]	85,488

[a]: Values presented in this column are from the Oregon Water Resources Department Water Rights Database. The values are for primary irrigation water rights, and they reflect the total acreage at the end of each period. These values include acreages yet to be developed.

[b]: Values in this column were derived by using the values in the first column and subtracting undeveloped acreages readily observed on a LANDSAT photograph.

[c]: Undeveloped acreage was not easily identified on the LANDSAT photograph. So, no adjustment of total acres was made.

[d]: This value was derived with the aid of OSU Experiment Station and Morrow County ASCS staff. Irrigated areas by crop were outlined on a LANDSAT photo. The outline was transferred to a map. The map was reviewed and corrected. Then, the map was entered into an electronic Geographic Information System (GIS). The GIS provided the acreage for each crop category. These acreages were totalled yielding the number shown.

[e]: This number was derived by: (179,880) - (233,695 - 224,996) = 171,181

[f]: This number was derived by: (171,181) - (224,996 - 195,058) = 141,243

Irrigated Agriculture Nitrogen Loading

An average annual nitrogen budget for selected crops grown in the Lower Umatilla Basin is presented in Table 1.6. The budget indicates residual nitrogen may remain in the soil after the growing season. That nitrogen could leach beyond the crop root zone. A review of IRZ Consulting (1993) and del Nero (1994) indicate nitrogen does penetrate beyond the root zone at some irrigated crop fields within the basin. However, IRZ Consulting (1993) observed no significant leaching below the root zone in the basin where good irrigation and soil fertility management (water and nitrogen applications timed and limited to actual crop need) was practiced.

Table 1.6 The average annual nitrogen budget for intensively managed Lower Umatilla Basin crops.

	ALFALFA (HAY)	FIELD CORN, GRAIN	PASTURE	POTATO-TUBERS	WATER-MELONS	WINTER WHEAT (GRAIN)
YIELD	6.5 T	185 Bu	3 T	480 cwt	16 T	123 Bu
N REQUIRED, LB/A	360	190	190	295		190
N APPLIED/PRESENT:						
N IN CROP RESIDUE, LB/A	40	60	30	90		60
N APPLIED, LBS/A	25	280	110	350	140	195
N RELEASED FROM SOIL, LB/A	300	60	40	80	80	75
N AVAILABLE, LB/A	365	400	180	520	220	330
N OUTPUT:						
DE-NITRIFICATION, LB/A	0	25	0	40	10	10
RESIDUE, LB/A	0	50	0	10		50
N REMOVED, LBS/A	320	130	160	205	130	130
N REMAINING IN PROFILE, LB/A	45	195	20	265	80	140

From "Lower Umatilla Basin Water Management Area Crop Production Practices and Groundwater Quality, May 1991; and individual contact with L. Fitch, OSU Hermiston Ag. Research and Extension Ctr, and V. Pumphrey, Retired Professor, OSU.

Nitrogen applied to irrigated crops in the basin--alfalfa, corn potatoes, pasture, watermelons and wheat--in the basin may have exceeded 20.5 million pounds total during the 1990 growing season (project analysis of Pumphrey and others, 1991). Nitrogen lost to deep percolation may have exceeded one million pounds assuming a five percent loss to deep percolation. Assuming a five percent loss appears conservative given Ritter (1989) and Vitosh (1991). They indicate nitrogen loss to deep percolation at agricultural fields in the United States can range from one to 50 percent depending upon the amount of nitrogen applied, the time of application, soil texture, and the amount and timing of water applied.

Food Processing

Basin History

Basin food processing activity before 1970 consisted of slaughterhouses, a cooperative cannery, potato fresh pack sheds and one specialty potato processor (Fitch, 1994; Kopecz, 1994). Slaughterhouse and cannery wastewater discharged to city sewers (Kopecz, 1994). The potato sheds produced little or no wastewater (Fitch, 1994).

Large-scale potato processing for fast food and other uses entered the region east of Boardman and south of Hermiston, during the 1970s. It expanded to dominate all local food processing activities. The processing plants generate large volumes of nutrient and/or salt rich wastewater daily. The wastewater is land applied and sometimes stored in ponds.

Food Processing Nitrogen Loading

Originally, the food processing facilities land applied their wastewater to limited acreages, during all seasons, and at amounts exceeding crop needs. This initial land application approach caused some local nitrate groundwater contamination. Today, facilities are expanding their land application areas, building or expanding wastewater storage, and scheduling wastewater application to meet crop nutrient and water needs. These changes are designed to reduce nitrate loading to groundwater by food processors.

Estimated land application area and nitrogen loading for all individual food processing facilities are presented in Table 1.7 and in Appendix 3C.

The total wastewater land application acreage has expanded from nearly 825 acres in 1977 to nearly 7,500 by 1992. Nitrogen land application rates generally decreased after 1991. The rates ranged from 14 to 2,500 pounds per acre per year from the 1970s through 1991. Since 1991, the application rates have ranged from 3 to nearly 680 pounds per acre per year. The decrease coincided with the land application area expansion. Leaching to deep percolation was not determined.

The process wastewater also contains salt which crops do not use. Salt application rates currently range in excess of 3,000 to nearly 30,000 pounds per acre per year at some sites (Appendix 3C).

Table 1.7 Approximate food processing industry total land application area and total nitrogen loading in the Lower Umatilla Basin for selected periods.

Period	Total Acreage (acres)	Total Nitrogen or TKN Loaded[a] (total pounds/yr)	Average Nitrogen or TKN Loading Rate (pounds/acre-yr)
1977	824	-	-
1981 - 1984	2,097	>1,074,361[b]	>512[b]
1985 - 1989	2,805	2,506,446	894
1991 - 1992	7,492	1,591,898	212

Values in this table were derived from Appendix 3C.

[a] Values in this column should be considered approximate values only

[b] These values are missing nitrogen loading by Port of Morrow.

Livestock

Background

Stewart and others (1967), Spalding and Fulton (1988), and other investigators have documented U.S. groundwater contamination from livestock waste. This includes the Burbank-Wallula area in Washington (Spalding and others, 1982). Nitrogen is the primary livestock waste component that contaminates groundwater (Goldberg, 1989). The potential for groundwater contamination depends upon waste management at livestock yards, waste ponds, and/or land application sites.

Basin History

Livestock production in the basin has occurred since approximately 1900 (Kopecz, 1994, Reed-no date). Figure 1.9 shows the production periods for sheep, turkeys, chickens, hogs, dairies and beef cattle. This production has contributed to the local economy and provided valuable crop nutrients.

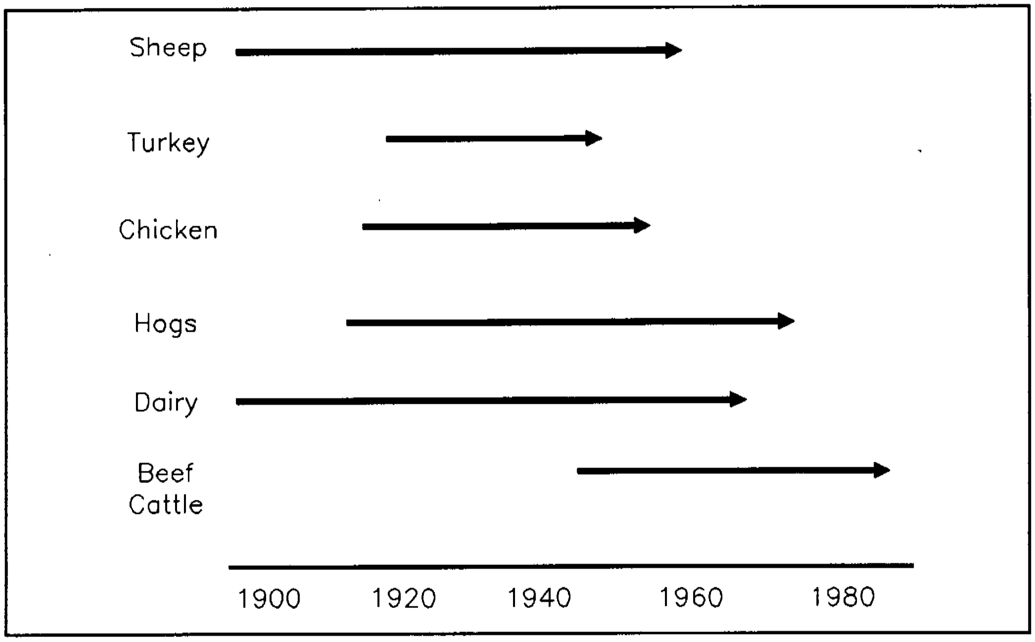

Figure 1.9 Approximate operational period for basin livestock commodities. (Source: Fitch, 1994, Pumphrey, 1994, and Kopecz, 1994).

Basin residents have valued and used livestock manure since early settlements. Very little, if any, commercial fertilizer was applied to crops from 1910 to 1930 (Kopecz, 1994). Instead, manure additions to the soil provided necessary crop nutrients and improved the soil tilth, water holding capacity, and resistance to wind erosion. Alfalfa was also used to provide some nutrients and to build up the soil (Tisdale, 1975). Manure use for Lower Umatilla Basin crop fertilization declined after World War II when the local dairy industry declined and produced less manure. The local cattle beef industry sustains continued manure use in the Lower Umatilla Basin.

Livestock Nitrogen Loading

Information necessary to calculate basin nitrogen loading from livestock waste is very limited. Some 1980s information exists for two large beef cattle operations, one large hog operation, and one dairy. Waste management at these facilities include waste removal from confined animal areas, waste storage in unlined ponds or stockpiles and land application. The amount of waste stockpiled, stored in ponds, sold and land applied varied by year. Calculations indicate that manure from basin livestock probably produced more than 3.4 million pounds of total nitrogen per year during the 1980s. However, nitrogen losses during storage possibly decreased the total nitrogen available for land application to around 780,000 pounds per year.

The total animal waste land application acreage varied during the 1980s, while the amount of waste and total nitrogen remained relatively constant. The total acreage apparently exceeded 1,350 acres some years and 14,350 acres other years. The actual acreage utilized each year was not obtained.

Actual nitrogen land application rates were not determined due to insufficient information. However, limited data from three facilities indicates annual nitrogen application of livestock waste possibly exceeded 15 to 78 pounds per acre. Consultants for one of these facilities recommended applying 300 to 450 pounds per acre. That same facility occasionally stockpiled waste at a 10-acre site in the years that land application acreage was unavailable. Nitrogen annually stockpiled possibly exceeded 35,000 pounds per acre.

Nitrogen leaching to deep percolation from land application, pond, stockpile, and animal yard sites was not determined due to insufficient information.

Domestic Sewage (municipal and on-site)

Background

Domestic sewage facilities include municipal, large on-site and individual on-site systems. Wastewater and sludge management at these facilities can include treatment, discharge to surface water, storage in ponds, land application, burial, or subsurface discharge through infiltration beds, sandfilters, drainfields or disposal wells.

Groundwater contamination from on-site systems has been documented. Oregon examples include mid-Multnomah County, Santa Clara/River Road, Clatsop Plains, La Pine and Irrigon.

Basin History: Municipal

Boardman, Echo, Hermiston, Irrigon, Stanfield, and Umatilla currently operate municipal sewage treatment facilities within the basin (DEQ Water Quality Files 9104, 26200, 38212, 42490, 84405, and 90659). Permits allow four facilities to discharge treated waste to the Umatilla or Columbia Rivers. Two facilities use sewage lagoons. Five facilities land apply sludge solids and/or sewage wastewater. One facility discharges collected septic tank effluent to the subsurface via infiltration beds.

City of Portland and Washington County, Oregon ship sewage sludge to the basin for land application at irrigated and non-irrigated sites. This activity began in the late 1980s and early 1990s (DEQ files 70725 and 90770).

Basin History: On-site

Six large on-site sewage systems operate in the basin. Facilities on file with the DEQ Water Quality Division are:

- Oregon Department of Transportation Stanfield Rest Areas (file 105049)
- Oregon Department of Transportation Boardman Rest Areas (file 64710)
- Hinkle Hotel (file 100132)
- Shady Rest Mobile Home Park (file 103745)
- Vista Park Mobile Home Park (file 100128)
- the U.S. Army Umatilla Depot Activity (file 91000)

Most of these facilities discharge domestic sewage water to drainfields and remove sludge for off-site treatment. The Boardman Rest Area uses evaporative lagoons. Army Depot sewage sludge was buried at the Depot's Active Landfill site until late 1993. Other large on-site facilities probably exist in the basin.

About 4,375 homes, mobile homes, businesses, public buildings, churches and other facility units outside of community sewer service areas in the basin are assumed to use individual on-site systems. This project identified these units from Morrow and Umatilla County Planning Offices tax lot records. The highest density of units are found near Hermiston, Boardman, and Irrigon.

Domestic Sewage Nitrogen Loading: Municipal

The total acreage available to land apply treated municipal waste in the Lower Umatilla Basin was once less than 400 acres. Land applied sludge from Portland and Washington County expanded that acreage to more than 2,700 acres by 1993. Historic and recent average annual land application rates for nitrogen at different sites ranged from none applied to nearly 215 pounds per acre.

Some municipal sewage wastewater deep percolation has occurred in the basin. The City of Irrigon currently discharges sewage wastewater to the subsurface via infiltration beds within a 2-acre area. The average nitrogen loading from the infiltration beds to the subsurface apparently increased from about 2,200 pounds per acre in 1990 to about 4,500 pounds per acre in 1992 (Table 1.8, Appendix 3E). The City of Echo sewage treatment lagoons reportedly lost 85 percent of the lagoon influent to subsurface seepage from 1976 until 1985 repairs. The average 1983 nitrogen loading from the lagoons was 195 pounds per acre (Appendix 3E).

Domestic Sewage Nitrogen Loading: On-site

Contamination from large or individual on-site systems are generally limited to localized areas near the systems. The large on-site systems identified by this investigation primarily discharge wastewater to the subsurface via drainfields or bottomless sand filters. One facility also uses dry wells. Deep percolation of nitrate-nitrogen from these systems appears to annually exceed 4,700 pounds over an area exceeding 10 acres (Table 1.9).

This investigation assumed all individual units are active and use individual on-site systems which discharge directly to the subsurface via drainfields. Deep percolation of nitrate-nitrogen from these systems may annually exceed 113,000 pounds for the entire basin (Table 1.10, Appendix 3G).

Table 1.8 Estimated nitrogen loading in the Lower Umatilla Basin by municipal sewage treatment facilities during 1992-1993.

Facility	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
City of Boardman[a] (1993)	Poplar trees	10	Nitrogen	pounds/acre-year	-	-	69
City of Echo[b]	Sludge land application area	54.5?	Nitrogen	Pounds/acre-year	0	0	0
City of Hermiston (1992)	Poplar trees and Wadekamper Ranch	161	Nitrogen	pounds/acre-year	139	6	22
City of Irrigon (1992)	Infiltration beds	2	Nitrogen	pounds/acre-year	-	-	4,550[c]
City of Stanfield (1993)	Sludge land application area	48	Nitrogen	pounds/acre-year	-	-	16
City of Umatilla (1992)	Current sludge land application area	7.7[d]	Nitrogen	pounds/acre-year	-	-	212
City of Portland (1992)	Madison Ranch	1809	Nitrogen	pound/acre-year	-	-	75
Unified Sewerage Agency (1993)	Madison Ranch	630	Nitrogen	pounds/acre-year	-	-	-[e]

See Appendix 3E for estimated nitrogen loading tables for individual facilities.

[a] City of Boardman land applied wastewater to 40 acres of alfalfa from 1986 - 1990. No land application occurred in 1991 or 1992.

[b] From 1976 to July 1985, the City of Echo lagoons lost approximately 85 percent of the influent to subsurface seepage.

[c] This value reflects nitrogen leaving the infiltration bed to the subsurface after nitrogen reduction/losses in the beds.

[d] Historic sludge land application area was an 80 acre site.

[e] Land application began in September 1993.

Sources: DEQ files: 26200, 42490
DEQ Northwest Regional Office Staff
DEQ Pendleton Office Staff
SCM Consultants, Inc (1990)
Beyeler (1993)
Richwine (1994)

Table 1.9 Estimated nitrogen loading estimate in the Lower Umatilla Basin by selected large on-site sewage treatment systems.

Year	Facility	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1978 - Present	Hinkle Railroad Inn (drainfield)	2.41	Nitrate-N	pounds/acre-year	551[a]	-	-
1993[b]	OR Dept of Transportation Boardman Rest Area (land application area)	5	Nitrogen	Pounds/acre	-	-	60
1993	OR Dept of Transportation Stanfield Rest Area West Bound (drainfield)	0.17	Nitrate-N	pounds total	-	-	244
1993	OR Dept of Transportation Stanfield Rest Area East Bound (drainfield)	0.17	Nitrate-N	pounds total	-	-	244
1991	Shady Rest Mobile Home Park (bottomless sand filter)	0.19	Nitrate-N	pounds total	-	-	441
1990	US Army Umatilla Depot Activity Administration Area (drainfield)	0.23	Nitrate-N	pounds total	-	-	2,483
1986	Vista Park Mobile Home Park (drainfield)	4.13	Nitrate-N	pound/acre	-	-	752

See Appendix 3F for estimated nitrogen loading tables for individual facilities.

[a] Value is based on the maximum discharge allowed by WPCF permit number 100195

[b] The only land application event since the facility began operating in 1977.

Facilities operating with drainfield values came from using available discharge flow information and by using a 40 mg/l nitrate-nitrogen concentration for drainfield effluent percolating by groundwater. The 40 mg/l nitrate-nitrogen concentration came from EPA (1980) and DEQ (Ronayne et al., 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Sources: DEQ files: 100132, 105049, 103745, 91000, 100128
DEQ Pendleton Office Staff
Bochsler and Hansen (1990)
Joleen Odens (1994)

Table 1.10 Estimated annual total nitrate-nitrogen loading from domestic septic systems in the Lower Umatilla Basin.

Units	Units Counted[a]	Estimated Annual Nitrate Loading[b] (pounds/year)
Homes/Mobile Homes	4,015	103,846
Public Places (Churches, Schools, Parks, Public Buildings)	40	1,035[c]
Work Places (Business, Shop/Industry)	320	8,277[c]
Grand Total	4,375	113,157[d]

[a] Units outside of sewer services areas identified from Morrow and Umatilla County Records. Some units may not be occupied. Other units may be serviced by large on-site systems.

[b] Estimate calculations used 25•8,644 pounds of nitrate per year per unit. This value was derived from using an average 213.3 gallon per day wastewater discharge rate for households/small businesses and 40 mg/l average nitrate concentration in septic tank effluent percolating to groundwater. The wastewater discharge rate for households/small businesses was calculated from Lower Umatilla Basin sewage treatment facility data. The 40 mg/L average nitrate concentration was derived from EPA (1980) and DEQ (Ronayne et al., 1982) literature as well as recent work conducted by DEQ employee Henning Larsen.

[c] The total amount of nitrate loading for these units may be larger than the estimates shown. The total population served by these units was not determined form the sources reviewed. However, some of these units may be inactive, out buildings without toilet facilities, or units with an alternate sewage treatment system.

[d] The column total differs from the number shown by 1 pound/year due to errors introduced by rounding numbers to a whole number.

Military Activities

Basin History

The U.S. Army Umatilla Depot Activity was established in 1941 and currently occupies 30.8 square miles north of Interstate 84 between Boardman and Hermiston (Dawson and others, 1982). Groundwater contamination exists beneath portions of the Depot. Constituents include metals, nitrate, explosives, and organic chemicals (Dawson and others, 1982, Ritchie and others, 1992, Mahannah and others, 1993, Machacek and others, 1993, Woodland and others, 1993, and Bowen and others, 1993).

Military Activities Nitrogen Loading

Historic and current Depot sites potentially contributing nitrate to groundwater include the Explosive Washout Lagoons, the Ammunition Demolition Area, the Administration Area sewage treatment facility, and the Active Landfill.

- About 85 million gallons of explosive washout water was discharged to the 0.09 total acres of the unlined Explosive Washout Lagoons from the mid 1950s to the mid 1960s. This activity contaminated groundwater with nitrate and other constituents (Dawson and others, 1982, Ritchie and others, 1992, Bowen and others, 1993).

- Deep percolation of nitrate-nitrogen at the Depot's sewage treatment facility from 1985 through 1990 possibly exceeded 2,450 pounds annually at a 0.23 acre site (Appendix 3H).

- Dried sewage sludge was disposed of at the 10-acre unlined Active Landfill (former gravel pit) until 1993 (Ritchie and others, 1992, Golder and Associates, Inc., 1992, Dana, 1995). Project information was insufficient to estimate nitrogen loading. Other investigators attributed nitrate in the vicinity's groundwater to an offsite source and possibly the landfill (Ritchie and others, 1992).

- Project information was insufficient to estimate nitrogen loading at the 20 sites within the 1,750 acre Ammunition Demolition Area. Although nitrogen amounts are unknown, other investigators concluded that activity within the area did not and will not contaminate groundwater (Dawson and others, 1982, Ritchie and others, 1992, Mahannah and others, 1993).

Other Loading Sources

A variety of additional land uses were investigated and found to be contributing very little or no nitrogen to area groundwater.

Solid Waste

Historic and current basin landfill activity includes Finley Buttes, Umatilla Buttes, U.S. Army Depot sites, trenches at the former Boardman Air Force Range, and possibly other sites. A review of DEQ Solid Waste Disposal Facility Permit files and facility reports indicate the use of liners to prevent deep percolation of leachate occurs at the Finley Butte landfill only.

Some landfills may or did receive waste containing nitrogen:

- Currently, each load disposed at the Finley Buttes and Umatilla Buttes landfills can contain up to 25 gallons of free liquid including non-digested sewage sludge and septic tank pumpings (DEQ Solid Waste Disposal Facility Permit File Numbers 394 and 143). Liners at Finley Buttes should prevent deep percolation. Project information was not sufficient to calculate nitrogen loading, if any, from Umatilla Buttes landfill.

- Septic tank pumpage was disposed of at three ponds near the current Umatilla Buttes landfill entrance from 1974 to 1983 (Advanced Sciences, Inc., 1992). Pumpage disposed in 1977 contained nearly 230 pounds Total Kjeldahl Nitrogen (organic nitrogen) only. Information was insufficient to calculate deep percolation of nitrogen, if any.

- The U.S. Army disposed of dried sludge at the Depot's Active Landfill (see military activities).

- Sewage runoff was observed in one disposal trench at the former Boardman Air Force Range (DEQ Environmental Cleanup File 1030). Information was not sufficient to calculate pounds of nitrogen or deep percolation, if any.

Electricity Generation

Electricity production is expanding in the Lower Umatilla Basin. Local production began with the construction of McNary hydroelectric dam near Umatilla in 1956 (Stephenson, 1994). The Portland General Electric (PGE) built a coal fired plant southwest of Boardman in 1980 (Carter, 1987). Since 1990, three natural gas electric co-generation facilities have been proposed for the basin (Barlow and Tipton, 1993, CH2MHill, 1992, IDA-West Energy Company, 1993).

Available information indicates possible loading from existing or proposed facilities is limited to salt and other constituents besides nitrogen. PGE has reported elevated nitrate concentrations in groundwater sampled in the vicinity of the coal fired plant. PGE attributes the contamination to nearby agriculture (Carter, 1987, 1988, 1989, 1990).

Union Pacific Railroad

By 1960, the Union Pacific Railroad Company consolidated three railroad terminals and began servicing diesel locomotives at the Hinkle site (DEQ Water Quality File 90860). Historic and current potential loading at the site primarily involves oil or diesel except for domestic sewage and grain washed out of railcars.

Pendleton Grain Growers

About three acres of Pendleton Grain Growers, Incorporated - Stanfield became an environmental cleanup site after a 1988 fire involving 10,000 pounds of agricultural pesticides and 600,000 pounds of various fertilizers. Pesticides were detected in soil 30 to 40 feet below an evaporative pond. Nitrate exceeding 10 mg/L in nearby groundwater was attributed to a neighboring cattle feedlot (DEQ Environmental Cleanup File 639, Gilles, 1993). Project information was not sufficient to estimate nitrogen loading at this site.

Groundwater Recharge

Lower Umatilla Basin groundwater recharge projects include the existing County Line Groundwater Recharge Project, the tentative City of Hermiston Groundwater Recharge Demonstration Project, and the proposed Echo Junction Aquifer Storage and Recovery Project. These projects seek to alleviate existing groundwater supply problems. Existing or potential nitrogen loading from these projects appear minor.

Accidents and Spills

Numerous accidents and spills reported to DEQ have occurred in the Lower Umatilla Basin since the late 1970s (Appendix 3K, Plate 3.7). Only a few involved nitrogen. These include several sewage overflows onto land and 1,000 gallons of fertilizer spilled along Powerline Road near Hermiston. Project information was not sufficient to estimate nitrogen loading from these incidents, but they appear small.

Hazardous Waste

No nitrogen or other constituent loading related to hazardous chemicals or waste handled or generated by some facilities in the Lower Umatilla Basin should be occurring.

Underground Storage Tanks

This projects expects no nitrogen loading related to underground storage tanks. However, some Umatilla Basin underground storage tanks have reportedly released petroleum products (DEQ Underground Storage Tank Cleanup List).

Natural Occurrence

Nitrogen from igneous rock, lightning, decomposing organic matter, and nitrogen fixation by bacteria can enter water (Davis and DeWeist, 1966, Hem 1985, Waring, 1949). Project information was not sufficient to estimate nitrogen loading from natural sources. However, low nitrogen concentrations detected in project groundwater samples collected at upgradient sites and statewide groundwater quality statistics by the U.S. Geological Survey (Miller and Gonthier, 1984) suggest nitrogen loading from natural sources is very low.

Groundwater Quality

A Focus On Nitrate

The Lower Umatilla Basin groundwater investigation focused on nitrate. However, the chemical analysis also tested for many other substances or constituents, which served the investigation in two ways. First, the analysis helped determine whether other constituents contaminated groundwater. Secondly, the relationship between the other constituents and nitrates were explored to provide a better understanding of the sources and fate of nitrate.

Nearly one-third of the project's groundwater sampling sites yielded samples with nitrate concentrations exceeding the 10 mg/L drinking water standards. Areas with nitrate concentrations greater than 10 mg/L are not evenly distributed. Higher nitrate concentrations in groundwater occur in or near the vicinities of Threemile and Sixmile Canyons, Boardman, Irrigon, the U.S. Army Umatilla Depot, County Line Road, and the Butter Creek-Umatilla River confluence. Samples with the highest concentrations came from an area between the Port of Morrow and Irrigon.

Data analyses indicate multiple sources are responsible for the nitrate contamination in the Lower Umatilla Basin. Sources that formerly and/or currently contributed nitrate, either alone or in combination, include:

- irrigated agriculture (including center pivots),
- food processing wastewater,
- livestock operations,
- domestic sewage, and
- military activities.

Nitrogen loading from these sources can occur in several ways:

- land application of chemicals or waste
- use of unlined ponds or lagoons, and
- use of drainfields or infiltration beds

Data analyses also provided information about nitrate travel times. It appears that nitrate leaching through soil can reach groundwater within one to nineteen months, given sufficient moisture. Once in groundwater, nitrate transport appears slow in portions of the basin. Natural groundwater flushing of nitrate may require decades. Flat gradients and well pumping or canal recharge contribute to a slow-moving flow, causing temporary flow reversals

This investigation used four types of sampling, a variety of laboratory chemical analyses, and a variety of data analyses to make these conclusions. The following discussion presents the science conducted and the conclusions obtained.

Sampling and Analyses

Introduction

The groundwater chemistry phase of the Lower Umatilla Basin Groundwater Management Area technical investigation included multiple groundwater sampling, laboratory analyses, and data analyses. The groundwater sampling included reconnaissance, bimonthly, synoptic, and sampling for nitrogen-isotopic analysis, with each type serving a different purpose.

Laboratories at Oregon Department of Environmental Quality, Oregon Department of Agriculture, Oregon State University Department of Agricultural Chemistry, and Boston University (nitrogen isotope) chemically analyzed the groundwater samples. Laboratory availability, the type of laboratory services offered, and project resources determined which laboratories were used.

Project analyses included using general statistics, some groundwater chemistry computer modeling, the evaluation of nitrogen-isotopes, and many maps and graphs to understand the prevalence, distribution, sources and fate of nitrate in local groundwater.

Groundwater Sampling Conducted

Reconnaissance Sampling

Characterizing Lower Umatilla Basin groundwater quality began with reconnaissance groundwater sampling conducted from July 1990 through October 1991. Oregon Department of Environmental Quality (DEQ) staff collected 206 reconnaissance samples. The DEQ, Oregon Department of Agriculture, and Oregon State University Department of Agricultural Chemistry laboratories conducted the chemical analyses.

The sampling effort provided a basic understanding about the nature, extent and concentration range of local groundwater contamination in the basin. That understanding directed decisions about subsequent groundwater sampling, laboratory analyses, and data analyses.

The reconnaissance sampling indicated area-wide nitrate contamination, elevated levels of total dissolved solids and scattered pesticide/industrial chemical detection within the designated investigation area.

Bimonthly Sampling

Ongoing bimonthly groundwater sampling at a specific group of 35 to 40 basin wells began in October 1991. The sampling effort provides information about seasonal and long term nitrate and other constituent concentration trends at different locations and along selected groundwater flow paths. These trends help determine any contamination concentration changes and any contaminant movement. They also help identify seasonal versus constant influences and sources.

The sampling occurs January, March, May, July, September, and November. The DEQ and Oregon Department of Agriculture laboratories conduct most of these chemical analyses.

Synoptic Sampling

Synoptic sampling, a single sampling event in June and July 1992, provided sufficient concurrent data for basin-wide analyses. Basin sampling occurred at 207 wells (179 with alluvial groundwater, 28 with basalt groundwater), 26 surface water locations, and one drain.

The concurrent data helped characterize the basin-wide distribution of nitrate and total dissolved solids in alluvial groundwater; characterize the relationship between nitrate, other constituents and contamination sources; identify various nitrate sources contaminating basin areas; and understand the fate of contaminants along additional alluvial groundwater flow paths. The data distinguished between the influences of dilution, mixing, evaporation and water-rock reactions in groundwater chemistry. It also helped to understand the relationship between groundwater in the alluvial and basalt water-bearing zones.

Collecting the synoptic samples was a cooperative effort between state agencies and eight local facilities. DEQ laboratory staff conducted the synoptic sampling chemical analyses which included nutrients (nitrate), major ions, and metals.

Nitrogen-Isotope Analysis

Sampling for nitrogen-isotopic analyses occurred during three 1993 and 1994 sampling events at approximately 20 wells, 3 lysimeters, and a food processing wastewater surge pond. Repeat sampling at many of these sites provided data to verify or improve the identification of nitrate sources and processes influencing Lower Umatilla Basin groundwater. The Boston University Stable Isotope Laboratory conducted the nitrogen-isotopic chemical analysis.

Data Analyses Conducted

General Statistics

Limited statistical analyses were conducted to identify the percent of sampling sites and samples having constituent concentrations within specific ranges. This was useful for defining the groundwater contamination problem in the Lower Umatilla Basin. It was not useful for characterizing the fate of the groundwater contamination or identifying the contamination sources.

Chemical Constituent Maps

Maximum concentration constituent maps and concentration contour maps were produced and analyzed (Plates 4.2 through 4.13). The maps show the concentration distribution of selected chemical constituents across the basin. That concentration distribution was compared to the distribution of current and historic land uses in the basin to identify groundwater contamination sources and other influences on the groundwater chemistry.

Nine maximum concentration maps were produced for nine chemical constituents: nitrate+nitrite-nitrogen, total dissolved solids (TDS), sodium, arsenic, chloride, phosphate, bromide, boron, and vanadium. These constituents were selected for different purposes. Nitrate is the focus of this investigation. TDS became a concern during the land use review and constituent loading assessment phases of this investigation. Arsenic and sodium were detected in Lower Umatilla Basin groundwater samples at concentrations that could pose health concerns. Phosphate, chloride, bromide, boron and vanadium were included to help identify nitrate sources contaminating local groundwater.

Two chemical concentration contour maps were produced for nitrate+nitrite-nitrogen and total dissolved solids (TDS) in alluvial groundwater during June-July 1992 using synoptic sampling data. These maps show distribution of high versus low nitrate and TDS concentrations in the basin's alluvial groundwater. They show that TDS concentration distribution variations appear related to different nitrate sources and other basin groundwater chemistry influences.

Graphical Analyses

Graphical methods were used to analyze the Lower Umatilla Basin groundwater and surface water chemistry data. The methods included a variety of x-y graphs, Piper trilinear graphs and Schoeller Diagrams. The x-y graphs show the relationship between a component, like constituent concentration or groundwater elevations plotted along a vertical axis and another component, such as time, location or another constituent plotted along the horizontal axis. Piper trilinear graphs and Schoeller Diagrams show the relationship between multiple constituents. The graphs were reviewed to identify processes and nitrate sources influencing the basin's groundwater.

Groundwater Flow Path

Several flow path analyses were conducted to better understand the human and natural influences affecting the basin's groundwater chemistry. Flowpath analyses investigate the chemical changes groundwater experiences from natural and human influences as it moves from an upgradient area to a downgradient location.

Basin-wide correlation between nitrate and other constituents is generally poor except for TDS and conductivity. This indicates the combination of influences affecting the groundwater chemistry varies across the basin. By focusing on smaller areas or flow paths, constituent correlations improved which helped project investigators identify local groundwater chemistry influences.

Computer Modeling Groundwater Chemistry Variations

This investigation used NETPATH (Plummer and others, 1991) and PHREEQE (Parkhurst and others, 1980) groundwater chemistry computer models for data analyses. NETPATH calculates the geochemical mass-balance between groundwater at the beginning and end of a groundwater flow path. PHREEQE calculates geochemical reactions. The computer models were selectively used to understand and distinguish between natural and human influences upon Lower Umatilla Basin groundwater.

Nitrogen Isotope Analyses

During 1993 and 1994, nitrogen isotope groundwater samples were collected. The nitrogen isotopic compositions of Lower Umatilla Basin groundwater were to supplement other nitrogen source identification data analyses.

Samples were collected from private wells in the Butter Creek drainage, and other wells in the area of the Depot's explosive washout lagoon, wells near areas of application of food processing wastewater, near past and present animal lots, and near irrigated agriculture where commercial fertilizers are applied.

Data Analysis Results

Introduction

Understanding the distribution, source, and fate of nitrate contaminated groundwater is the primary purpose of the Lower Umatilla Basin groundwater technical investigation. The complexity of natural processes, land uses, groundwater flow, and groundwater chemistry in the basin made using various data analyses necessary to achieve that understanding.

Groundwater contains many dissolved chemical constituents related to natural and/or human influences. Distinguishing between various natural and/or human influences on the groundwater chemistry requires a careful analyses of groundwater chemistry and the hydrogeologic environment. Understanding unique chemical constituent proportions and correlations helped identify groundwater contamination sources. Understanding the natural chemical changes aided the understanding of groundwater occurrence and flow in an area.

Constituents

Nitrate

Nearly 31 percent of the project sampling sites had groundwater nitrate+nitrite-nitrogen concentrations greater than the current 10 mg/L standard for drinking water. The percent of samples and sites with concentrations exceeding 10 mg/L is greatest for groundwater from alluvial sediments. The greatest concentrations detected in groundwater sampled from alluvial sediments and basalt water-bearing zones were 76 mg/L and 64 mg/L respectively.

Conversely, approximately 26 percent of the sampling sites had groundwater nitrate+nitrite-nitrogen concentrations less than 2 mg/L.

Areas of high and low nitrate+nitrite-nitrogen concentrations are not uniformly distributed across the basin (Plates 4.2 and 4.3). Areas where nitrate+nitrite-nitrogen concentrations in project groundwater samples exceed 10 mg/L include:

- Threemile and Sixmile Canyons;
- Boardman;
- between the U.S. Navy Bombing Range, U.S. Army Umatilla Depot Activity, Irrigon, and the wildlife refuge (the highest concentration area);
- between Irrigon and Umatilla;
- the northeast corner of the Army Depot;
- the central area of the Army Depot;
- between the Army Depot and Lost Lake;
- the general Butter Creek and Umatilla River confluence area;
- between Interstate 82 and the Umatilla River; and
- between Stanfield Loop Road and Diagonal Road near the Cold Springs Reservoir.

Sources responsible for nigher nitrate concentrations across the basin appear to vary by location. Past and/or current general sources include:

- Irrigated agriculture, including center pivots;
- Food processing wastewater land application;
- Livestock operations;
- U.S. Army Umatilla Depot Activity;
- Sewage waste from municipal infiltration beds, large on-site systems, and areas with concentrated individual septic systems.

Dilution from canals or surface water appears to reduce nitrate concentrations along the Columbia River, near the High Line Canal, Carty Reservoir and Lost Lake. Significant mixing between Umatilla River water and groundwater appears to occur north of Interstate 84 and east of the Umatilla River.

Types of Nitrogen

Nitrogen converts into different components of the nitrogen cycle. These components are, in order of decreasing oxidation state, nitrate, nitrite, ammonia and organic nitrogen. References to Total Kjeldahl nitrogen considers the sum of organic nitrogen and ammonia nitrogen.

Nitrate Sources for Threemile and Sixmile Canyon Area

Historic and current land uses within Threemile and Sixmile Canyons include the Air Force Bombing Range, the PGE plant, a large beef cattle feedlot, and a large farm which has used feedlot animal waste to fertilized crops.

Project and facility alluvial groundwater sampling at the J.R. Simplot Feedlot and PGE's monitoring wells detected elevated nitrate, total Kjeldahl nitrogen (TKN) and ammonia concentrations. The elevated TKN and ammonia values suggest nitrogen conversion to nitrate is locally incomplete and they strongly indicate an animal waste or another organic nitrogen source influences local groundwater. Commercial fertilizer may also be a contamination source. Higher nitrate concentrations in basalt groundwater indicate a connection exists between water in the alluvial sediments and the shallow basalt water-bearing zones in the Taggares Farm vicinity and PGE's ash disposal area. Lower concentrations within the Carty Reservoir vicinity suggests the reservoir dilutes nearby groundwater.

Nitrate Sources for Boardman to west Umatilla

Historic and current land uses within this area include two municipalities, the Navy Bombing Range, the Army Depot, irrigated agriculture, livestock operations, food processing, municipal and on-site sewage systems, and landfills. Sources of nitrate contaminating groundwater varies across the area.

Elevated nitrate concentrations south of Boardman appear primarily related to irrigated agriculture, with some local contamination at relative lower concentrations from animal operations and septic systems.

- Wastewater land application appears responsible for elevated nitrate concentrations at the Port of Morrow and Lamb-Weston sites east of Boardman and northeast of the Army Depot, respectively.
- Irrigated crops appear responsible for elevated nitrate between the Port of Morrow and Irrigon, and along the Army Depot's western boundary.
- Irrigation related activity and septic systems appear responsible for elevated concentrations north of the Depot.
- Animal operations and irrigated agriculture appear primarily responsible for nitrate in groundwater south of the Depot.
- Elevated groundwater nitrate concentrations detected in the US Army Depot active landfill area appears to be a Depot source, possibly dried domestic sludge disposed at the landfill.
- Historic activity at the Army Depot's explosive washout lagoons is responsible for elevated groundwater nitrate concentrations in that vicinity.
- Elevated nitrate concentrations were detected in some basalt groundwater samples indicating a route exists for nitrate to travel to some basalt water-bearing zones.

Nitrate Sources for Butter Creek to Umatilla

Historic and current land uses within this area include food processing, livestock, municipal and on-site sewage systems, and a landfill. Sources contaminating groundwater with nitrate vary.

- Food processing wastewater appears primarily responsible for elevated nitrate concentrations at the Butter Creek-Umatilla River confluence vicinity and outside the northeast corner of the U.S. Army Depot.
- Animal waste appears to be the primary source of elevated nitrate in alluvial groundwater sampled near C&B Livestock. Concentrations decrease downgradient. Canal leakage may be responsible for some of that decrease.
- Irrigated agriculture appears responsible for some elevated nitrate concentrations detected in groundwater sampled northwest of C&B Livestock.
- Septic systems appear to be an important influence upon the groundwater chemistry in the area north of Interstate 84 and west of the Umatilla River where project sampling detected some elevated nitrate concentrations.

Nitrate Sources For Umatilla to Hat Rock to Echo Meadows

Historic and current land uses within this area included four municipalities, irrigated crops, livestock, food processing, domestic sewage, and a railroad yard.

Irrigated crop activity appears primarily responsible for groundwater nitrate concentrations exceeding 10 mg/L with septic systems additionally responsible in some areas. Sources responsible for groundwater nitrate concentrations below 10 mg/L include septic systems, animal waste, irrigated crop activity, and wastewater land application. Dilution from canal leakage appears to be an important influence in the area.

Total Dissolved Solids

Total Dissolved Solids (TDS) became a concern during the land use review and constituent loading assessment phases of this investigation. More than 25 percent of the project groundwater sampling sites had TDS concentrations greater than the current 500 mg/L secondary (aesthetic) drinking water standard. The percent of sampling sites with maximum concentrations exceeding 500 mg/L is greatest for groundwater from alluvial sediments. The greatest concentration detected in groundwater sampled from alluvial sediments and basalt water-bearing zones was 1200 mg/L and 1600 mg/L respectively.

Areas of high and low TDS concentrations are not uniformly distributed across the Lower Umatilla Basin (Plates 4.4 and 4.5). Locations of high and low TDS concentration areas are similar to the high and low nitrate+nitrite-nitrogen concentration areas with some exceptions. The exceptions appear related to the nitrate sources. Two areas with the highest TDS concentrations are located along Six Mile Canyon and between Boardman and Irrigon. Dilution appears responsible for lower TDS concentration along the Columbia River, northwest of Lost Lake, Carty Reservoir, within Hermiston basin, the terrace south of Hermiston and the Echo and Umatilla Meadows area.

Arsenic

Arsenic in groundwater can pose a health risk. Plate 4.6 shows the maximum concentrations detected across the basin by project sampling. Only four alluvial groundwater sampling sites had total arsenic concentrations exceeding the current 0.05 mg/L drinking water standard. The four sites are dispersed: the northwest corner of the U.S. Army Umatilla Depot Activity; the east side of the Depot; east of the Depot's northeast corner; and west of Stanfield.

Sodium

Natural water commonly contains low levels of sodium. Sources include human activity and natural processes. Elevated sodium concentrations in groundwater can pose a health risk to persons on a physician prescribed sodium restricted diet.

Nearly 85 percent of all project sampling sites had total sodium concentrations in groundwater greater than the 20 mg/L currently recommended for persons with a physician prescribed sodium restricted diet. Plate 4.7 shows the maximum concentrations detected in basin groundwater by project sampling. The highest concentrations detected in groundwater from alluvial sediments versus basalt water-bearing zones was 300 mg/L and 140 mg/L respectively. However, basalt water-bearing zones had the highest average maximum concentration.

Chloride

Natural water commonly contains chloride. Sources include human activity and natural processes. Plate 4.8 shows the distribution of maximum chloride concentration detected by project sampling. Only one project sampling site had chloride in groundwater exceeding the current secondary (aesthetic) drinking water standard (250 mg/L). That site obtains groundwater from basalt.

Phosphate, Boron, and Bromide

The occurrence and relative proportion of phosphate, boron, and bromide to other chemical constituents in groundwater can occasionally help identify nitrate sources. Plates 4.9, 4.10 and 4.11 show the maximum concentrations detected in the basin by project sampling. Lower phosphate concentrations were often found in or near irrigated crop areas.

Vanadium

Vanadium concentrations in Lower Umatilla Basin groundwater are an unusual curiosity (Plate 4.12). Typically vanadium concentrations in groundwater rarely exceeds 0.01 mg/L (Hem, 1985). However, average maximum concentrations in basin groundwater from basalt water-bearing zones and alluvial sediments, respectively, are 0.02 mg/L and 0.04 mg/L. The maximum concentration detected was 2 mg/L in groundwater from alluvial sediments.

Volatile Organic Compounds and Pesticides

Volatile organic compounds (VOC) or pesticides from human activity were infrequently detected in Lower Umatilla Basin groundwater (see Plate 4.13). Most groundwater samples containing VOCs and/or pesticides came from alluvial sediments. Project sampling detected only one compound, ethylene dibromide (EDB), at concentrations exceeding current drinking water standards. Project sampling also detected 1,1,2,2 tetrachloroethylene (1 site), chloroform (4 sites), toluene (1 site), atrazine (6 sites) and dacthal acid (4 sites).

Graphical Observations and Interpretations

State agency staff conducted graphical analyses of Lower Umatilla Basin sampling data to identify the chemical and physical processes influencing the groundwater chemistry variations observed in the basin. alluvial groundwater data and basalt water-bearing zone groundwater data were analyzed separately, because the groundwater came from different hydrogeologic units.

Basin-wide Correlations

Correlations suggest a common influence. Total dissolved solids (TDS) and electrical conductivity best correlate with nitrate+nitrite-nitrogen concentrations basin-wide. A poor correlation generally exists between nitrate+nitrite-nitrogen and other chemical constituents. These poor correlations basin-wide indicate significantly different basin groundwater chemistry histories may exist, as represented by the various constituents that accompany nitrate in groundwater.

Figure 1.10 shows nitrate+nitrite-nitrogen versus TDS and sulfate for all project groundwater samples. The change from scatter below 1/mg/L nitrate+nitrite-nitrogen to correlation above 1 mg/L suggests the dominating chemical influence upon local groundwater possibly changes from natural processes to human activity.

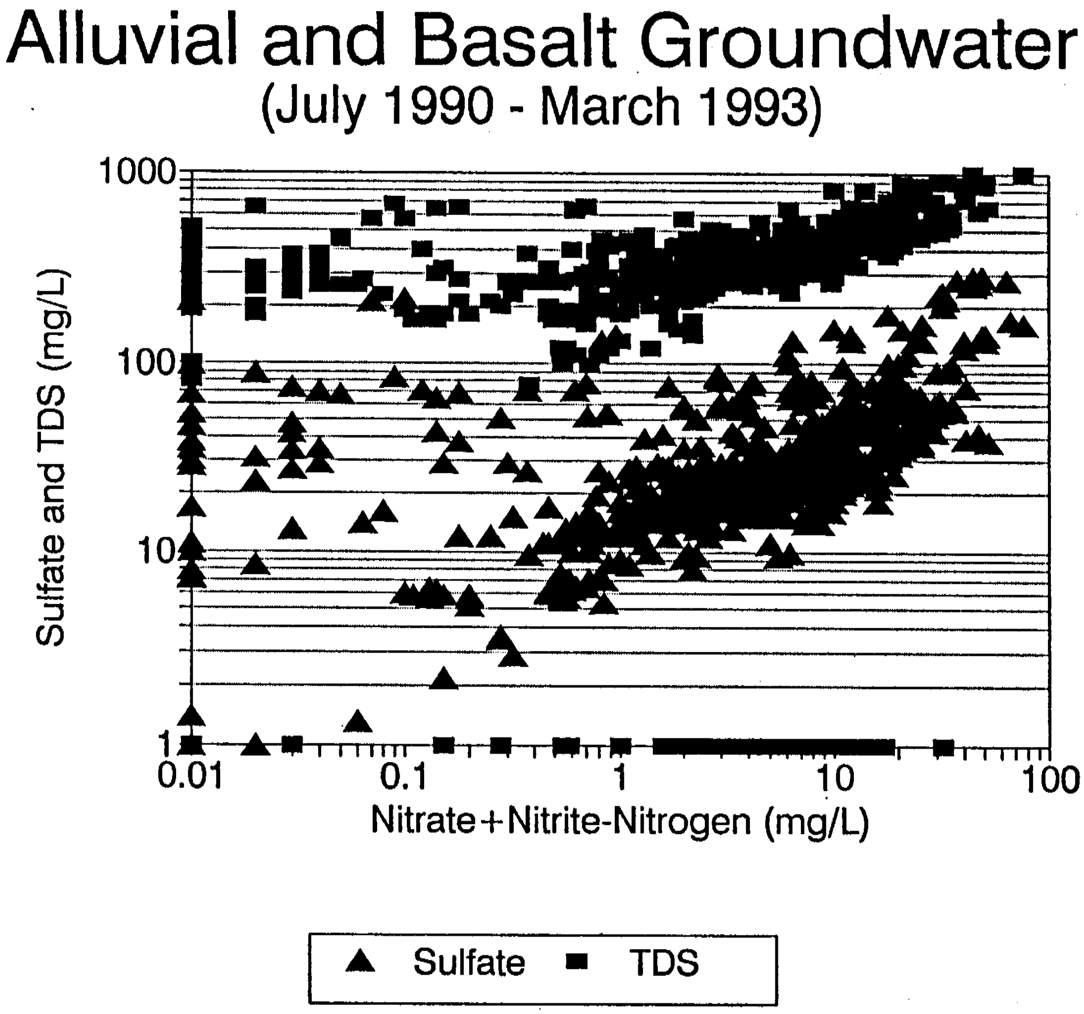

Figure 1.10 Nitrate+nitrite-nitrogen versus total dissolved solids and sulfate in Lower Umatilla Basin groundwater.

Evaporation and Mixing Influences

An understanding of the basin's evaporation and mixing influences helped determine any effects they may have on the basin's groundwater chemistry, and better identified the sources of contamination.

Evaporation appears to influence groundwater associated with many wells in the basin. However, the data graphed are often displaced from the evaporation line toward chemical compositions representing potential nitrate sources. Constituent versus constituent graphs indicate evaporation and mixing influences the alluvial groundwater chemistry in the Lower Umatilla Basin. Chloride versus potassium graph along an approximate evaporation trend that begins with a dilute source such as the Columbia or Umatilla Rivers.

The Umatilla River may be receiving nitrate and TDS from groundwater or runoff. Groundwater in some basalt water-bearing zones appear hydraulically connected to alluvial groundwater. In chloride versus nitrate+nitrite-nitrogen graphical analyses, the alluvial groundwater samples show evaporation evidence. However, nitrate concentrations greater than expected for simple evaporation of a source are consistent with a model of water mixing with nitrate enriched waters.

Piper Trilinear Graph and Schoeller Diagram Results

Groundwater samples related to specific nitrate sources did not graph uniquely on these diagrams. However, the diagrams did assist efforts to link some groundwater samples indirectly to nitrate sources.

Most groundwater samples plotted as mixed-cation\bicarbonate dominated and calcium\bicarbonate dominated water on the Piper trilinear diagrams. Chloride and sulfate proportion variations observed on the trilinear graphs often correlated to groundwater nitrate+nitrite-nitrogen concentration variations over time and by location. Occasionally, calcium proportions correlated similarly or inversely to nitrate+nitrite-nitrogen concentrations.

Many major ion concentrations in Lower Umatilla Basin groundwater sampled often correlated to nitrate+nitrite-nitrogen concentration variations over time and by location. This relationship appeared on Schoeller diagrams as similar line patterns shifting up, down, or superimposing when nitrate+nitrite-nitrogen concentration increased, decreased, or remained unchanged, respectively. Detectable phosphate concentrations often correlated inversely to groundwater nitrate+nitrite-nitrogen concentration variations over time and by location on these diagrams.

Nitrate Versus Time

Nitrate concentrations commonly fluctuate in Lower Umatilla Basin groundwater with some exceptions. The nitrate concentration peaks generally occurred during the non-growing season. The peaks occurred less frequently during the mid-summer months. Other constituents often had concentration peaks during fall, winter, and spring months also.

The concentration peaks occurring primarily during fall, winter, and spring may relate to one or more influences. It may relate to the time needed for nitrogen, other constituents, and water applied at land surface to travel to groundwater. It may also relate to when nitrogen, other constituents, and water can most easily escape to groundwater.

Relatively steady nitrate+nitrite-nitrogen concentrations over time were observed for groundwater samples from some wells. Steady nitrate+nitrite-nitrogen concentrations above 1 mg/L appear related to a constant source like septic systems or nitrate accumulating in areas where limited groundwater movement occurs.

Comparing constituent concentration versus time graphs did not distinguish different sources and processes.

Influence of Multiple Nitrate Sources

Constituent versus constituent graphs helped characterize the influence of some nitrate sources upon Lower Umatilla Basin groundwater. June-July 1992 data for groundwater sampled at wells within or near areas with septic systems, animal feedlots, food processing wastewater land application, and irrigated agriculture were graphed. The rationale for this analysis is that nitrate generally travels in water percolating from the surface to groundwater. That water will contain other constituents that reflect its source and the chemical modifications that occurred during its history. Therefore, the water percolating downward carrying nitrate from a specific land use, may have an identifiable chemical signatures.

The relationship between total dissolved solids (TDS) and nitrate+nitrite-nitrogen concentrations was graphically analyzed (Figure 1.11). The constituent concentrations correlated well for each land use represented, which means multiple sources contribute nitrate and TDS to basin groundwater. The amount of nitrate and TDS contributed by each land use activity varies. For example, groundwater sampled in areas associated with irrigated agriculture, animal feedlots, and food processing wastewater land application had a wide nitrate+nitrite-nitrogen and TDS concentration range. Conversely, the concentration range in groundwater sampled in areas associated with septic systems was much more limited. The concentrations were generally for less than 15 mg/L for nitrate+nitrite-nitrogen concentrations and less than 500 mg/L for TDS.

Analysis of potassium versus bromide and chloride versus potassium yielded three findings. First, groundwater influenced by septic systems has lower chloride concentrations than other sources in addition to having lower TDS and nitrate concentrations. Second, the influence of food processing wastewater upon groundwater chemistry is significantly different from the influence of other sources in terms of bromide to potassium and chloride to potassium relations. Third and most importantly, each potential source groups into separate fields on the graphs, regardless of their location (e.g., the septic systems field represents both Hermiston and Irrigon). These graphs are useful for identifying land uses potentially influencing basin groundwater.

The influence of individual food processing wastewater sources were distinguished on magnesium versus sulfate and calcium graphs. The chemistry differences may relate to the source water used, human activity unique to the facility operation, or geochemical processes unique to the land application area.

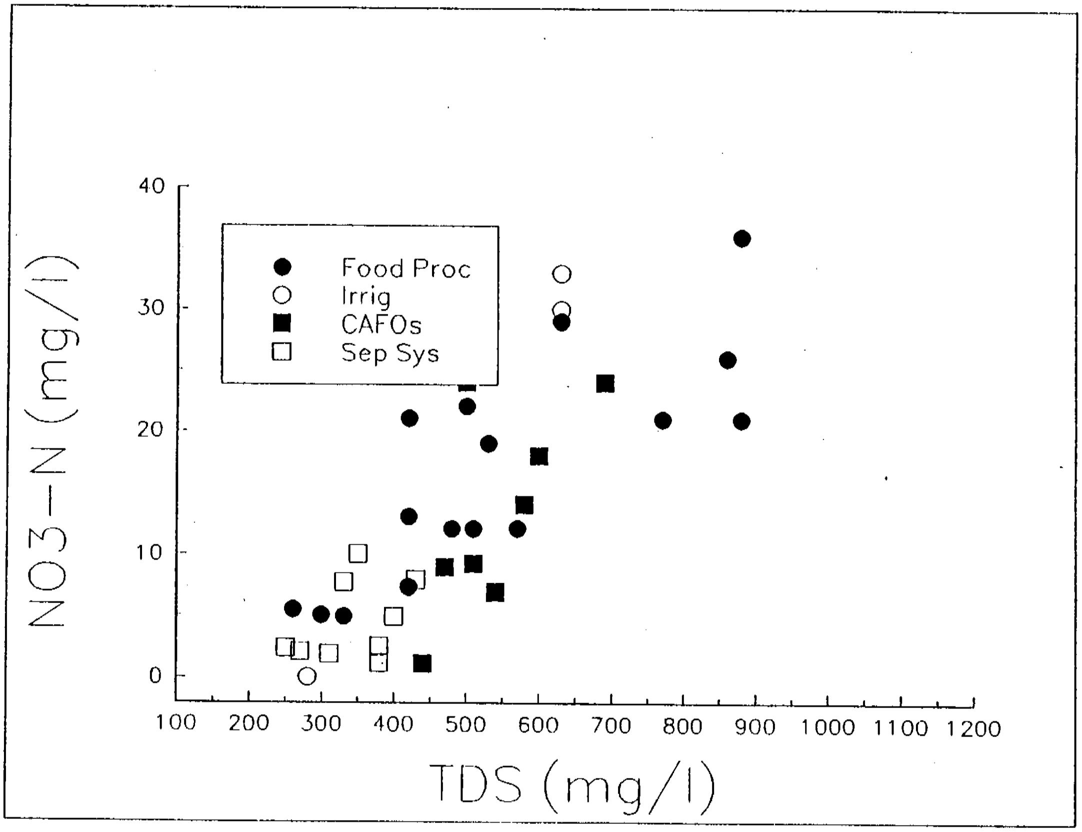

Figure 1.11 Total dissolved solids versus nitrate+nitrite-nitrogen for groundwater sampled near potential nitrate sources (septic tank influences graph within a limited area).

Note: Nitrate+nitrite-nitrogen and TDS share a generally positive correlation for all activities.

Groundwater Flow Path Results

A Butter Creek flow path and a composite flow path through the U.S. Army Umatilla Depot were analyzed. The analyses provided these conclusions.

- Multiple influences affect the groundwater chemistry along each groundwater flow path, including influences unrelated to nitrate.

- More than one source contributes nitrate to groundwater along each groundwater flow path.

- Nitrate relates better to calcium and chloride than sodium and sulfate along each groundwater flow path.

- Constituent concentrations in groundwater along the Butter Creek flow path do not progressively increase downgradient. This would be expected from chemical influences limited to progressive water rock reactions or non-point source loading. Instead, stationary groundwater chemistry anomalies or irregularities exist along the flow paths.

- Analysis of the Butter Creek flow path data revealed a stationary concentration peak for nitrate+nitrite-nitrogen and other constituents along the flow path (Figure 1.12). The stationary peak implies that there is no tendency for concentrations to migrate downgradient with time. The data analyzed suggests that the source of the dissolved constituents and elevated nitrate is local, and with some seasonal variations.

Groundwater Chemistry Model Results

This investigation used NETPATH to assess and refine interpretations of natural and human influences on groundwater chemistry along selected groundwater flow paths. The following results from individual NETPATH analyses apply to the Lower Umatilla Basin in general.

- Cyclic evaporation-dissolution may be occurring in the vadose (unsaturated) zone, contributing to elevated TDS in groundwater.

- Water from canal leakage influences the local groundwater chemistry.

- Mixing of deeper alluvial groundwater with infiltrating water primarily explains the alluvial groundwater chemical composition observed.

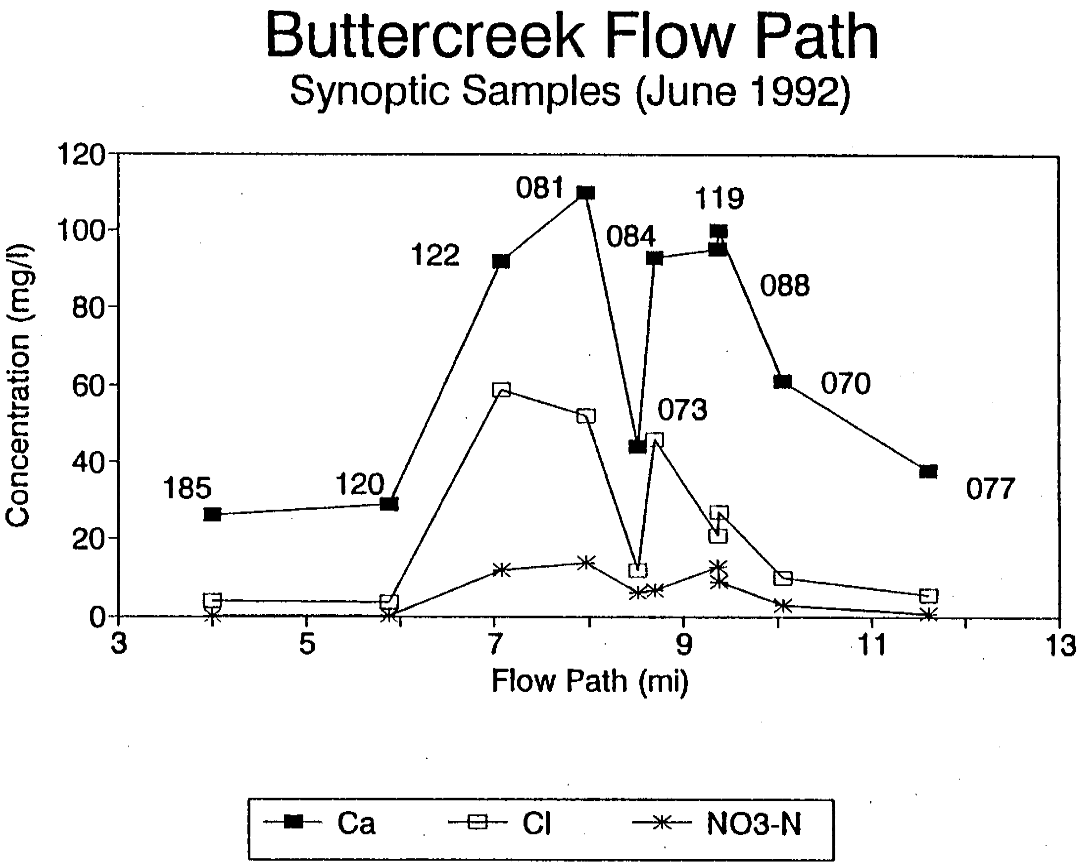

Figure 1.12 Variation of calcium, chloride, and nitrate+nitrite-nitrogen along the Butter Creek flow path.

Evaluation of Canal Leakage

Project analysis used the NETPATH groundwater chemistry computer model to evaluate the influence of canal leakage upon nitrate concentrations in groundwater flowing into the Hermiston basin from upgradient sites south of Hermiston.

The model scenario allowed upgradient groundwater to mix with canal water while undergoing water-mineral reactions. The model solutions indicate that locally, canal water significantly affects the groundwater chemistry diluting nitrate as it moves downgradient.

The modeling results indicate that the percentage of groundwater recharge from canal water in the immediate downgradient vicinity of the canals may exceed 95 percent of the groundwater. This suggests canal leakage is the principle source of recharge to shallow water-bearing zones supplying some domestic wells.

The Evaluation of Water-Mineral and Evaporation Influences

The groundwater chemistry computer model program NETPATH was used to evaluate the chemical relationship between groundwater and the aquifer material along the Butter Creek flow path.

The aquifer material is glaciofluvial in origin, consisting largely of basaltic fragments varying in size from small boulders to sand. Volcanic glass, clay minerals and secondary minerals such as calcite, are common constituents.

Groundwater undergoes minor changes along a flow path as a result of water-rock mineral reactions typical of a groundwater basalt system.

To recognize the various sources of nitrate loading that may have affected groundwater compositions in the Lower Umatilla Basin area, the investigation considered the natural water-mineral reactions within the saturated zone.

Computer modeling with NETPATH indicated that the bulk of the compositional variation could be accounted for by groundwater interaction with basalt glass and clay minerals, with less contribution from the secondary minerals gypsum (or mirabilite), calcite and dolomite.

This investigation used PHREEQE to assess the likelihood that constituent concentrations in some basalt groundwater samples are or are not a result of natural water-rock reactions. The results suggest an external calcium source influences some basalt groundwater through hydraulic connection with alluvial groundwater.

Two scenarios were explored. One scenario had "unimpacted" basalt groundwater dissolve calcium bearing basalt minerals (plagioclase and clinopyroxene). The other scenario had the same groundwater dissolve basaltic glass with a chemical composition described by Allan and Strope (1983). The results from both scenarios indicate obtaining the observed calcium concentrations from natural water-rock reactions is unlikely. To test the application of NETPATH to groundwater, wells immediately upgradient and downgradient of a single Simplot irrigation circle (field 1A) were chosen. The results indicate that shallow groundwater, presumably originating as water applied within the irrigation circle, has impacted deeper regional groundwater.

A possible origin of the higher TDS shallow groundwater is cyclic evaporation-dissolution, where repeated application-evaporation of wastewater leads to the precipitation of dissolved salts in the soil and vadose zone. Subsequent "flushing" of this zone with more dilute waters leads to dissolution of those phases and leaching of the components downward.

The results from both scenarios indicate calcium in groundwater influenced by natural water-rock reactions only will reach saturation with calcite and dolomite at concentrations much lower than observed in groundwater samples collected. Reaching saturation should limit the calcium concentration in the groundwater. The basalt glass scenario result indicates potassium and phosphate concentrations in groundwater should exceed 60 mg/l and 25 mg/L respectfully if water-basalt glass reactions were responsible for the calcium concentrations observed. These elevated potassium and phosphate concentrations were not observed in Lower Umatilla Basin basalt groundwater samples collected.

In summary, these analyses support the hypothesis that evaporation and ambient groundwater mixing with water infiltrating from various nitrate sources influences the alluvial groundwater chemistry.

Evaluation of Food Processing Wastewater Influence

An abrupt increase in TDS was detected in groundwater along the Butter Creek flow path between two closely spaced domestic wells during the June-July 1992 project synoptic sampling (Figure 1.12). The chemical evolution of groundwater between those wells was modeled by NETPATH as a mixing model. The shallow groundwater at a nearby food processor monitoring well was mixed with groundwater from the upgradient domestic well. It is significant that the overall chemistry pattern for the impacted downgradient well closely resembles the chemistry pattern of shallow unconfined groundwater at the nearby food processing monitoring well. Because of the shallow groundwater chemistry at the monitoring well reflects the infiltration of food processing wastewater, it is logical to extend that conclusion to the downgradient site as well.

Nitrogen Isotopic Analysis Results

Stable nitrogen isotopes, reported as "delta values" or parts per thousand, behave predictably, making them useful indicators of geochemical or biochemical processes. Significant differences in nitrogen isotopic composition (delta ^{15}N) were observed between some alluvial groundwater in the basin. The delta ^{15}N valves for individual groundwater showed minor differences over time for most of the repeat samples collected.

Evaluation of Nitrate Sources

Nitrogen isotopic analysis of the nitrogen isotopic identified some nitrate sources in the following areas:

- An organic waste influence is clearly evident from the delta ^{15}N values for groundwater sampled from a well (UMA 258) located within an established food processing land application area north of the Umatilla River and east of the Butter Creek Highway.

- A commercial fertilizer influence is clearly evident from the delta ^{15}N values for groundwater sampled from three irrigation wells located north of Highway 730 between Boardman and Irrigon. The delta ^{15}N values remained constant over time despite nitrate+nitrite-nitrogen concentration fluctuations. That indicates the nitrogen source remains uniform and hydraulic flushing of nitrate is very slow. The delta ^{15}N values for the eastern wells are higher. That indicates an additional nitrate source influence is possible.

- The influence of animal waste appears evident from the delta ^{15}N values related to groundwater sampled from a well (UMA 133) located along County Line Road approximately 2 miles south of Interstate 84. Historic and current animal waste sources are located nearby.

- Delta ^{15}N values related to groundwater sampled from wells near the U.S. Army Umatilla Depot Activity explosive washout lagoons indicates most of the nitrate in the groundwater came from explosive contaminants.

- Delta ^{15}N values related to other groundwater samples collected were not diagnostic of a single nitrogen source. Instead, the values indicate mixed nitrogen influences.

Evaluation of Denitrification

Denitrification is a natural process converting dissolved nitrate into nitrogen gas. Denitrification was recognized in groundwater from a single monitoring well (UMA 258) on the Simplot property. The combination of high organic matter and shallow water tables provide for an adequate reducing environment.

Current isotopic data indicates no area-wide denitrification occurs within the Lower Umatilla Basin. This finding does not preclude denitrification occurring locally in flood plain deposits next to existing drainages in appropriate conditions.

Evaluation of Hydraulic Flushing

The nitrogen isotopic sampling results provide evidence of low groundwater flow velocities in the basin. Analysis of groundwater samples collected over a 13-month period at Boardman-Irrigon area irrigation wells showed nitrate concentrations in groundwater varied between well sites, but varied little over time at individual well sites. Analysis also showed no significant isotopic variation over time in samples collected from individual wells. These results support hydrogeologic conclusions that a large volume of very slow moving groundwater underlies the Boardman-Irrigon area.

The low groundwater flow velocities in the Hermiston, Umatilla Ordnance Depot, and Boardman-Irrigon areas leads to an important conclusion. The process of natural hydraulic flushing of the existing nitrate from the groundwater in these areas will be slow. Therefore, the implementation of any practices to reduce future nitrate loading may not have an immediate impact on the observed nitrate concentrations in groundwater in these areas.

Alluvial-basalt Groundwater Interconnection

Observations suggest groundwater in some basalt water-bearing zones originally comes from shallow alluvial groundwater affected by surface activities. A positive correlation exists between total dissolved solids (TDS) versus calcium with the highest calcium concentration approximately 150 mg/L. Analysis using groundwater chemistry computer modeling indicates achieving the higher calcium concentrations through natural water-rock reactions rather than an external process is unlikely.

Review of other constituent versus constituent graphs also indicate an external source affects the groundwater chemistry in some basalt water-bearing zones. The chloride concentrations reach values exceeding 220 mg/L. The chloride probably did not come from the basalt, suggesting alluvial and some basalt groundwater are related.

In terms of TDS and nitrate+nitrite-nitrogen, it is apparent that the trend defined by some basalt groundwater is very similar to that exhibited by alluvial groundwater (Figure 1.13). That groundwater sampled from the basalt well graphed similar to alluvial groundwater is important. No basalt mineral can serve as the chloride source. Additionally, potassium concentrations in basalt minerals are very low. The conformance indicates alluvial groundwater and groundwater in the water-bearing zones experienced the same processes such as evaporation. Locally, they appear to be hydraulically connected.

Samples collected from Lower Umatilla Basin basalt water-bearing zones graph in a manner that suggests alluvial and some basalt groundwater experienced the same influences such as evaporation. This indicates a hydraulic connection exists between alluvial groundwater and some basalt water-bearing zones.

Information presented in the hydrogeology chapter support alluvial groundwater directly entering some basalt water-bearing zones. Saturated alluvial sediments directly contact some basalt water-bearing zones in some areas. Additionally, some wells are constructed improperly. These wells may provide a direct conduit from the alluvial aquifer to one or more basalt-water bearing zones below.

Nitrate Travel Time

Land Surface to Groundwater

Available evidence indicates that water can readily infiltrate basin soils and can travel rapidly through the unsaturated silts, sands, and gravels which overlie the alluvial aquifer. Because of this, the aquifer is highly susceptible to contamination from land surface activities.

Evidence of rapid nitrate travel to groundwater includes constituent concentrations correlating to groundwater elevation at some sites. Figure 1.13 is an example. Most of these correlations related to sampling sites where groundwater came primarily from coarse-grained or flood plain alluvial sediments and constructed well depths ranging from 19 to 110 feet. The correlations suggest constituent loading at these sites relates to local groundwater recharge, and the travel time to groundwater is relatively short for conditions existing during the compared times.

Constituent concentrations and groundwater elevations appeared to not correlate or correlate inversely at other sites. Possible explanations for the inverse correlations were explored.

The relationship between groundwater elevations and well screen or open interval elevations were explored as a possible explanation for the apparently opposite correlations observed. Analysis suggests the influence of groundwater elevations relative to well construction fails to apply in the Lower Umatilla Basin.

Time lags were explored as a possible explanation for apparently opposite and no correlation observed between groundwater elevation and constituent concentration graphs.

A time lag became suspected when several groundwater elevation and constituent concentration graphs related to the same site had uniquely similar fluctuations that occurred at different times. The graphs correlated similarly when the graphs were shifted to superimpose the uniquely similar fluctuations. Other apparently opposite or no correlation graph sets also correlated similarly when a time lag shift was considered. Graph sets with observed time lags primarily related to sampling sites where groundwater came from fine grained sediments and constructed well depths exceeded 100 feet. Observed time lags for nitrate ranged from 0 to 18 months. Analysis indicates the nitrate time lags may change significantly when sufficient water is available.

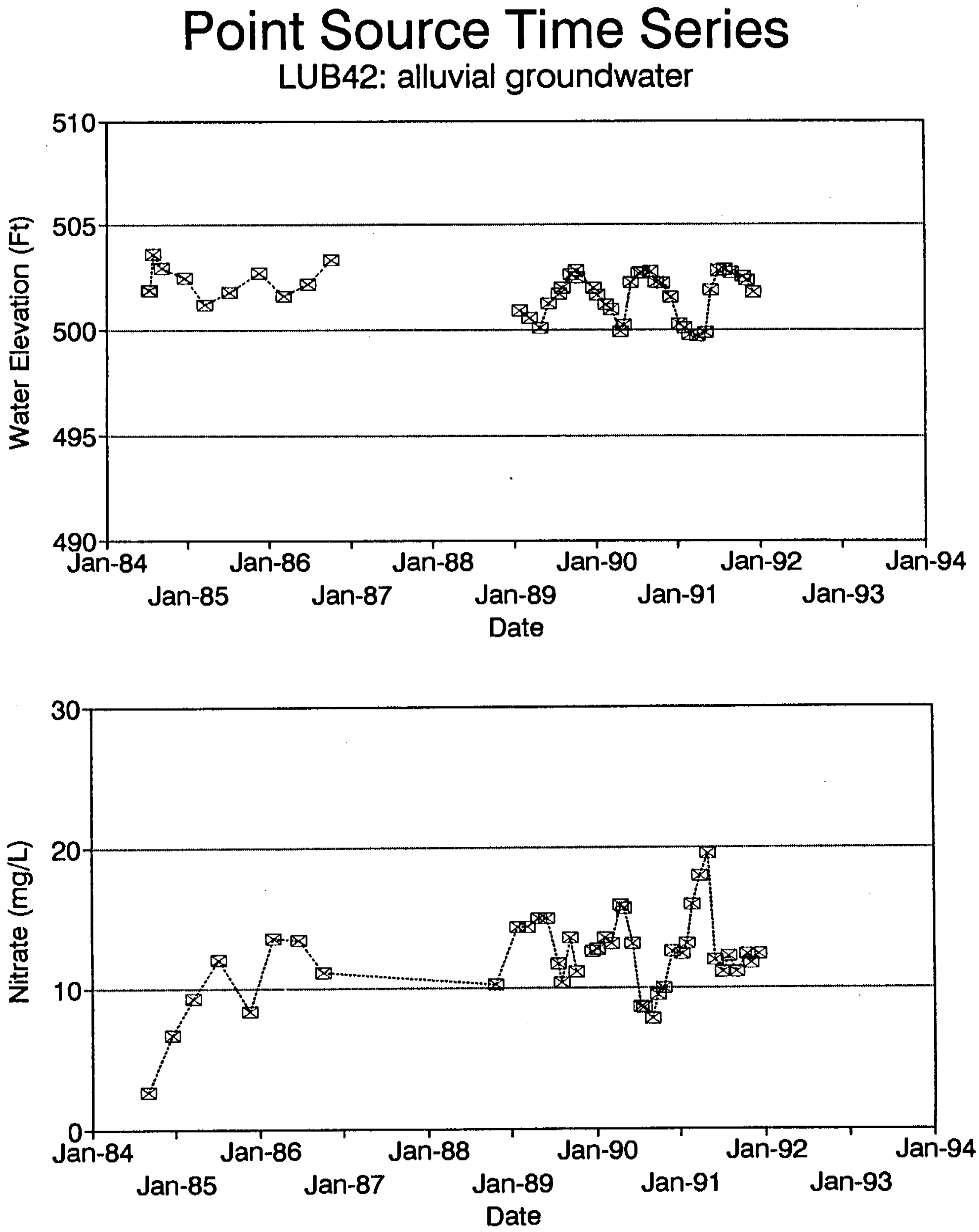

Figure 1.13 An example of similar nitrate concentration and groundwater elevation fluctuations in the Lower Umatilla Basin.

The very similar and time lag related groundwater elevation versus constituent concentration correlations have very important implications for the Lower Umatilla Basin. The correlations indicate nitrate may move to groundwater more quickly than the years and decades previously estimated by other investigators.

Travel Time in Groundwater

Nitrate transport in groundwater depends upon groundwater flow. Hydrogeologic analyses indicate groundwater flow in the alluvial aquifer may vary between less than one foot (silts and silty sands) to one-half of a mile (sands and gravels) per year. Seasonal variations can make flow considerably less.

Flat gradients in coarse-grained deposits create a slow-moving flow that can sometimes be reversed by well pumping or canal recharge. A well-documented example of slow and reversed groundwater travel can be found near the Umatilla Ordnance Depot. Estimated flows indicate that groundwater from the center of the Depot should travel to the Umatilla River within 10 to 40 years. However, seasonal water-level measurements in Depot wells indicate that flow directions can vary by up to 180 degrees during the year due to off-site pumping and recharge.

Nitrogen isotopic analyses also indicate low groundwater flow velocities exist in the basin. No significant isotopic variation over time were observed in samples collected from individual wells in the Boardman-Irrigon area. That indicates a large volume of very slow moving groundwater underlies the area.

A review of Plate 4.2 provides additional evidence of slow groundwater nitrate transport in portions of the basin. For example, elevated nitrate+nitrite-nitrogen in the middle of the U.S. Army depot appears related to the Depot's explosive washout activity which ended by the mid-1960s. Nitrate from the washout lagoons appears to have moved less than four miles (possibly less than 0.5 miles) over three to four decades.

Investigative Overview Summary

The Oregon Department of Environmental Quality (DEQ) established the Lower Umatilla Basin as a Groundwater Management Area in 1990, based upon high nitrate-nitrogen concentrations in groundwater samples.

Nitrate concentrations in Lower Umatilla Basin groundwater exceed 10 mg/L and 20 mg/L in many areas. These levels cause the greatest concern for infants less than six months of age, who are at risk of developing "blue baby syndrome" or methoglobinemia.

An interagency groundwater quality investigation to identify the sources of nitrate-nitrogen began in July 1990. The basin study area encompasses about 550 square miles of northern Morrow and Umatilla counties between Willow Creek, Cold Springs Reservoir and the Columbia River. The area is drained by the Umatilla River, Butter Creek and the Columbia River.

Most of the study area occupies an undulating plain that slopes gently to the north. The Lower Umatilla Basin can be considered semi-arid, with hot dry summers and cool moist winters. Annual precipitation varies between 8-10 inches.

Groundwater quality problems exist within the Lower Umatilla Basin Groundwater Management Area (GWMA). Nitrate, total dissolved solids, arsenic, and sodium concentrations exceed the drinking water standard or recommended limit at different locations. Atrazine, ethylene dibromide (EDB), dacthal/dacthal metabolites, chloroform, and toluene have been detected in some groundwater samples. Explosives, chemicals, nitrate, semi-volatile compounds and metals have been detected in U.S Army Umatilla Depot Activity area groundwater samples collected and analyzed by Depot consultants.

Identifying the sources of these contaminants required sophisticated data analyses. The hydrogeology, varied land uses, and natural chemistry complicated an understanding of the basin's groundwater chemistry/quality. Nitrate, the focus of the investigation, is associated with a variety of Lower Umatilla Basin land uses. An intensive analysis investigating the complex and inconsistent relationship between nitrate and other constituents helped to determine likely sources.

Hydrogeology

Aquifers contain and transmit water moving from recharge to discharge areas.

A shallow unconfined to semiconfined aquifer occurs in the alluvial sediments between the cities of Boardman, Umatilla and Echo. Multiple confined aquifers occur in the underlying basalt flows. The alluvial aquifer and shallow basalt aquifers are the main source of domestic water for rural residents of the area. The alluvial aquifer is also a major source of municipal water for the cities of Hermiston, Irrigon, and Boardman. In localized areas, alluvial groundwater is also an important source of irrigation water.

The available evidence indicates that water readily infiltrates basin soils, traveling rapidly through the unsaturated silts, sands, and gravels which overlie the alluvial aquifer. Because of this, the aquifer is highly susceptible to contamination from activities at the land surface.

Canal and ditch leakage are the principal sources of recharge to the alluvial aquifer. Deep percolation of irrigation water is also an important recharge source, especially in areas which are irrigated by flooding or with low efficiency sprinkler systems. Deep percolation also occurs in areas exclusively irrigated by center pivots. In localized areas, leakage from reservoirs and streams provides an important source of recharge. Recharge from precipitation is minimal. Water conservation measures, such as liner improvements for canals, by irrigation districts and individual farmers will reduce the volume of recharge over time.

Flow directions in the alluvial aquifer are highly variable and are constrained by the "topography" of the underlying basalt surface. Flow directions are also influenced by the seasonal pumping of high-capacity wells and by seasonal leakage from canals. Average flow velocities may be as low as 0.0001 miles per year (0.002 feet per day) in the silts and silty sands and as high as 0.50 miles per year (8 feet per day) in the sands and gravels. Net displacement of water over a year's time may be considerably less because of seasonal variations in hydraulic gradients and flow directions.

The geometry of the shallow basalt aquifers and limited water level data indicate that most recharge to the basalts comes from the Columbia River and the alluvial aquifer. Therefore, water quality in the shallow basalt aquifers will be related to the quality of recharge water from these sources.

Substantial quantities of groundwater are discharged from the alluvial aquifer by wells. In the Ordnance area, pumpage has exceeded recharge since 1986 and groundwater levels are declining. Pumpage discharge between Boardman and Umatilla is buffered by recharge from the Columbia River. Groundwater supplies in this area are developed at the expense of the Columbia River. Pumpage in the Hermiston area is currently less than annual recharge but the capacity for additional development is unknown.

The lack of deep seals in many wells probably allows water from the alluvial aquifer to migrate downward to aquifers in the underlying basalts. The commingling of basalt aquifers through open bore holes provides a pathway by which water and contaminants can easily migrate from shallow to deeper aquifers.

Land Use and Nitrogen Loading

The Lower Umatilla Basin's soil conditions and hydrogeological properties make local groundwater very vulnerable to contamination from many different land uses. For example, the project and/or other investigations have detected nitrate, metals, organic compounds, and explosives contaminating local groundwater. As land uses continue to expand and evolve, other potential contaminants may leach through basin soils as easily as nitrate. Project sampling confirmed extensive areas of nitrate-nitrogen groundwater concentrations near or exceeding the U.S. E.P.A. drinking water limit of 10 mg/L.

This investigation focused on nitrate. The potential for a land use to contaminate groundwater with nitrate or another constituent relates to loading. Groundwater contamination can occur whenever water (or another liquid) and nitrate (or another contaminant) released exceeds or bypasses:

- removal by crops or other vegetation;
- removal by evaporation; and
- soil capacity to prevent deep percolation.

Nitrogen Loading

Irrigated Agriculture

Irrigated agriculture is the dominant land use in the basin. In 1992, it appears to have used nearly 180,000 acres or 51 percent of the total study area. A review of other studies conducted in the basin indicate some nitrogen escapes beyond the root zone at some irrigated crop fields even under conservative management strategies.

An OSU study estimated more than 20.5 million pounds of nitrogen were applied to 1990 crops. Using a more conservative figure of 7 million pounds per year since 1975 (141,243 acres, 50 pounds nitrogen per acre), the total nitrogen loss to groundwater may exceed 350,000 pounds annually.

Food Processing

Large-scale potato processing, for fast food and other uses, generates large volumes of nutrient and salt-rich wastewater. Since the early 1980s, the food processing industry has produced at least one million pounds of nitrogen per year.

Efforts to better manage food processing wastewater land application are in progress. Food processors expanded land application acreage from about 825 acres in 1977 to nearly 7,500 acres by 1992. At the same time they decreased the amount of nitrogen (pounds per acre) annually applied to those sites. Year-round land application has generally ended, and the use of lined wastewater ponds has increased.

Livestock

Livestock at two large beef operations, one large hog operation and one dairy probably produced more than 3.4 million pounds of total nitrogen annually during the 1980s. If stored, the total nitrogen available for land application may have exceeded 780,000 pounds or animal waste per year . The amount of waste stockpiled, sold and land applied (possibly more than 14,000 acres at times) varied from year to year.

Information has been insufficient for determining livestock nitrogen loading for the 1990s.

Domestic Sewage

Nitrate from domestic sewage is a concern mainly in areas with a high density of on-site systems.

Land application of domestic sewage from municipal systems has expanded in the last decade. By 1993, municipal land application appears to have expanded from applying less than 7,000 pounds of nitrogen annually to less than 400 acres to applying more than 140,000 pounds annually to more than 2,700 acres. Municipal sludge imported from the City of Portland and Washington County, Oregon sewage sludge is primarily responsible for the expansion.

One municipal sewage system and most on-site sewage systems discharge sewage wastewater directly to the subsurface. The City of Irrigon apparently released 9,100 pounds of nitrogen directly to the subsurface through two acres of infiltration beds in 1993. Six large on-site systems appear to release at least 4,700 pounds of nitrogen per year to about ten acres. About 4,300 individual on-site systems may release about 113,000 pounds of nitrogen per year.

Other Potential Sources

Two Lower Umatilla Basin environmental cleanup sites, the US Army Depot and the Pendleton Grain Growers, involved nitrogen. Significant loading occurred at the U.S. Army Umatilla Depot Activity Washout Lagoons. Approximately 85 million gallons of explosives washout water discharged to the lagoons (0.09 acres total) from the mid-1950s to the mid-1960s. Project information was insufficient to estimate nitrogen loading at these sites.

Some nitrogen loading is linked to two solid waste disposal facilities in the Lower Umatilla Basin. Less than 250 pounds per year of septic tank pumpage was disposed in three lagoons/ponds near the current Umatilla Butte Landfill entrance from 1974 to 1983. The US Army disposed of dried sludge from the Umatilla Depot Activity sewage treatment facility within a 10-acre Depot landfill since the early 1980s until late 1993. Project information was not sufficient to estimate loading at the Depot landfill, but other investigators identified the landfill as possibly contributing to local groundwater nitrate contamination.

Available information indicates possible loading from existing or proposed electricity generation facilities appears limited to salt and constituents other than nitrogen. PGE has reported elevated nitrate in groundwater sampled in the vicinity of their coal fired plant, and attributes the contamination to nearby agriculture.

Nitrogen loading from existing or proposed groundwater recharge projects appears minor.

No nitrogen or other constituent loading should be occurring in the Lower Umatilla Basin related to hazardous waste/substance handling or generation.

No nitrogen loading associated with underground storage tanks in the Lower Umatilla Basin is suspected. Some tanks have reportedly released petroleum products.

Groundwater Quality

The Lower Umatilla Basin investigation focused on nitrate. However, chemical analyses also tested for many other substances or constituents, which served the investigation in order to determine whether other constituents contaminated groundwater and explore the relationship between the other constituents and nitrates.

Nitrate

Nearly one-third of the project's groundwater sampling sites yielded samples with nitrate concentrations exceeding the 10 mg/L drinking water standard. Areas with nitrate concentrations greater than 10 mg/L are not evenly distributed. Higher nitrate concentrations in groundwater occur in or near the vicinities of Threemile and Sixmile Canyons, Boardman, Irrigon, the U.S. Army Umatilla Depot, County Line Road, and the Butter Creek-Umatilla River confluence.

The project sampling detected the highest concentrations between the Port of Morrow and Irrigon, with concentrations as high as 76 mg/L. Local facilities have reported groundwater nitrate concentrations greater than 100 mg/L.

Data analysis indicate multiple sources are responsible for the nitrate contamination in the basin's groundwater. Sources that formerly and/or currently contribute nitrate, either alone or in combination, include irrigated agriculture (including center pivots), livestock operations, food processing wastewater land application, unlined wastewater lagoons, sewage systems using drainfields or infiltration beds and military activities.

Data analyses also provided information about nitrate travel times. It appears that nitrate leaching through the soil can reach groundwater in one to eighteen months, given sufficient moisture for transport. Once in groundwater, nitrate transport appears slow in portions of the basin. Natural groundwater flushing of nitrate may require decades. Flat gradients and well pumping or canal recharge can temporarily reverse flows.

Other Influences

Data analyses indicate not all influences affecting the groundwater chemistry in the basin contribute nitrate. These influences include cyclic evaporation and dissolution in the vadose (unsaturated) zone, canal leakage causing dilution, and a minor influence from water-rock interactions. Analyses also indicate a hydraulic connection exists between alluvial groundwater and basalt water bearing zones.

Support for Groundwater Quality Conclusions

Support for these conclusions came from sampling which included reconnaissance, bimonthly, and synoptic activities, and sampling for nitrogen isotopic analysis. Laboratory activities included analyzing samples for nitrate, other nutrients, major ions, metals, other inorganic constituents, volatile organic compounds, pesticides, and nitrogen isotopic composition.

Data analysis activities included using general statistics, chemical constituent distribution maps, multiple graphical analyses, groundwater chemistry computer modeling for selected areas, and stable nitrogen isotope interpretations.

Chapter 2

Hydrogeology

Karl C. Wozniak
Oregon Water Resources Department

1995

Chapter 2: Hydrogeology

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Well Identification and Location Systems

Wells in this report are identified by well log numbers assigned by the Water Resources Department. Each "number" consists of the first four letters of the county in which the well is located and a six-digit number. Wells with more than one well log are assigned the number of the earliest log of record. Wells without logs on file at the Water Resources Department are designated by the letters LUB (Lower Umatilla Basin) and an arbitrary sequence number.

Wells sampled by the Department of Environmental Quality (DEQ) are also identified by a three-character project code (UMA) and a three-digit number. Cross references are made in appendix A.

Well locations in this report are based on the public land survey system. Each location is designated by listing land tracts of descending size (Figure 2.1). For example, the well location 4N/28E-11aab indicates a well within township 4 north, range 28 east (36 square miles), section 11 (1 square mile). The first letter following the section (a) represents the quarter section (160 acres), the second letter (a) the quarter-quarter section (40 acres), and the third letter (b) the quarter-quarter-quarter section (10 acres).

Locations of geographic features are also referenced to the public land survey system but, following convention, are designated by land tracts of increasing size. For example, the notation NW/NE/NE 11-4N/28E indicates a feature in the northwest quarter (10 acres) of the northeast quarter (40 acres) of the northeast quarter (160 acres) of section 11 (1 square mile) in township 4 north, range 28 east (36 square miles).

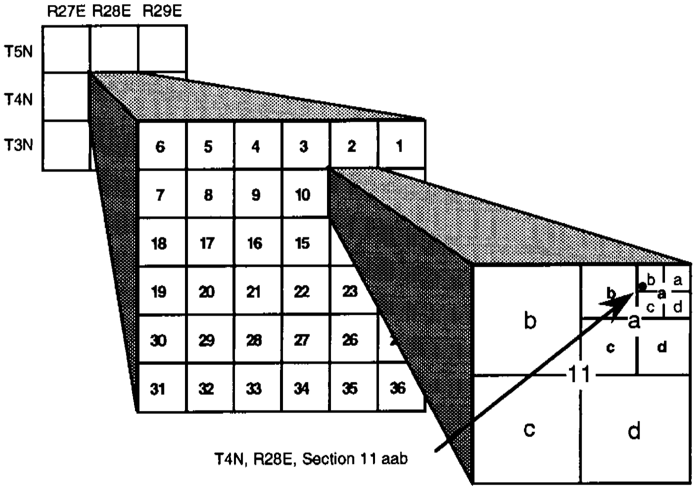


Figure 2.1 Well location system

Abstract

The Lower Umatilla Basin study area encompasses about 550 square miles of northern Morrow and Umatilla counties between Willow Creek, Cold Springs Reservoir, and the Columbia River. The area is drained by the Umatilla River, Butter Creek, and the Columbia River.

The Umatilla Basin is a topographic and structural trough between the Columbia Hills of Washington and the Blue Mountains of Oregon. The Dalles-Umatilla syncline, which forms the axis of the trough, is roughly coincident with the Columbia River between Arlington and Umatilla, Oregon. The basin and surrounding highlands are underlain by a thick sequence of Columbia River Basalt flows which are locally deformed by faults and folds. Up to 250 feet of alluvial sediments overlie the basalt flows near the basin axis.

A shallow unconfined to locally confined aquifer occurs in the alluvial sediments of the Umatilla basin. Multiple confined aquifers occur in the underlying basalt flows. The alluvial aquifer and shallow basalt aquifers are the main sources of domestic water for rural residents of the area. The alluvial aquifer is also a major source of municipal water for the cities of Hermiston, Irrigon, and Boardman and, an important source of irrigation water in local areas. Deeper basalt aquifers are major sources of irrigation water in many areas of the basin.

The principal water-producing zones of the alluvial aquifer occur in sands and gravels deposited by catastrophic floods during the Pleistocene Epoch. Flood sands and gravels occur in broad tracts of varying thickness or as thin beds encased in silts or clays. The main productive areas occur in three east to northeast-trending shallow troughs which are largely filled with coarse sands and gravels. Thin sand and gravel beds also produce moderate quantities of water in areas of the aquifer which are dominated by silt and fine-grained sand.

The available evidence indicates that water readily infiltrates the soils of the basin and travels rapidly through the unsaturated silts, sands, and gravels which overlie the alluvial aquifer. Therefore, the aquifer is highly susceptible to contamination from activities at the land surface.

The principal source of recharge to the alluvial aquifer comes from leaking canals and ditches. Additional recharge comes from applied irrigation water. Irrigation recharge is probably highest in areas irrigated by flooding but also occurs in areas irrigated by center pivots. In local areas, leakage from reservoirs and streams is an important source of recharge. Recharge from precipitation is minimal. The volume of recharge to the alluvial aquifer will decrease over time as irrigation districts and individual farmers implement water conservation measures.

Regional flow in the alluvial aquifer is to the northwest with discharge to the Umatilla and Columbia rivers; however, flow directions vary considerably over space and time. Flow is influenced by the "topography" of the underlying basalt, by seasonal pumping of high-capacity wells, and by seasonal recharge from

leaking canals. Seasonal reversals of flow are documented beneath the southern one-half of the Umatilla Ordnance Depot and may occur elsewhere.

Average flow velocities in the alluvial aquifer may be as low as 0.0001 miles per year (0.002 feet per day) in the silts and silty sands and as high as 0.50 miles per year (8 feet per day) in the sands and gravels. Net displacement of water over a year's time may be considerably less because of seasonal variations in hydraulic gradients and flow directions.

Total pumpage discharge from the alluvial aquifer is estimated between 65,000 and 98,000 acre-feet per year. In the Ordnance area, pumpage has contributed to periodic water-level declines, including a decline which spans from 1986 to 1993. Pumpage near the Columbia River, between Boardman and Umatilla, is buffered by recharge from the river. Groundwater supplies in this area are relatively unlimited but are developed at the expense of the Columbia River. Additional pumpage capacity probably exists in the Hermiston area but excess capacity will likely be diminished by water conservation projects in the Hermiston and Stanfield irrigation districts.

Water-bearing zones within shallow Columbia River basalt flows are limited to thin breccia or fracture zones at the top or base of individual flows. The dense interiors of flows are relatively impermeable and confine groundwater to discrete tabular aquifers. Existing data indicate that permeabilities in the breccia zones are moderately high and storage capacities are low.

The geometry of the shallow basalt aquifers indicates that they are hydraulically connected to the alluvial aquifer and the Columbia River. Recharge is mostly from the alluvial aquifer but some recharge may be induced from the Columbia River by pumping.

Groundwater flow directions in the shallow basalt aquifers are parallel to the regional dip of the basalt flows, which is northerly toward the Columbia River throughout most of the study area. Discharge is to the Columbia River.

Because recharge to the shallow basalt aquifers is from the alluvial aquifer and the Columbia River, water quality in the shallow basalt aquifers is related to quality of water in these sources.

The lack of deep seals in many wells probably allows water from the alluvial aquifer to migrate downward to aquifers in the underlying basalt flows. The commingling of basalt aquifers through open boreholes also provides a pathway by which water can migrate from shallow to deeper basalt aquifers. These pathways may be responsible for some of the contamination that is found in the shallow basalt aquifers.

Chapter 2 : Hydrogeology

Introduction

A shallow unconfined to locally confined aquifer occurs in the alluvial sediments of northern Morrow and Umatilla counties between the cities of Boardman, Umatilla, and Echo. Multiple confined aquifers occur in basalt flows which underlie the sediments. The alluvial aquifer and the upper two or three basalt aquifers are the principal sources of domestic groundwater in the basin. The alluvial aquifer is also the primary source of municipal water for Boardman and a major source for Hermiston and Irrigon. In local areas, the alluvial aquifer is also developed as a source of irrigation water. Deeper basalt aquifers are major sources of irrigation water in the area and serve as important sources of municipal water for Hermiston and Irrigon. The deeper basalt aquifers are the sole source of municipal water for Echo, Stanfield, and Umatilla.

During the 1980s and early 1990s, widespread nitrate contamination was found in wells that produce water from the alluvial aquifer and shallow basalt aquifers. Nitrate levels in many of the wells exceeded state and federal drinking water standards. This report characterizes the hydrogeology of these shallow contaminated aquifers.

Purpose and Scope of Work

The primary purpose of this investigation is to provide a framework for understanding how contaminants enter and travel through shallow aquifers in the Lower Umatilla Basin. This is accomplished by describing the geometry, hydraulic properties, recharge sources, and flow systems of the various aquifers. A secondary purpose of the study is to evaluate groundwater supplies in the shallow aquifers.

Previous Investigations

Geologic field investigations that encompass all or part of the study area include those by Bretz (1925, 1928), Allison (1933), Hogenson (1964), Newcomb (1967), Robison (1971), Walker (1973), and Swanson and others (1981). Site-specific geologic field studies within the study area include those by Portland General

Electric (1973), Shannon and Wilson (1972a, 1972b, 1973a, 1973b, 1973c), Bechtel (1973), and McCall (1975).

Regional geologic reports or compendiums which are pertinent to the Lower Umatilla Basin include Bretz (1925, 1928, 1929, 1969), Bretz and others (1956), Newcomb (1966, 1967, 1970), Baker and Nummendal (1978), Farooqui and others (1981), Waitt (1985), Schuster (1987), and Reidel and Hooper (1989). General overviews of the regional geology are presented by Allen and others (1986) and Orr and others (1992).

A variety of hydrogeologic studies include all or part of the Lower Umatilla Basin. Wagner (1949) summarized the early use of groundwater in Morrow and Umatilla counties and compiled drillers' logs for early wells. Newcomb (1959, 1961) described the general features which control groundwater occurrence in Columbia River Basalt flows. The first comprehensive study of groundwater in the Umatilla Basin was produced by Hogenson (1964), who mapped the general geology, compiled water well data, and summarized groundwater occurrence by geologic unit. Robison (1971) modified and extended Hogenson's geologic map and summarized the hydrology of aquifers within the Columbia River Basalt Group. A recent inventory of wells and water levels are reported by Davies-Smith and others (1983).

The geologic framework of regional aquifers in eastern Oregon and Washington is characterized by Drost and others (1990). A digital model which simulates regional groundwater flow in the Umatilla Plateau and Horse Heaven Hills area of Oregon and Washington is described by Davies-Smith and others (1988).

The Oregon Water Resources Department (WRD) has published several reports on groundwater in selected portions of the Umatilla Basin. Sceva (1966) and McCall (1975) discuss water-level declines in saturated sands and gravels in the vicinity of the Umatilla Ordnance Depot. Artificial recharge of these sediments is described and evaluated by Miller (1985). Additional reports document declining water levels in basalt aquifers near Ordnance (Sceva, 1966; McCall, 1975); in the Butter Creek-Hermiston area (Bartholomew, 1975; Norton and Bartholomew, 1984); in the vicinity of Ella Buttes (Zwart, 1988); and in the Hermiston-Stanfield-Echo area (Zwart, 1990).

Numerous site-specific groundwater studies have been conducted throughout the study area. Most are unpublished reports available on file at the Water Resources Department or at the Department of Environmental Quality (DEQ). A brief list by geographical locality follows.

Carty Reservoir and vicinity (2N/24E and 3N/24E):
    Shannon and Wilson (1972a, 1973a)
    Bechtel (1973)
    Portland General Electric (1993)

Finley Buttes (2N/26E and 3N/26E)
    David J. Newton Associates, Inc. (1990, 1991)
    Finley Buttes Landfill Company (1992)

Boardman/Irrigon area (5N/26E)
    CH2M Hill (1975)
    CH2M Hill (1992a)
    Cascade Earth Sciences (1992a, 1992b, 1993)

Umatilla Ordnance Depot (5N/27E):
    Dawson (1982)
    Century Environmental Sciences (1986)
    Dames & Moore (1992, 1994a, 1994b)

Butter Creek drainage:
    Sweet-Edwards/EMCON (1990)
    EMCON Northwest (1992)
    CH2M Hill (1991, 1992b, 1992c)
    Lamb-Weston (1992)

Umatilla River drainage between Echo and Hermiston:
    Applied Geotechnology, Inc. (1993)
    Sweet, Edwards & Associates (1983, 1985, 1987)
    Cascade Earth Sciences (1992c)
    EMCON Northwest (1992)
    Cascade Earth Sciences (1992d)

Hermiston Airport area:
    Cascade Earth Sciences (1990, 1991)

Cold Springs Reservoir:
    Acree (1988)

Investigative Methods

A large body of geologic and hydrologic information exists concerning the Umatilla Basin. Some of this information is readily available in published reports but much of it resides in scattered unpublished reports and files at various government agencies. Every attempt was made to compile and review as many sources of relevant information as possible. A considerable amount of data from unpublished reports was used to augment data collected during the investigation.

A geologic map for the study area (Plate 2.2) was compiled based on maps by Hogenson (1953, 1964), Robison (1971), Walker (1973), Shannon and Wilson (1973b), and Swanson and others (1981). The map was modified during the investigation based on reconnaissance field mapping and air photo interpretations.

Drill cuttings from 10 water wells were examined to determine the nature of geologic units in the sub-surface and to interpret the descriptions of geologic materials by well drillers. In addition, descriptions on water well logs were systematically compared to descriptions on the geologic drill logs of nearby monitoring wells. This information was used to construct geologic cross sections to show the distribution of geologic units in the subsurface.

Over 700 wells were used as the principal data set for the investigation. Only wells with well logs and reliable locations were included in the set. Approximately 230 of the study wells are monitoring wells with surveyed locations and elevations. Locations for the remaining wells were determined by several methods. Approximately 180 wells were field-located on 7.5-minute topographic maps during the investigation. Another 200 were field-located during earlier WRD investigations. Locations for an additional 30 wells were obtained from 7.5-minute maps in unpublished reports at WRD or DEQ. About 90 well locations were determined by plotting surveyed coordinates from WRD water rights files onto 7.5-minutes maps. Land surface elevations for non-monitoring wells were estimated from contours on 7.5-minute maps.

Locations for surveyed monitoring wells are probably accurate to ±10 feet; elevations are probably accurate to several tenths of a foot. The accuracy of locations for wells which were physically sited during the study is estimated to be ±50 feet; elevation accuracy is estimated to be ±5 feet. The accuracy of locations and elevations for the remaining wells may be less precise.

Approximately 130 field-located wells were selected for periodic water-level measurements. Historical water levels, spanning from 2 to 40 years, were available for about 40 of these wells. Water levels were also compiled for approximately 230 monitoring wells with periods of records ranging from 1 to 10 years. Many of the monitoring wells have been measured monthly or quarterly over the last 3 to 4 years.

Seasonal variations in water levels were documented using reported water levels for monitoring wells. In addition, digital water-level recorders were installed in several wells to monitor seasonal changes in water level caused by irrigation practices, climatic events, and the pumping of wells. Recorder hydrographs were also available for 4 wells on the Umatilla Ordnance Depot. Selected hydrographs are shown in figures throughout the text.

In order to develop a regional picture of groundwater levels at specific times, approximately 120 field-located wells were measured during three 10-day synoptic rounds conducted in February 1991, August 1991, and February 1992 (Appendix 2.B). Reported water levels from monitoring wells were used to augment synoptic measurements if they were made within 2 weeks of the synoptic rounds. The rounds were timed to occur before and near the end of the irrigation season. The February 1991 data set was used to contour the water table for the alluvial aquifer (Plate 2.4).

One aquifer test was conducted to determine the hydraulic properties of the alluvial aquifer (Appendix 2C. The results of other aquifer tests were compiled for comparison.

Plate 2.1 shows the locations of selected wells and illustrates the various kinds of data associated with each well.

Acknowledgements

Many residents in the study area generously provided access to their wells for periodic water-level measurements and displayed great interest in the groundwater resources of the basin. Special thanks go to Don and Jim Key for allowing the author to instrument one of their wells with a continuous recorder and for allowing an aquifer test to be conducted on a nearby well. Additional thanks go to Sam Godwin, W. Bryan Wolfe, and the Oregon Department of Transportation for allowing continuous recorders to be installed in their wells for extended lengths of time.

Jerald Rea of the Port of Morrow, Jeff Lyon of Simplot, Mike Henderson of Lamb-Weston, and Lance Horn of A. E. Staley Manufacturing provided valuable assistance by coordinating well measurement schedules to coincide with synoptic rounds and, by providing well and water-level data to the author. Thanks also go to Don Eppenbach of the City of Irrigon for providing access to city monitoring wells and to Barry Beyeler of the City of Boardman for providing information on the city's Ranney collector and wellhead demonstration project. Particular thanks are given to Dr. Charles Lechner of the Army Environmental Center for providing electronic files of water-level measurements and copies of reports for ongoing investigations at the Umatilla Ordnance Depot.

Generous assistance was provided by many professional colleagues at WRD and DEQ during the course of this study. Doug Woodcock began the original investigation, was responsible for the initial planning, and participated in much of the field work. Sarah Gates, Jan Koehler, and Ken Lite also helped with the field work. The draft report was reviewed by Jerry Grondin, Donn Miller, Ken Lite, Marc Norton, and Doug Woodcock. Special acknowledgement is also given to members of WRD's Geographic Information System Section. Ken Rauscher developed the original programs for preparing digital cross sections and was responsible for the research, design, and layout of many of the preliminary maps. Mike Ciscell prepared many of the final maps and served as a consultant for data analysis and map layout.

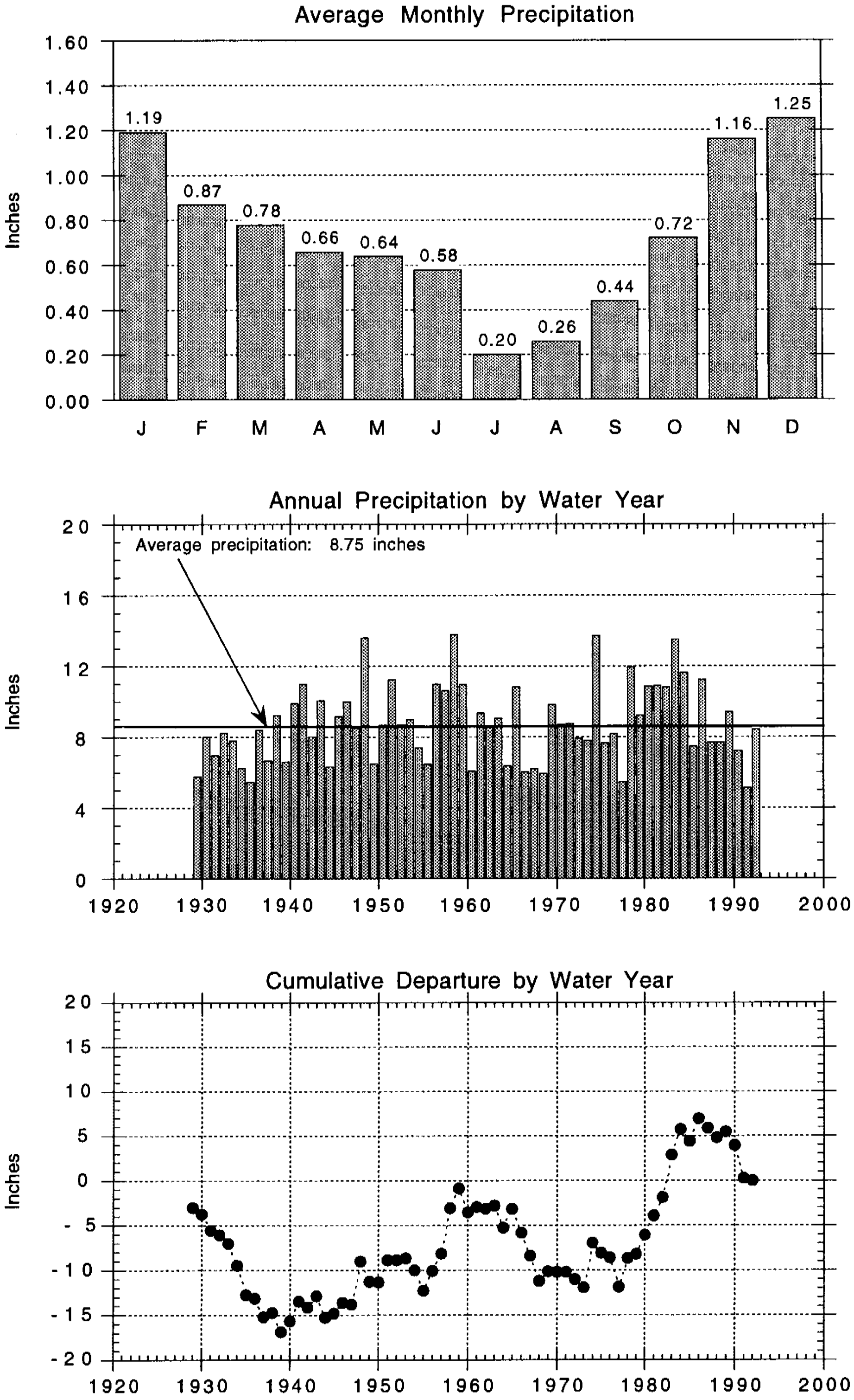


Figure 2.2 Precipitation at the Hermiston airport weather station: monthly, annual, and cumulative departure (1928-1992)

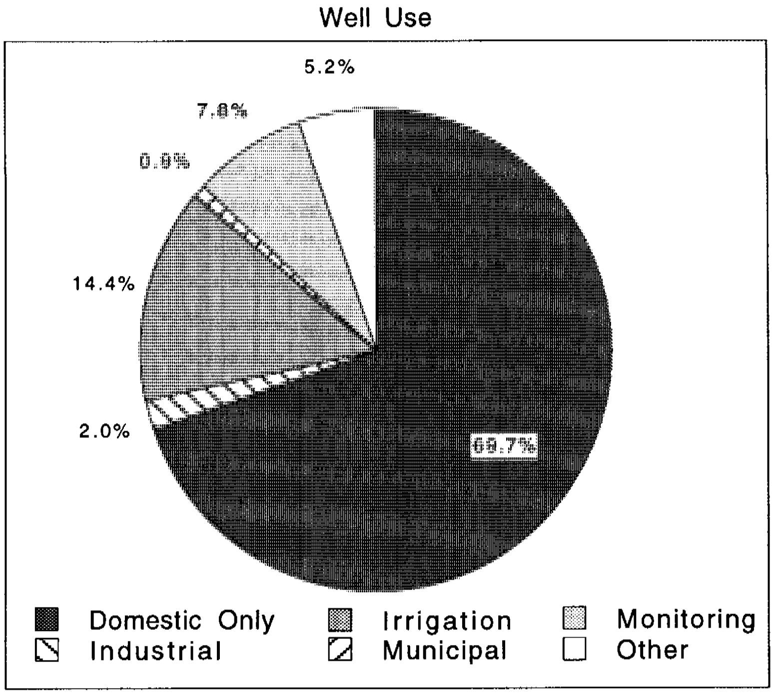
Geography and Climate

The Lower Umatilla Basin study area occupies about 550 square miles of northern Morrow and Umatilla counties between Willow Creek, Cold Springs Reservoir, and the Columbia River (Plate 2.1). The area is part of the Umatilla Lowlands, a portion of the Deschutes-Columbia Plateau physiographic province that is adjacent to the northern foothills of the Blue Mountains (Hogenson, 1964; Orr and others, 1992). The basin is drained by the Umatilla River, Butter Creek, and the Columbia River.

Most of the study area occupies an undulating, northward-sloping plain that lacks an integrated drainage system. Elevations on the plain range from 250 feet near the Columbia River to 750 feet at its southern margin. South of the plain, dissected hills rise to elevations above 1200 feet. Shallow canyons drain the hills but generally do not continue across the plain to the north. Ephemeral streams from the hills generally infiltrate the ground within a short distance of the base of the hills.

The Lower Umatilla Basin has a semiarid climate characterized by hot dry summers and cool moist winters. Annual precipitation varies with elevation and ranges from about 8 inches near the Columbia River to about 10 inches near the southern study boundary (based on data from Johnsgard, 1963).

Average precipitation by water year (October through September) is 8.75 inches at Hermiston, a figure considered typical for most of the study area (Figure 2.2). About 70% of the yearly total occurs during the months of October through March. Most of the total falls as rain but snowfall is significant in some years. Precipitation trends are shown by plotting cumulative departure from the long-term average (Figure 2.2). Rising trends indicate periods of above average precipitation; falling trends indicate periods of below average precipitation. A notable rising trend occurred between 1978 and 1986, followed by a declining trend through 1992.



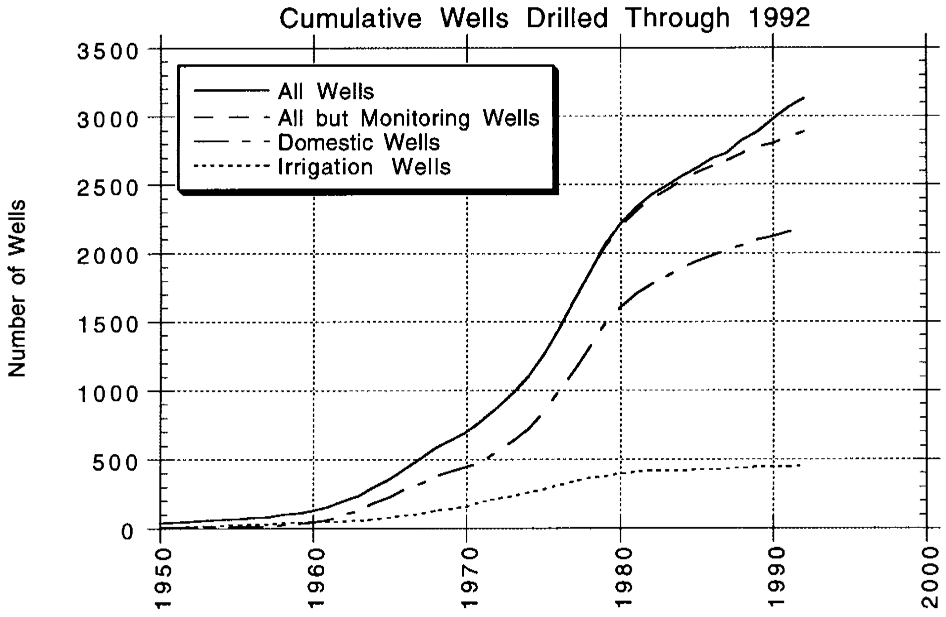
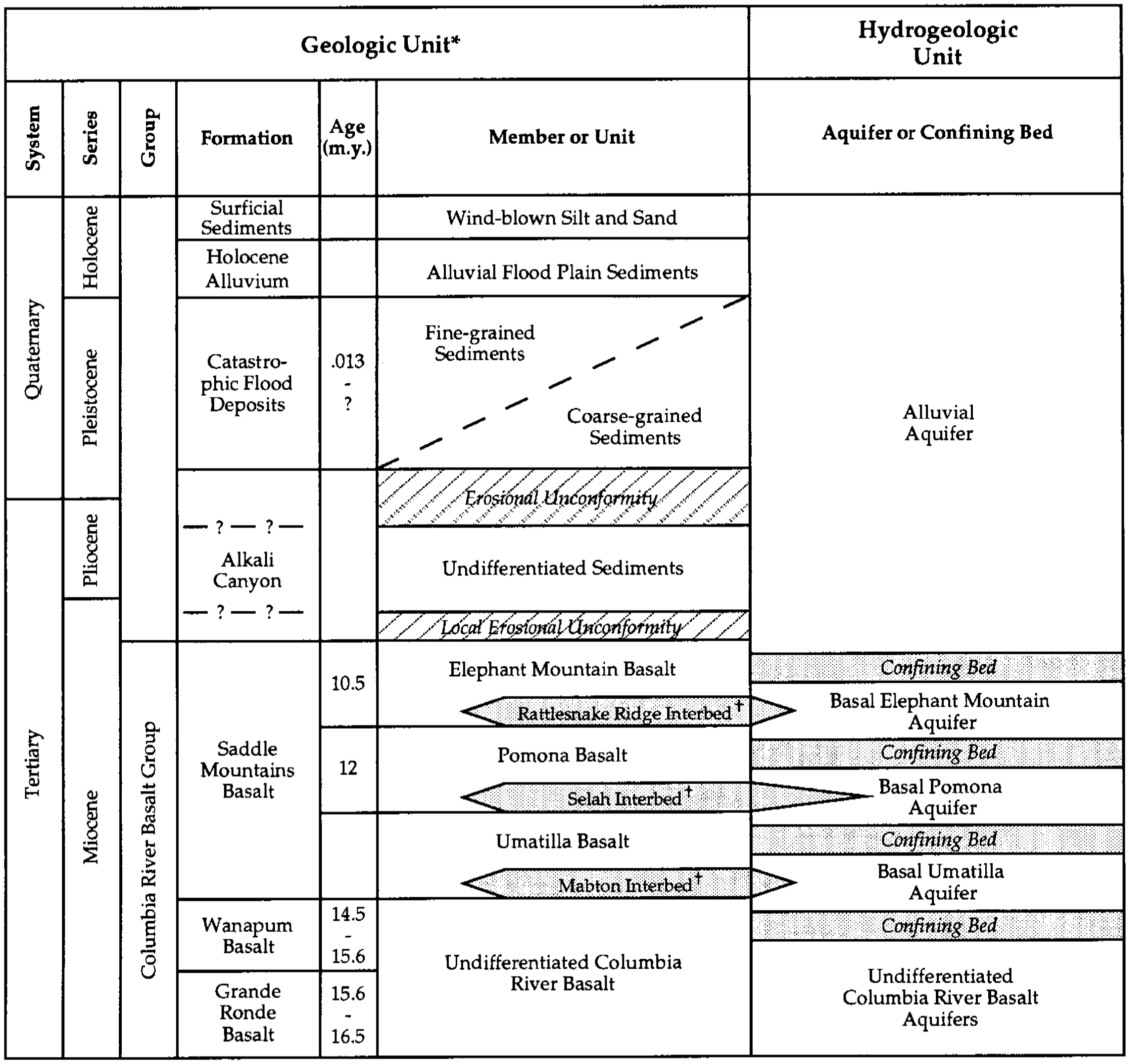


Figure 2.3 Well use and cumulative wells drilled through 1992

Groundwater Development

Well log files at the Water Resources Department indicate that 3130 wells (all aquifers) have been drilled in the study area through the end of 1992. The distribution of wells is shown on Plate 5. Domestic wells account for 70% of the wells in the basin, followed by irrigation wells at 14% (Figure 2.3). Although 2183 domestic well logs are on file, a Department of Environmental Quality survey shows a total of 4375 rural septic systems (Jerry Grondin, DEQ, personal communication). Assuming one domestic well per septic system, this suggests that the state has records for only 50% of the domestic wells in the area.

A cumulative graph of wells drilled over time (Figure 2.3) reflects the history of groundwater development in the study area. Prior to 1960, groundwater use was relatively stable and largely limited to stock, domestic, and municipal wells. Between 1960 and 1980 groundwater was extensively developed as a source for irrigation water. Few irrigation wells have been drilled since 1980 because of water-use restrictions triggered by declining water levels in many aquifers. Use of groundwater for domestic purposes has increased significantly since 1960 and is likely to increase in the future. Changes in the slope of the cumulative curve for domestic wells probably reflect changes in economic conditions and changes in the rate of rural population growth. Concerns about aquifer contamination have resulted in the drilling of several hundred monitoring wells since the early 1980s, including about 125 on the Umatilla Ordnance Depot.



Geologic Unit*						Hydrogeologic Unit
System	**Series**	**Group**	**Formation**	**Age (m.y.)**	**Member or Unit**	**Aquifer or Confining Bed**
Quaternary	Holocene		Surficial Sediments		Wind-blown Silt and Sand	Alluvial Aquifer
			Holocene Alluvium		Alluvial Flood Plain Sediments	
	Pleistocene		Catastro-phic Flood Deposits	.013 - ?	Fine-grained Sediments Coarse-grained Sediments	
Tertiary	Pliocene		— ? — ? — Alkali Canyon — ? — ? —		*Erosional Unconformity*	
					Undifferentiated Sediments	
					Local Erosional Unconformity	
	Miocene	Columbia River Basalt Group	Saddle Mountains Basalt	10.5	Elephant Mountain Basalt	*Confining Bed*
					Rattlesnake Ridge Interbed†	Basal Elephant Mountain Aquifer
				12	Pomona Basalt	*Confining Bed*
					Selah Interbed†	Basal Pomona Aquifer
					Umatilla Basalt	*Confining Bed*
					Mabton Interbed†	Basal Umatilla Aquifer
			Wanapum Basalt	14.5 - 15.6	Undifferentiated Columbia River Basalt	*Confining Bed*
			Grande Ronde Basalt	15.6 - 16.5		Undifferentiated Columbia River Basalt Aquifers

*Modified from Tolan and others, 1989 †Ellensburg Formation

Figure 2.4 Comparison of geologic and hydrogeologic units

Geologic Framework

The Umatilla Basin is a topographic and structural trough between the Columbia Hills of Washington and the Blue Mountains of Oregon. The axis of the trough is roughly coincident with the Columbia River between Arlington and Umatilla, Oregon. The basin and surrounding highlands are underlain by multiple basalt flows which are locally deformed by faults and folds. Up to 250 feet of sediments overlie the basalt flows near the basin axis.

The Umatilla Basin is a part of the Columbia Plateau, a regional downwarp between the Rocky mountains and the Cascade Range. The basin lies at the southern margin of the Yakima Fold Belt, a portion of the Columbia Plateau characterized by east-west trending anticlinal ridges and synclinal basins (Reidel and others, 1989).

From oldest to youngest, the principal stratigraphic units in the basin are the Columbia River Basalt Group, the Ellensburg Formation, the Alkali Canyon Formation, and Pleistocene catastrophic flood deposits (Figure 2.4). Thin deposits of Holocene Alluvium occur in the lower drainages of the Umatilla River and Butter Creek and a veneer of windblown (aeolian) silt and sand overlies most of the lower portion of the basin. The major structures of the basin (Plate 2.2) are the Dalles-Umatilla Syncline, a structural trough which forms the axis of the basin, and the Service Anticline, a north-south trending fold and fault complex which is aligned with Umatilla, Hermiston, and Emigrant Buttes. The distribution of geologic units and structural features is shown on the geologic map and sections of Plates 2.2 and 2.3.

Stratigraphic Units

Columbia River Basalt Group and Interbedded Ellensburg Formation

Between 17.5 and 6.0 million year ago, large outpourings of fluid basaltic lava flooded the Columbia Plateau. The resulting lava field is collectively known as the Columbia River Basalt Group (Swanson and others, 1975). Most of the lavas were extruded from linear vents in eastern Washington and Oregon, and western Idaho. Many of the eruptions released tremendous volumes of lava over short periods of time. The resulting flows advanced as sheetfloods which obliterated the pre-eruption topography over vast areas. Smaller flows also occurred but were restricted to river drainages and topographic lows. In general, the volume and frequency of eruptions diminished over time. In some instances, the time interval between eruptions was long enough to allow sediments to accumulate in low-lying areas. The resulting sedimentary interbeds are formally assigned to the Ellensburg Formation.

Throughout the eruptive history of the basalts, the central portion of the Columbia Plateau was subsiding and the Blue Mountains were rising (Reidel and others, 1989). In general, this influenced the regional distribution of lavas by preventing younger flows from travelling as far to the south as older flows. Thus, the total thickness of the lava field decreases from north to south. Within the Yakima Fold Belt, the distribution of flows was also influenced by faults and folds which were developing at the same time the basalt flows were being emplaced. The age, volume, and regional distribution of the principal basalt units are presented by Tolan and others (1989) and Reidel, Tolan, and others (1989) and summarized in Orr and others (1992).

Three formations of the Columbia River Basalt Group occur in the Umatilla basin. From oldest to youngest these are the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Each formation is composed of multiple members and each member consists of one or more individual lava flows. Within the basin, the total thickness of the basalts is probably at least 5000 feet and may exceed 10,000 feet (Davies-Smith and others, 1988). In contrast, the deepest well in the study area (UMAT 5450) penetrates 1275 feet of basalt.

Grande Ronde and Wanapum flows are exposed on Service Buttes, several miles south of the study area. Wanapum flows are also exposed on the western bluffs of the Umatilla River near Echo and immediately east of the study area in Cold Springs Canyon, Despain Gulch, and Stage Gulch (Swanson and others, 1981). Both units occur at depth in the study area and are principally developed as sources of irrigation water. Neither unit is differentiated on the maps and cross sections of this report.

Saddle Mountains Basalt occurs at or near land surface throughout most of the study area. Aquifers within these lavas are common sources of water for domestic wells. Three members occur in the study area, each consisting of a single flow. From oldest to youngest, these are the Umatilla, Pomona, and Elephant Mountain basalts. Sedimentary interbeds are common at the base of these lavas but the distribution of sediments is uneven across the basin. Interbeds were not mapped at the surface but are shown on the geologic sections of Plate 2.3. General features of each member and its associated interbed are summarized below.

Umatilla Member

The Umatilla Member occurs in the study area as a medium-to-dark gray, aphyric (lacking visible crystals) basalt that ranges up to 100 feet thick. The flow is exposed in a narrow strip that parallels the Columbia River from about two miles east of McNary Dam to beyond the eastern boundary of the study area. At Hat Rock State Park, the Umatilla forms the brim of the hat. A twenty-foot thick, porous, brecciated flow top, overlain by Pomona basalt, is exposed at an elevation of 430 feet in an old railroad cut just west of the park (NW/NW 15-5N/29E), adjacent to the Columbia River. The base of the flow is also exposed in the bed of the Columbia River near the park.

The top of the Umatilla flow is also exposed in a limited area at the northern base of Hermiston Butte at an elevation of 460 feet. No other exposures occur within the study area but Swanson and others (1981) map limited exposures in Cold Springs Canyon, about 2 miles east of Cold Springs Reservoir, and on the north side of Despain Gulch, in sections 16 and 17 of 4N/30E. At both localities, the base of the flow occurs at an elevation of about 700 feet.

East of Service Anticline, outcrop patterns of the Umatilla flow, and flows of the immediately underlying Wanapum Basalt, indicate that the southern limit of the Umatilla flow occurs in a northeast-trending zone just north of the city of Echo. A northeast-trending ridge, defined by structure contours on the top of the Columbia River Basalt Group (Plate 2.2), is interpreted as the approximate southern margin of the flow.

No exposures of the Umatilla member occur west of Service Anticline in Oregon, but the flow is exposed at various localities west of the anticline along the Washington side of the Columbia River. This suggests that the formation of the Service Anticline predates the Umatilla flow. Data from the current investigation were insufficient to confirm or deny the subsurface occurrence of the Umatilla Basalt in Oregon west of the anticline. Geologic mapping by Swanson and others (1981) shows that the Umatilla Basalt is breached in the bed of the Columbia River immediately west of the study area.

Selah Interbed

The Selah interbed consists of vitric tuffs (fine glassy volcanic ash) and weakly indurated siltstones and sandstones which accumulated in river channels and flood plains prior to the eruption of the Pomona basalt (Schmincke, 1967; Smith and others, 1989). On drillers' logs, Selah sediments are commonly described as blue or green clay. The Selah interbed does not occur east of the Service Anticline. West of the anticline, the Selah is thin to nonexistent near the southern margin of the study area, but thickens toward the Columbia River. The Selah also thickens dramatically from east to west along the Columbia River. Near the city of Umatilla, the Selah is about 15 feet thick; near Boardman, it is about 150 feet thick.

Pomona Member

The Pomona Member is a light-to-medium gray basalt characterized by slender (6 to 12 inch diameter) undulating columns, sparse phenocrysts (macroscopic crystals) of olivine and plagioclase, and scattered glomerocrysts (clusters of macroscopic crystals) of olivine, plagioclase, and clinopyroxene. Outcrop and subsurface data indicate a maximum thickness of about 150 feet.

The Pomona is widely exposed at land surface east of Service Anticline. East of the city of Umatilla, it crops out in a wide band on both sides of highway 730. At Hat Rock State Park, erosional remnants of the Pomona form the "hat" and "boat" of Hat Rock and Boat Rock. Immediately west of the park, the base of the Pomona is at about 430 feet elevation and its eroded top is at 510 feet elevation. Three miles to the south, the top of the flow is exposed at elevations above 650 feet along the northern shore of Cold Springs Reservoir. In several isolated alluvial valleys immediately southwest of Hat Rock State Park, the Pomona has been completely stripped away by erosion (Plate 2.2 and cross section E-E', Plate 2.3). Outcrop patterns show that the Pomona dips gently to the west along the Columbia River. The base of the flow reaches river level at about 1.5 miles east of McNary Dam.

Umatilla Butte is wholly composed of Pomona basalt. The Pomona also occurs as erosional "islands", surrounded by alluvial sediments, along the crest of the Service Anticline, from Hermiston Buttes to Emigrant Buttes. At Hermiston Butte, the eroded top of the Pomona is at 610 feet elevation and the base is at 480 feet elevation — a total exposed thickness of 130 feet. Immediately north and south of the butte, sediments occur from land surface to depths of 80 feet in an area where the Pomona has been completely removed by erosion. The Pomona has also been removed by erosion in the Umatilla River valley where the valley crosses the Service Anticline.

The southernmost exposure of Pomona Basalt east of Service Anticline occurs at Emigrant Buttes, where the top of the flow is at about 750 feet elevation. Outcrop patterns indicate that the southern margin of the Pomona flow occurs in a northeast-trending zone between Emigrant Buttes and Cold Springs Reservoir. A northeast-trending ridge, defined by structure contours on the top of the Columbia River Basalt (Plate 2.2), is interpreted as the approximate southern margin of the flow north of the Umatilla River.

West of Service Anticline, the upper surface of the Pomona is exposed beneath the southwestern arm of Carty Reservoir. It is also exposed as a north-trending dip slope in the floor of the Umatilla River between Three Mile Dam and the Columbia River. Outcrop relationships indicate that the southern margin of the Pomona Basalt occurs in an east-west zone roughly coincident with the boundary between townships 2N and 3N. The location of this margin (not shown on Plate 2.2) is well documented in the Carty Reservoir area (Shannon and Wilson, Inc., 1972a) but is poorly constrained to the east. Outcrop patterns in Washington indicate that the Pomona is breached in the bed of the Columbia River between Crow Butte Island and the western boundary of the study area (Swanson and others, 1981).

Rattlesnake Ridge Interbed

The Rattlesnake Ridge interbed is a deposit of silt, clay, and vitric tuff that underlies the Elephant Mountain basalt throughout most of the study area. On drillers' logs it is commonly described as blue or green clay. The thickness of the interbed is commonly less than 10 feet but ranges up to 30 feet. Systematic variations in thickness were not observed.

Elephant Mountain Member

The Elephant Mountain Member is a single, dark grey or black, aphyric basalt flow. The flow is widespread west of Service Anticline but is not found to the east. Good exposures occur between Boardman and Willow Creek along the

Columbia River. South of this area, the flow is covered by up to 150 feet of alluvial sediments or wind-blown silts and sands. Near the Columbia River, the Elephant Mountain ranges from 70 to 80 feet thick. Near its southern margin, roughly coincident with the southern boundary of the study area, the flow thins to less than 40 feet thick.

In places, the Elephant Mountain Basalt and the underlying Rattlesnake Ridge interbed are breached by troughs which rest on the upper surface of the Pomona Basalt (Plates 2.2 and 2.3). In most instances, the troughs are filled with Pleistocene catastrophic flood sediments which obscure the underlying basalt flows. Many of the troughs are coincident with stream drainages and appear to be caused by stream erosion after the emplacement of the Elephant Mountain flow, but before the deposition of the flood sediments. Examples occur in the lower Umatilla River valley between Butter Creek and the Columbia River and, in Sixmile Canyon north of Carty Reservoir. Similar erosional troughs are expected where the northern drainages of Juniper Canyon and Sand Hollow are obscured by a cover of catastrophic flood deposits as they exit from the dissected hills to the south. The drainage areas of these valleys are similar in size to the drainage area of Sixmile Canyon. This suggests that pre-modern streams in these drainages also cut into the surface of the Elephant Mountain basalt prior to the deposition of the the flood sediments. However, the occurrence of troughs in these areas could not be confirmed because of the lack of wells.

The Elephant Mountain flow is also breached by an east-west trough which occurs along the southern border of the Umatilla Ordnance Depot (Plate 2.2 and cross section C-C', Plate 2.3). The origin of this feature is obscure, since it is not directly associated with any modern drainage, but its morphology suggests that it is also an erosional feature.

The Columbia River breaches the Elephant Mountain flow in several places along the Dalles-Umatilla Syncline where the base of the flow rises above the level of the river. One breached section occurs between the mouth of the Umatilla River and section 16 of 5N/27E. A second occurs just west of Crow Butte Island.

Alkali Canyon Formation

The Alkali Canyon Formation consists of tuffaceous silts and sands and moderately indurated gravels which were shed from the rising Blue Mountains in late Miocene and Pliocene times (Farooqui and others, 1981; Smith and others, 1989). Within the study area, these deposits have also been mapped as Pliocene fanglomerate (Hogenson, 1964; Robison, 1971) or as the Dalles Formation (Newcomb, 1966; Shannon and Wilson, 1972a).

In the Lower Umatilla Basin, Alkali Canyon sediments form a wedge-shaped deposit that is exposed between elevations of 750 and 1500 feet. The wedge attains a thickness of 250 feet near its northern limit and thins to zero in the south. Thicknesses are generally less than 50 feet to the east of the Service Buttes Anticline and greater than 150 feet to the west of the anticline.

Catastrophic Flood Deposits

During the Pleistocene Epoch, a dam of glacial ice periodically blocked the drainage of the Clark Fork River near Missoula Montana forming a large body of water known as glacial Lake Missoula. Episodic failure of the dam released tremendous volumes of water which swept across western Washington and down the Columbia River drainage basin. These floods are variously referred to as the Spokane floods, the Bretz floods, or the Missoula floods. Estimates of the number of floods range from 8 (Bretz, 1969) to more than 40 (Waitt, 1985). The last flood occurred about 13,000 years ago (Baker, 1978).

The torrent of water released by each flood stripped soil and sediment from the land, scoured the underlying rock surfaces, and deposited extensive tracts of boulders, gravel, sand, and silt. The resulting sediments are informally referred to as catastrophic flood deposits (Farooqui and others, 1981). The sands and gravels of this unit form extensive deposits in the lowlands of the Umatilla Basin and are the principal groundwater-producing zones in the sediments which overlie the Columbia River Basalt Group.

Within the Umatilla Basin, the distribution of flood gravels and scoured basalt surfaces indicates that some of the floods crested at elevations near 750 feet, near the top of Emigrant Buttes (Bretz, 1925; Hogenson, 1964). As flood waters exited the basin near Arlington, the narrow profile at the entrance of the Columbia River Gorge caused a temporary, hydraulic ponding of water. The slackwater conditions allowed clay, silt, and fine sand to settle out in upstream areas. Pebbles and boulders which were embedded in ice rafts were also released as the ice was stranded at shorelines and melted. These fine-grained sediments and their associated erratics are found at elevations up to 1150 feet, the approximate upper limit of ponded water in the basin (Allison, 1933; Hogenson, 1964).

For the purposes of this study, the flood deposits are divided into two assemblages: a predominantly coarse-grained assemblage of boulders, gravels and medium- to coarse-grained sands (Pscfc) and, a predominantly fine-grained assemblage of silts, fine-grained sands, and clays, with interbeds of sand and gravel (Pscff). For brevity, these will also be referred to as coarse-grained flood deposits or fine-grained flood deposits. The assemblages are differentiated on geologic cross sections (Plate 2.3) but were not mapped separately at land surface.

Coarse-grained flood deposits (Pscfc) occur at or near land surface throughout most of the Lower Umatilla Basin at elevations below 750 feet. These sediments are equivalent to the glaciofluviatile deposits of Hogenson (1964), the Older alluvium of Robison (1971), and the fluvioglacial deposits of Walker (1973). Total thickness ranges up to 200 feet. The thickest accumulations occur in three shallow, east- to northeast-trending troughs: one along the Columbia River between Umatilla and Boardman, a second between Hermiston Butte and Hat Rock State Park, and a third which spans the southern part of Umatilla Ordnance Depot. Along the trough axes, coarse-grained sediments rest on a scoured basalt surface or on a floor of fine-grained flood sediments; away from the axes they lap onto basalt highs or the assemblage of predominantly fine-grained sediments. The coarse-grained deposits thin to the north and south as the floor of each trough rises away from its axis. The shape, orientation, and position of the troughs suggest that they were eroded by the Missoula floods and that their coarse-grained fill was deposited by main-channel flood currents.

On water well reports, coarse-grained flood deposits are commonly described as sands, gravels, or boulders. On the geologic logs of monitoring wells they are described as poorly-sorted sands and gravels; where differentiated, gravel clasts are generally reported as basalt and less frequently as quartz.

Exposures of coarse-grained flood deposits can be seen in many quarries in the area. The deposits typically occur as unconsolidated, poorly-sorted, clast-supported gravels with lenticular interbeds of medium- to coarse-grained sand or, as thick, cross-bedded sequences of fine- to coarse-grained sand with lenticular beds of gravel. Pore spaces in the gravel are partly void or filled with fine- to coarse-grained sand. About 70% of the examined gravel clasts are angular fragments of basalt; the remainder are rounded fragments of granitic, metamorphic, and volcanic rock which are not native to the Umatilla Basin. Quarries with good exposures of these deposits are located near Hermiston (NE 7-4N/29E), Umatilla (SW 16-5N/28E), and Irrigon (NW 30-5N/27E, SE 10-4N/26E), and adjacent to the Umatilla Ordnance Depot (SW 26-4N/27E, NE 28-4N/27E, SE 10-4N/26E).

Predominantly fine-grained catastrophic flood deposits (Pscff) occur as silts, fine silty sands, and clays, with interbeds of sand and gravel. These include sediments between elevations of 750 and 1150 feet which were described as pebbly silts by Allison (1933) and mapped as glacial-lake sediments by Hogenson(1964) and Walker (1973). Well reports and drill cuttings show that similar deposits commonly underlie coarse-grained flood deposits in the subsurface below elevations of 750 feet. Water well reports commonly describe the finer fraction of these deposits as brown, tan, or yellow clay, or as claystone, clay and sand, or clay and gravel. On the geologic logs of monitoring wells, they are described as yellow or brown sandy silt, silty sand, clayey silt, or silty clay, and less commonly, as silty sand or silty gravel. Mica is noted at scattered localities. A comparison of geologic drill logs with nearby water well logs suggests that many of the sediments that water well drillers describe as brown or yellow clay are in fact sandy silts or silty fine-grained sands.

Interbeds of fine sand, sand, and gravel are common in the predominantly fine-grained flood deposits. The beds are typically less than 5 feet thick, but aggregate thickness ranges up to 40 feet. In general, the coarse-grained beds cannot be correlated over any distance based on the descriptions on water well logs. Monitoring wells at scattered localities describe the presence of quartz, quartzite, and mica grains within these beds. Examples include a 4-feet thick quartz sand at a depth of 140 feet in UMAT 5365 (4N/28E-6aba) and, a 4-feet thick gravel containing quartzite and mica at a depth of 175 feet in LUB 73 (3N/28E-3cc).

The total thickness of predominantly fine-grained flood deposits ranges up to 200 feet. In general, the fine-grained sediments thicken away from the troughs which contain coarse-grained flood sediments. Thick accumulations of fine-grained flood sediments occur beneath the terrace between Hermiston and Stanfield, beneath the northeastern part of the Umatilla Ordnance Depot, and beneath the lower part of the Butter Creek and Umatilla River drainages.

Silts, sands, and silty sands of the predominantly fine-grained flood deposits are interpreted as slackwater sediments deposited during the ponding phase of the various floods. They are equivalent to the Touchet Beds of the Walla Walla Valley (Flint, 1938). The interbeds of sand and gravel are interpreted as lag sediments, deposited during the main flooding phase, when currents were strong or, during the transition between initial flooding and ponding, when current strength was waning. The interbedding of fine and coarse-grained sediments probably reflects the occurrence of multiple floods of various strengths. Other criteria that would support multiple floods are generally not noted on the logs of water wells or monitoring wells. However, several monitoring well logs report thin beds of red or reddish-brown clay and silt within the fine-grained sediments northeast of the Umatilla Ordnance Depot. These beds may be buried soil horizons which formed between successive floods.

Prior to the late 1960s, most geologists were skeptical about the occurrence and nature of the Missoula floods (Baker, 1978). This has led to some confusion about the relative ages of fine- versus coarse-grained flood sediments in the Lower Umatilla Basin. For example, Allison (1933) believed that his pebbly silts were younger than gravels near the Columbia River that Bretz (1925; 1928) had ascribed to catastrophic floods. Hogenson (1964) reversed this relationship by assigning an early Pleistocene age to his glacial-lake deposits and a late Pleistocene age to his glaciofluviatile deposits. Current knowledge of multiple floods and a better understanding of the hydraulics of the floods indicate that these sediments are equivalent in age, but span a range of times.

Holocene Alluvium

During the last 12,000 years, thin deposits of micaceous silt, sand, and gravel have accumulated in the flood plains of Butter Creek and the Umatilla River. These alluvial sediments are largely composed of reworked loessal soils, reworked catastrophic flood sediments, and basaltic gravels washed from the upper reaches of local stream drainages. In most areas, Holocene sediments overlie Pleistocene catastrophic flood deposits. Upstream from Echo, in the Umatilla River valley, Holocene sediments may rest directly on basalt bedrock. Because of similarities in composition, the subsurface contact between Holocene Alluvium and underlying flood deposits cannot generally be determined with confidence based on the sediment descriptions on well logs.

Surficial Deposits

A windblown deposit of micaceous silt and sand veneers most of the Lower Umatilla Basin. The unit ranges up to 30 feet thick but is typically less than 10 feet thick. Active and stabilized dunes can be observed on undisturbed surfaces but dunes have been obliterated in most irrigated areas. Most of the soils of the basin are formed in this deposit.

Geologic Structures

The Dalles-Umatilla Syncline and the Service Anticline are the principal structures in the Lower Umatilla Basin (Plate 2.2). These features control the orientation of Columbia River basalts and the geometry of the land surface. They have also influenced the pattern of erosion in the basalts and the distribution of sediments overlying the basalts. The lack of deformation in the overlying sediments indicates that structural growth ended prior to the deposition of the sediments.

The Dalles-Umatilla Syncline (Newcomb, 1967) forms a regional topographic low which controls the modern course of the Columbia River between Arlington and Umatilla, Oregon. The syncline is typically mapped as a single fold within the Umatilla Basin but the precise nature of the structure, and the location of its axis, are obscured by a cover of alluvial sediments in most places along the river. Several authors have extended the syncline eastward from Umatilla to Pendleton (Newcomb, 1967; Tolan and Reidel, 1989) but the current investigation indicates that the fold terminates at the Service Anticline, near the Port of Umatilla.

Well correlations on the Oregon limb of the Dalles-Umatilla Syncline indicate that dips are about 50 feet per mile to the north. Outcrop patterns and subsurface correlations indicate that the syncline plunges to the west between Umatilla and Irrigon and to the east between the western boundary of the study area and Boardman (Plate 2.2).

Service Anticline is an alignment of buttes and ridges that extends from Sillusi Butte in Washington to Service Buttes in Oregon. Between Umatilla Butte and Service Buttes, the structure is expressed as a chain of isolated basalt buttes which are surrounded by alluvial sediments. Hogenson (1964) and Shannon & Wilson (1973b) describe minor faults associated with the structure but map it as an anticline along its entire length. Robison (1971) notes that a closed fold is not visible along most of the structure and infers bounding faults on both sides of the buttes along most of the structural trend. Data from the current investigation are not sufficient to resolve the nature of the structure in most places but outcrop and well log data suggest that faulting has produced at least 250 feet of vertical structural relief on the west side of Hermiston Butte (Plate 2.2 and cross section F-F', Plate 2.3). In addition, structure contours define a narrow, north-south trough immediately east of Hermiston Butte that may be a fault or a tightly-folded syncline.

The "topography" of the surface of the Columbia River Basalt Group (Plate 2.2) reflects tectonic deformation (folding and faulting) and erosion. West of Service Anticline the basalt surface has undergone only minor erosion and largely reflects the structural dip of the Elephant Mountain Basalt.

East of Service Anticline, the basalt surface is characterized by several northeast-trending ridges and troughs. The broadest trough, which underlies Hermiston, is a low-amplitude syncline which has been accentuated by erosion during the Missoula floods. Ridges south of the Hermiston trough are interpreted as the southern margins of the Pomona and Umatilla basalts, modified by erosion during the Missoula floods.

Groundwater Occurrence

Groundwater occurrence is influenced by the distribution of geologic units and the variation of permeability and porosity within each unit. These factors affect the ability of water to migrate into the ground and travel through the groundwater system. They also govern how easily groundwater can be extracted by wells.

Water well logs indicate the presence of multiple water-bearing zones in the Lower Umatilla Basin. The principal zones occur in sands and gravels which overlie the Columbia River Basalt Group or in breccia/fracture zones within the Columbia River Basalt flows. The upper two or three basalt flows and the overlying sands and gravels contain the most widely used sources of domestic groundwater. These shallow aquifers are the focus of this report.

Aquifer Units

For the purpose of this study, four shallow aquifer units are defined on the basis of stratigraphic boundaries. These boundaries segregate groundwater into discrete zones with distinctive water levels and flow paths. From upper to lowermost, these are the alluvial aquifer, the basal Elephant Mountain aquifer, the basal Pomona aquifer, and the basal Umatilla aquifer. The basalt aquifers will alternatively be referred to as the Elephant Mountain aquifer, the Pomona aquifer, and the Umatilla aquifer. The relationship between aquifer units and geologic units is shown is Figure 2.4.

Conceptual Model of the Groundwater Flow System

Figure 2.5 shows a conceptual model of the shallow groundwater flow system in the basin. An understanding of the flow system at any given locality can be gained by referencing the schematic model to the geologic sections and maps on Plates 2.2, 2.3, and 2.4.

Groundwater recharge comes from precipitation, deep percolation of irrigation water (percolation past the root zone), and leakage from canals, streams, and reservoirs. The recharge area for the alluvial aquifer is very broad because porous and permeable sediments overlie the aquifer throughout most of its extent. Recharge areas for the basalt aquifers are narrow because porous and permeable zones in the basalt flows are generally restricted to tabular breccia or fracture zones at the top or base of flows (Figure 2.6). Because the breccias typically constitute less than ten percent of a flow's thickness, their surface area is relatively small where exposed at land surface or beneath a cover of sediments.

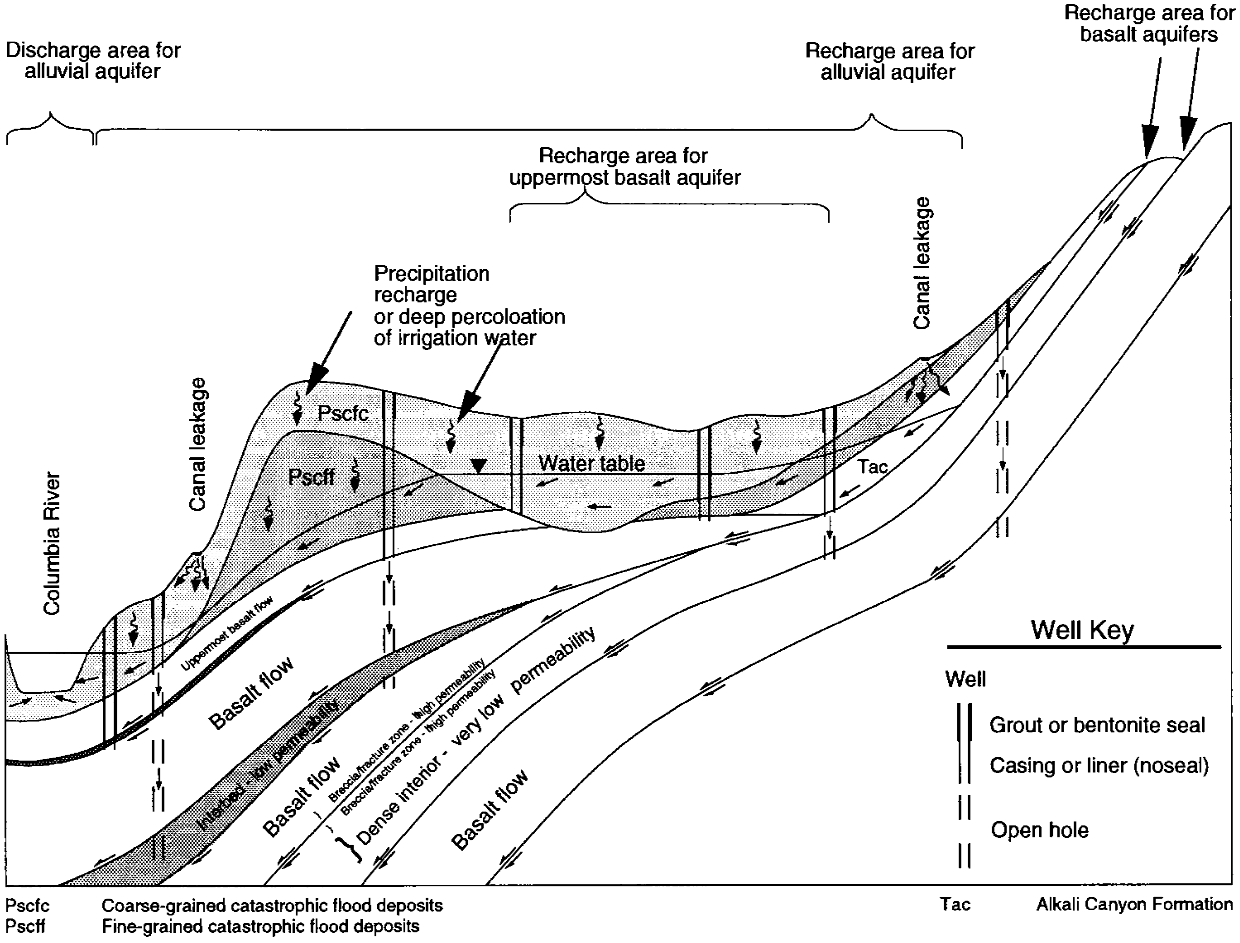


Figure 2.5 Conceptual model of the shallow groundwater flow system

Groundwater in the shallow aquifers is constantly flowing toward the Columbia and Umatilla rivers where it is discharged from the groundwater system to become stream flow. Discharge from the basalt aquifers to the rivers is probably inefficient except where individual flows are breached in one of the riverbeds. Some alluvial groundwater is also discharged to underlying basalt aquifers where updip margins of lava flows are exposed at the base of the alluvial aquifer.

Water wells impact the groundwater and surface water system in several ways. If annual pumpage exceeds annual recharge, the volume of groundwater in storage will decrease and water levels in an aquifer will drop. Pumpage from wells can also change groundwater flow paths, especially in areas where high-capacity wells are clustered. Wells can also allow water to migrate between aquifers with different hydraulic heads. This mixing, or commingling, of groundwater can occur in the annular space behind ungrouted well casing or in open well bores that penetrate more than one aquifer.

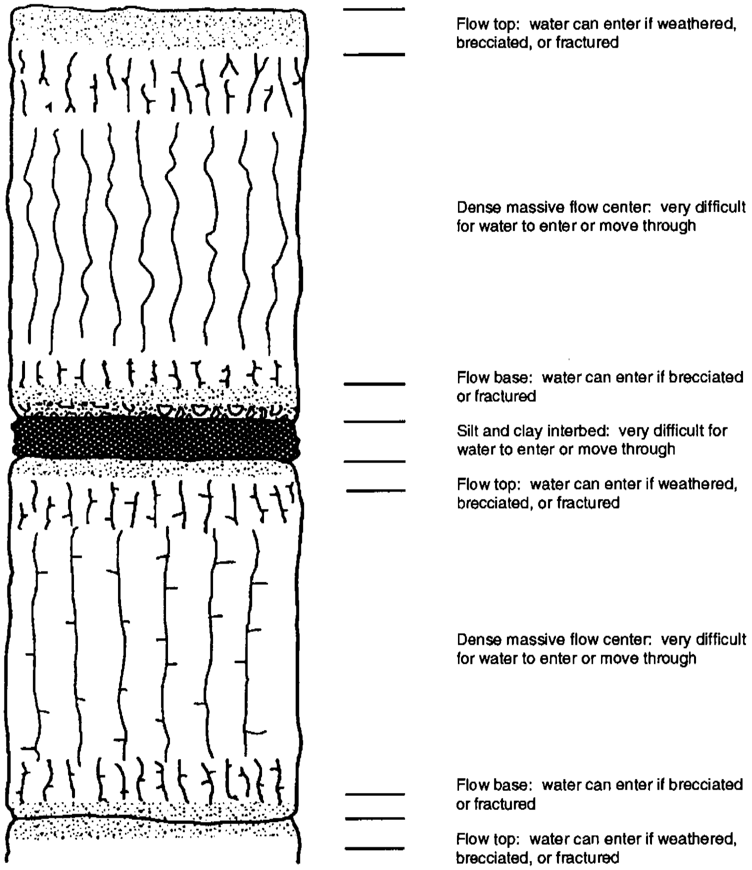


Figure 2.6 Idealized relationship between basalt stratigraphy and groundwater occurrence.

Alluvial Aquifer

The alluvial aquifer includes all saturated sediments which overlie the Columbia River Basalt Group and any saturated breccia/fracture zones at the top of the uppermost basalt flow. Sedimentary units within the aquifer include Holocene Alluvium, Pleistocene catastrophic flood deposits, and the Alkali Canyon Formation (Figure 2.4). The principal water-bearing zones occur in sands and gravels within the flood deposits (Plates 2.3 and 2.4).

The boundaries of the productive aquifer are approximated by the limits of the water-level contours shown on Plate 2.4. Limiting contours correspond to areas where the saturated thickness is generally less than 20 feet or where well yields are insufficient for most consumptive uses. Scattered well logs indicate that thin saturated zones occur at considerable distances beyond the limits of the contours. Most of the productive alluvial groundwater resource occurs within the area between Boardman, Cold Springs Reservoir, and Echo but, an isolated resource occurs in the sediments of Sixmile Canyon between Carty Reservoir and the Columbia River.

The upper surface of the Columbia River Basalt Group defines the approximate base of the alluvial aquifer (Plate 2.2). The subsurface "topography" of this bedrock surface is the primary factor controlling the thickness of the alluvial aquifer. The aquifer thins above local bedrock highs and thickens above bedrock lows. The aquifer also thins to the south and east as the basalt surface rises to higher elevations. The saturated thickness of the aquifer can be estimated at any locality by subtracting the elevation of the basalt surface from the elevation of the water table.

In a general sense, the water-level contours on Plate 2.4 can be thought of as the slope, or gradient, of the water table. In this sense, groundwater flows "downslope", or down gradient, from areas of high to low hydraulic head. Regional water-level highs generally correspond to areas of regional recharge and regional water-level lows correspond to areas of potential discharge. Local water-level mounds indicate areas of local recharge.

Water-Bearing Units

Holocene Alluvium

Holocene Alluvium occurs as a thin veneer of silt, sand, and gravel in the Butter Creek flood plain and in the Umatilla River flood plain upstream of Butter Creek. In most areas these deposits are saturated to within several feet of land surface and water levels are within a few feet of the elevation of adjacent streams.

Catastrophic Flood Deposits

Catastrophic flood deposits are the principal water-bearing unit in the alluvial aquifer (Plates 2.3 and 2.4). Flood sediments include gravels, sands, silts, and clays. Where saturated, the sands and gravels yield moderate to high quantities of water to wells. Silts and silty sands locally yield small quantities of water to wells. Hydraulic properties vary geographically within the flood deposits and correlate to the distribution of coarse-grained versus fine-grained sediments. In general, the permeability of the coarse-grained deposits is much higher than that of the fine-grained deposits. This is reflected by higher well yields and lower hydraulic gradients in the coarse-grained sediments.

Predominantly coarse-grained catastrophic flood deposits (Pscfc) occur as broad tracts of sands and gravels. Extensive saturated deposits occur as lobate areas that are centered on three east to northeast-trending troughs (highlighted in yellow on Plate 2.4). Each area is characterized by a saturated thickness greater than 10 feet, low hydraulic gradients (typically less than 10 feet per mile), and high well yields. Yields in high capacity wells are commonly greater than 1000 gallons per minute and range up to 4000 gallons per minute. Collectively, these areas represent the most productive part of the alluvial aquifer. Saturated coarse-grained flood deposits also occur in Sixmile Canyon and tributary canyons between Carty Reservoir and the Columbia River. Outside of these areas, groundwater occurs in predominantly fine-grained flood sediments (Pscff) or in thin saturated zones within coarse-grained flood sediments.

Predominantly fine-grained catastrophic flood deposits (Pscff) occur as clays, silts, sandy silts, and gravelly silts with thin interbeds of sand and gravel. Silts and silty sands are the predominant sediment type. Where saturated, these deposits are characterized by hydraulic gradients greater than 25 feet per mile and well yields up to 500 gallons per minute. In some areas the sand and gravel interbeds are locally confined by overlying beds of silt or clay. The confining beds and the sand and gravel interbeds are laterally discontinuous; in many cases they cannot be traced for distances greater than one mile. The cumulative thickness of saturated sand and gravel beds is as high as 30 feet but commonly totals less than 5 feet. In some areas, sands and gravels are absent. Productive confined sands occur locally on the terrace between Hermiston and Stanfield, in the Umatilla River valley below Umatilla Meadows, and in the vicinity of Lost Lake (10-3N/27E). Well yields in these areas range up to 500 gallons per minute but are commonly less than 100 gallons per minute. Elsewhere, well yields from the fine-grained deposits are sufficient for domestic purposes only.

The following sections summarize the hydrogeologic characteristics of the flood deposits on a region by region basis.

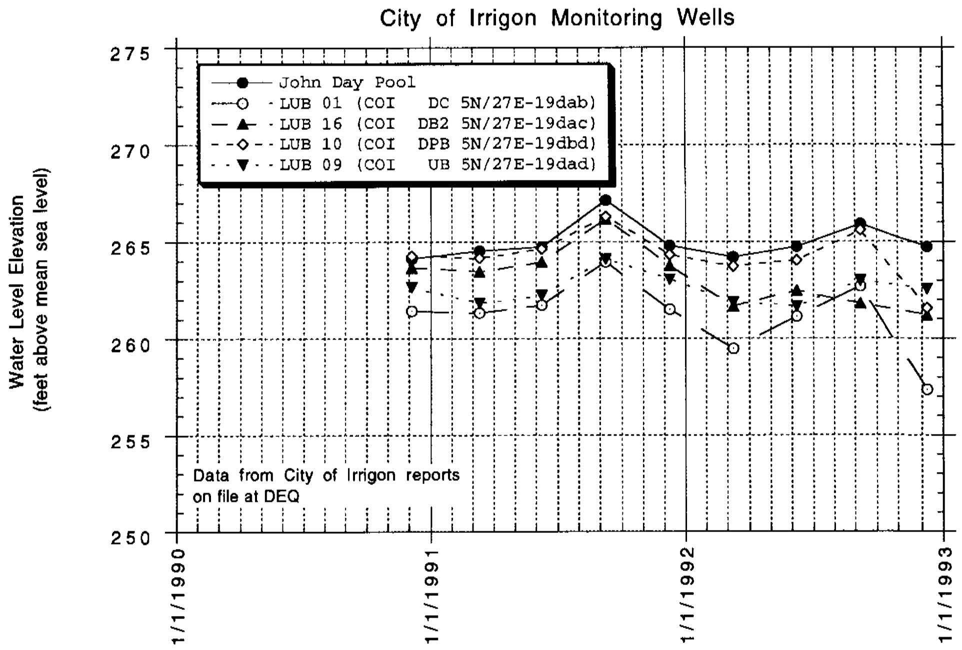
Boardman-Umatilla Area

Coarse-grained catastrophic flood deposits fill the trough of the Dalles-Umatilla syncline along the Columbia River between Boardman and Umatilla. The saturated thickness of these deposits exceeds 40 feet at the river but decreases toless than 10 feet as the surface of the underlying basalt rises to the south (cross sections B-B', C-C', and D-D', Plate 2.3). Groundwater flow is generally to the north with discharge to the Columbia River. Adjacent to the river, groundwater elevations are within several feet of the John Day pool level (average pool elevation, 265 feet). Data from monitoring wells near the Port of Morrow (Cascade Earth Sciences, Ltd., 1993) show that hydraulic gradients are 2 to 4 feet per mile near the river but increase abruptly to 50 feet per mile about 2 miles south of the river (Figure 2.8B). The hinge line at which this change occurs is roughly equivalent to the elevation at which the basalt surface (the base of the alluvial aquifer) rises above the John Day pool level (cross section B-B', Plate 2.3). Although water-level data is sparse elsewhere, the general pattern of water levels, the continuity of the sands and gravels, and the geometry of the underlying basalts suggests that similar conditions occur along the river between Boardman and Umatilla(see cross sections C-C′ and D-D′, Plate 2.3).

Groundwater levels in coarse-grained flood deposits adjacent to the Columbia River are 2 to 4 feet higher in the summer than in the winter (Figure 2.7). These changes correspond to seasonal variation of the John Day pool level. Pool level is typically 267 feet elevation in the summer and 261 feet in the winter (personal communications, Art Fong and Fred Miklancic, U.S. Army Corp of Engineers). Because the hydraulic gradient of the aquifer is very low near the river, rapid rises in pool level may temporarily reverse the gradient near the river and cause river water to flow into the aquifer. Not enough data is available to substantiate such reversals in the study area but reversals have been documented in a similar setting at the Hanford Site in Washington state (Gilmore and others, 1993).

In contrast, monitoring wells in section 1 of 4N/25E, and sections 6 and 7 of 4N/26E, at distances greater than 1 mile from the river, show lower water levels in summer and higher levels in winter (Figure 2.8A). June 1992 water-level contours suggest that these trends are caused by the pumping of a high-capacity well in section 36, 5N/25E, near MORR 696 (Figure 2.8B). Similar effects are expected to the east near a cluster of high-capacity irrigation wells which are located along the boundary between 4N/26E and 5N/26E (Plate 2.6). Pumping impacts in this area are likely to be intensified because of an abrupt decrease in saturated thickness to the south.

After the John Day dam was completed in April of 1968, alluvial groundwater levels rose up to 25 feet in the Boardman area (Robison, 1971; unpublished charts in Oregon Water Resources Department's Groundwater files). Similar rises occurred along the river between Boardman and Umatilla. For example, UMAT 3294 (5N/27E-14dda), halfway between Irrigon and Umatilla and 1300 feet south of the river, had a pre-dam static water-level elevation of 253 feet in February 1966 compared to a post-dam elevation of 266 feet in February 1991.



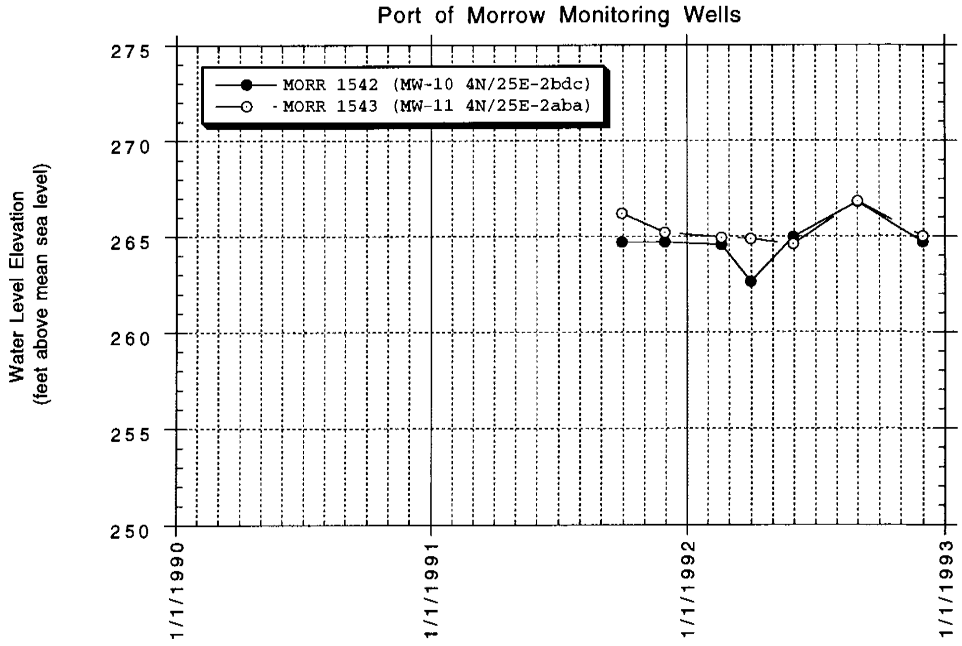
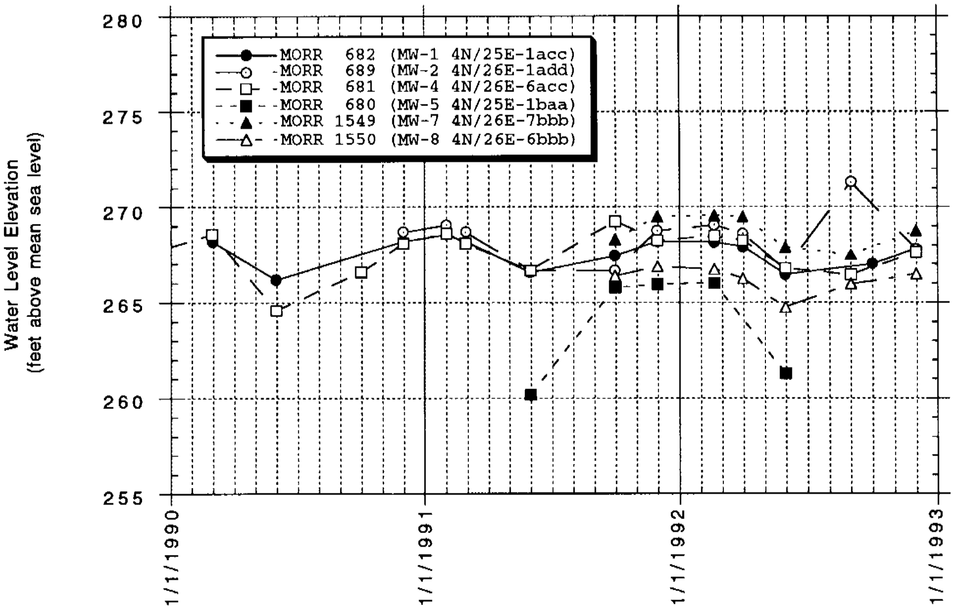


Figure 2.7 Effect of river stage on groundwater levels in coarse-grained flood deposits adjacent to the Columbia River between Irrigon and Boardman

A Port of Morrow Monitoring Wells



B Port of Morrow Vicinity Map

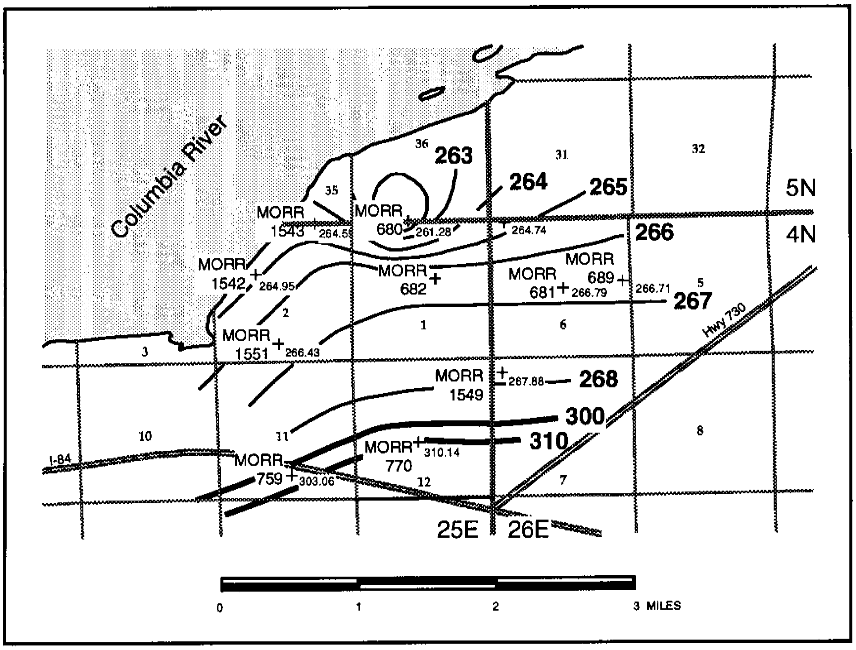


Figure 2.8 Possible effects of pumping on groundwater levels in coarse-grained flood deposits east of the Port of Morrow

Seasonal or long-term lowering of the John Day pool will cause groundwater levels in the alluvial aquifer to decline. The decline will be greatest adjacent to the river and least near the southern margin of the saturated coarse-grained deposits as delineated on Plate 2.4. South of this margin, the base of the alluvial aquifer rises above the level of the John Day pool and saturated thickness decreases dramatically. Saturated thickness in the southern area is unlikely to be impacted by pool changes since it is dependent upon local recharge and groundwater influx from the south. The configuration of the water table at any John Day pool level can be predicted by finding the equivalent line of elevation on the basalt surface. This will be the approximate location of the new hinge line which separates the low-gradient area to the north from the thinly-saturated high-gradient area to the south.

Umatilla Ordnance Depot Area

The nature of the alluvial aquifer in the Ordnance area has been the focus of some controversy. McCall postulated that fine-grained sediments separated saturated gravels into eastern and western areas (his Westland Road and Lost Lake-Depot subareas) with minimal hydraulic connection. McCall also constructed a water table map which inferred that groundwater in both areas flowed northerly, with discharge to the Columbia River. In contrast, Miller (1985) concluded that gravels in the northern two-thirds of both areas were hydraulically connected and that groundwater flow was to the northeast, with discharge to the Umatilla River. Based on a more extensive data set, the current investigation supports Miller's conclusion that the gravels are part of a single hydraulic system but finds that groundwater flow in the area is more complex than proposed by either author (see Plate 2.4).

Predominantly coarse-grained catastrophic flood deposits fill an east-west trough centered on the southern part of the Umatilla Ordnance Depot (see cross sections C-C' and D-D' on Plate 2.3). McCall (1985) and others have informally referred to these sediments as the Ordnance gravels. The saturated portion of the "gravels" (highlighted in yellow on Plate 2.4) is centered on the trough axis and forms an elongate lobe which extends from the western boundary of the Depot to the Umatilla River. Seasonal and long-term hydrographs show that water-level trends are consistent over broad areas within the gravels (Figures 2.9, 2.10, 2.11). These factors indicate that the gravels are part of a single hydraulic unit that responds to the same set of stresses over a broad area.

Saturated thickness in the gravels ranges up to 125 feet near the center of the trough but thins to zero as the underlying contact with predominantly fine-grained flood sediments rises above the water table to the north and south (Plate 2.3, cross sections C-C' and D-D', and Plate 2.4). A similar thinning is inferred to the west but cannot be confirmed due to a lack of well control. In February 1991, groundwater elevations ranged from 495 to 500 feet throughout most of the gravels but varied by less than 1 foot across the southeastern quarter of the Depot (Plate 2.4). Because well-head elevations were not surveyed outside of the Depot, most of the water-level variation in these areas may be due to uncertainties in those elevations. If so, the hydraulic gradient was probably less than 1.5 feet per mile throughout most of the extent of the gravels.

Figure 2.9 shows long-term hydrographs for representative wells completed in coarse-grained flood deposits east and south of the Depot. The major trends are a water-level decline between 1960 and 1978, a rise between 1978 and 1986 and a decline from 1986 to 1993. These trends roughly parallel the historical development of groundwater in the area but, they also correlate to long-term fluctuations in annual rainfall (Figure 2.2) (Miller, 1985). The correlation with rainfall is believed to be indirect since precipitation recharge is considered to be negligible in the area (see section on precipitation recharge below). Irrigation pumpage in the Ordnance area began in the early 1950s, increased slowly through the early 1960s, and accelerated between 1965 and 1976. In 1976, pumpage was stabilized by regulation at about 13,000 acre-feet per year south of the Depot and at about 6000 acre-feet per year east of the Depot. Also, in 1976, the County Line Water Improvement District (CLWID) began artificial recharge of the aquifer via a leaky canal, 2.5 miles in length, located about one mile south of the Depot (Plate 2.4). Recharge from the canal has averaged about 5200 acre-feet per year through 1993. In the mid 1980s, the Westland Irrigation District lined several miles of the A canal and replaced the F canal with pressurized pipes. This has probably resulted in decreased recharge to the gravels and may be responsible for some of the water-level decline between 1986 and 1993 (see the section on canal leakage recharge below).

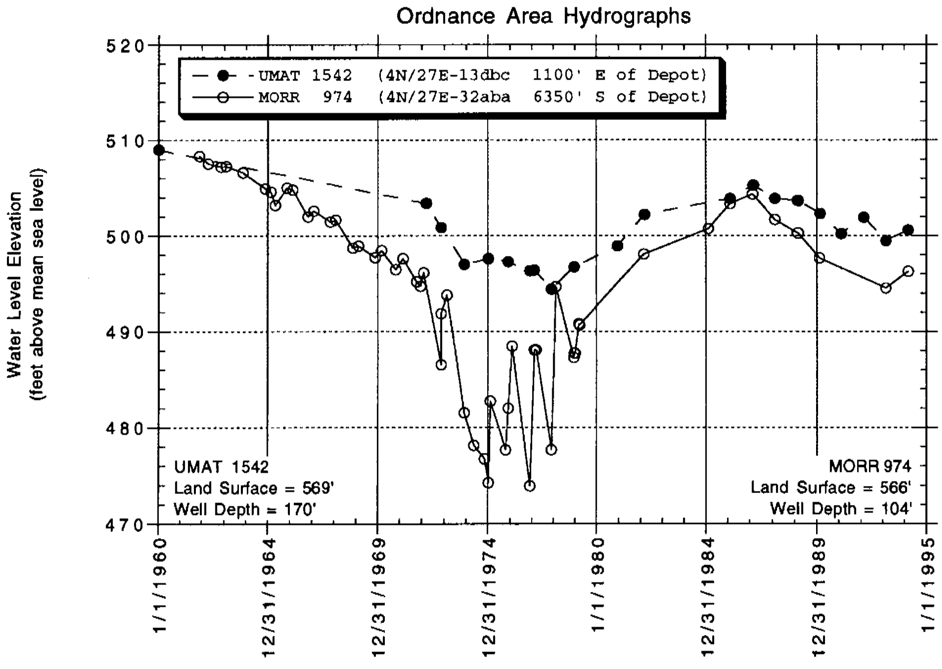


Figure 2.9 Long-term hydrographs of representative wells completed in coarse-grained flood deposits east and south of the Umatilla Ordnance Depot

An example of seasonal water-level fluctuations in the gravels is illustrated by the continuous recorder hydrograph for MORR 963 (Figure 2.10). At the beginning of the irrigation season, water levels fall in response to pumpage from nearby irrigation wells. Near the end of the irrigation season, water levels reach their lowest point. This is followed by a gradual rise which corresponds to a recovery from pumping and possibly some precipitation recharge. A steep rise in water level between early February and late March 1992 corresponds to artificial recharge from the County Line Water Improvement District's recharge canal. The beginning of this rise occurs within several days of the filling of the recharge canal. Similar responses in wells near the canal are noted by Miller (1985).

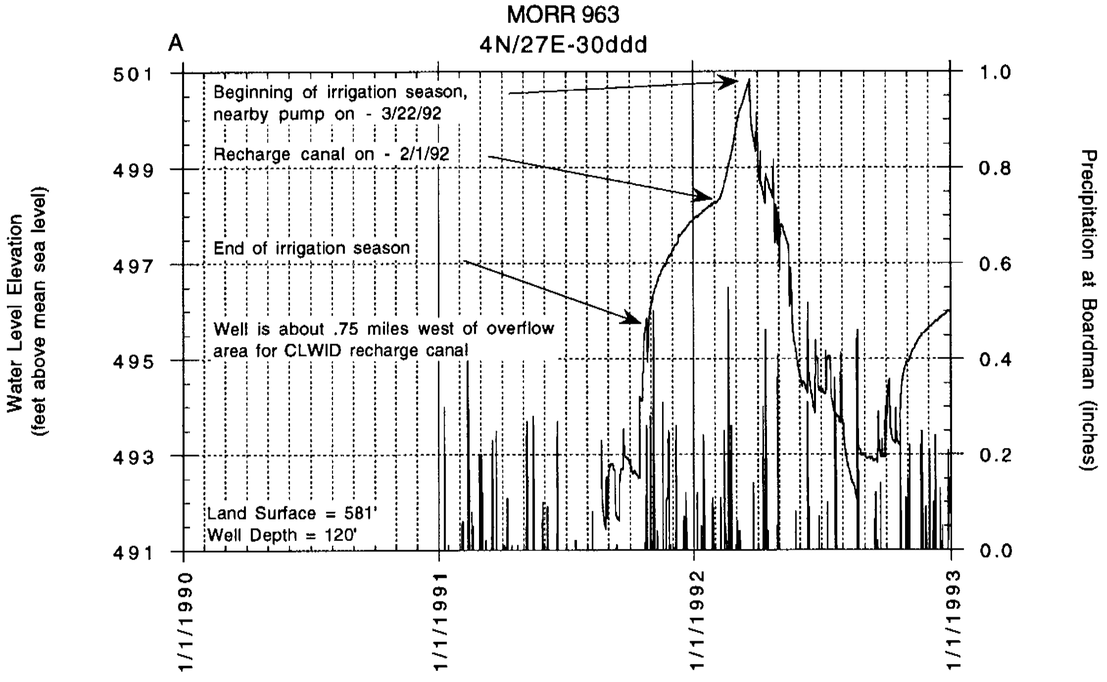
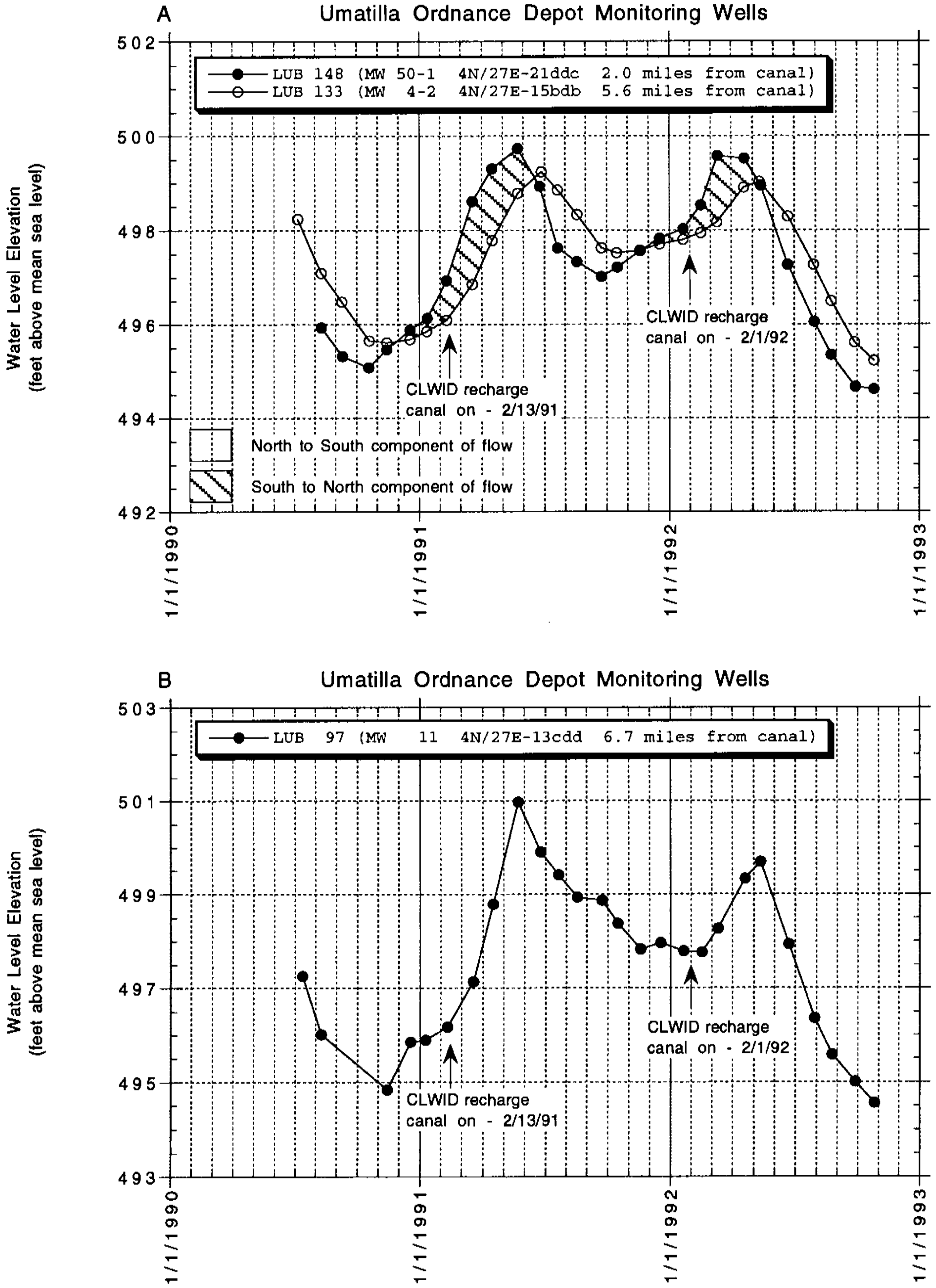


Figure 2.10 Seasonal hydrograph of continuous recorder well completed in coarse-grained flood deposits south of the Umatilla Ordnance Depot

On the Umatilla Ordnance Depot, widely-spaced monitoring wells completed in the gravels display seasonal trends which correspond to those of MORR 963 (Figure 2.11). Seasonal fluctuations have an amplitude of about 5 feet and water level elevations are generally within 2 to 3 feet over a broad area. The timing of the major changes in water level trends is related to the distance from major pumping centers and recharge sources. For example, peaks and troughs occur earlier in the year at wells which are closer to the southern and eastern boundary of the Depot (Figure 2.11), adjacent to areas of major irrigation withdrawals from the alluvial aquifer (Plate 2.6). Similarly, a change from gradual to steep water-level rise in late winter occurs earlier in wells near the southern boundary and correlates to distance from the CLWID recharge canal (Figure 2.11). Continuous recorder hydrographs for Depot wells confirm these patterns in detail for the period from August 1990 through October 1991 (Dames & Moore, Inc., 1992).



Fiugre 2.11 Seasonal hydrographs of representative wells completed in coarse-grained flood deposits on the Umatilla Ordnance Depot. A, Wells in south-central part of Depot; B, Well near eastern boundary of Depot

Depot monitoring wells completed in fine-grained flood deposits show notably different water-level trends compared to wells completed in coarse-grained flood deposits. Between July of 1990 and October of 1992, most fine-grained wells show annual water-level rises between 0.5 and 3 feet and little or no seasonal fluctuation (Figure 2.12). Annual water level rises are greatest along the eastern and western boundaries and decrease toward the interior of the Depot. One well near the center of the Depot (LUB 130) shows a small annual water-level decline. Along the western boundary of the Depot, these trends produce a bending, or refraction, of the water-level contours which indicates that groundwater is flowing onto the Depot from the southwest (Plate 2.4). Rising groundwater levels in the northeastern part of the Depot correspond to inflow from a groundwater mound which is centered about one-half mile east of the northeast corner of the Depot.

The contrasting seasonal behavior of groundwater in fine-grained versus coarse-grained sediments in the Ordnance area is consistent with a large permeability contrast caused by an abrupt lateral change from channel-filling sands and gravels in the south to slackwater silts and clays in the north. This lateral permeability contrast dampens the seasonal water-level fluctuations which occur within the coarse-grained deposits. The efficiency of this hydraulic boundary as a barrier to flow cannot be determined from the present data.

Investigations on the Depot (Dames & Moore, 1992; Dames & Moore, 1994b) show that flow directions in the coarse-grained flood deposits (their Ordnance Aquifer) fluctuate seasonally in response to off-site pumping and recharge. In general, flow directions are to the east and south in summer and autumn and to the north and west in winter and spring. Additional variation is seen at other times of the year. The rough nature of these seasonal changes can be seen in Figure 2.11A by noting that the relative flow direction between any two wells is reversed when their water level trends cross on a hydrograph.

Water levels on Plate 2.4 indicate that the predominant direction of groundwater flow in the coarse-grained deposits in February 1991 was easterly toward the Umatilla River. Water levels also indicate some northwesterly outflow from the coarse-grained deposits, with discharge to the Columbia River. However, the permeability contrast between the coarse-grained and fine-grained deposits probably restricts the rate and volume of flow to the northwest. Dames & Moore (1994b) suggest that water-level declines in the coarse-grained deposits have decreased past the point where hydraulic heads are sufficient to drive groundwater into the fine-grained sediments to the north (their northern Aquifer). On this basis, they show a narrow groundwater divide separating the finer-grained sediments in the north from the coarse-grained sediments in the south (see their Figures 3-8 to 3-14). It seems unlikely, however, that localized sources of recharge could maintain such a narrow divide over the breadth of the Depot.

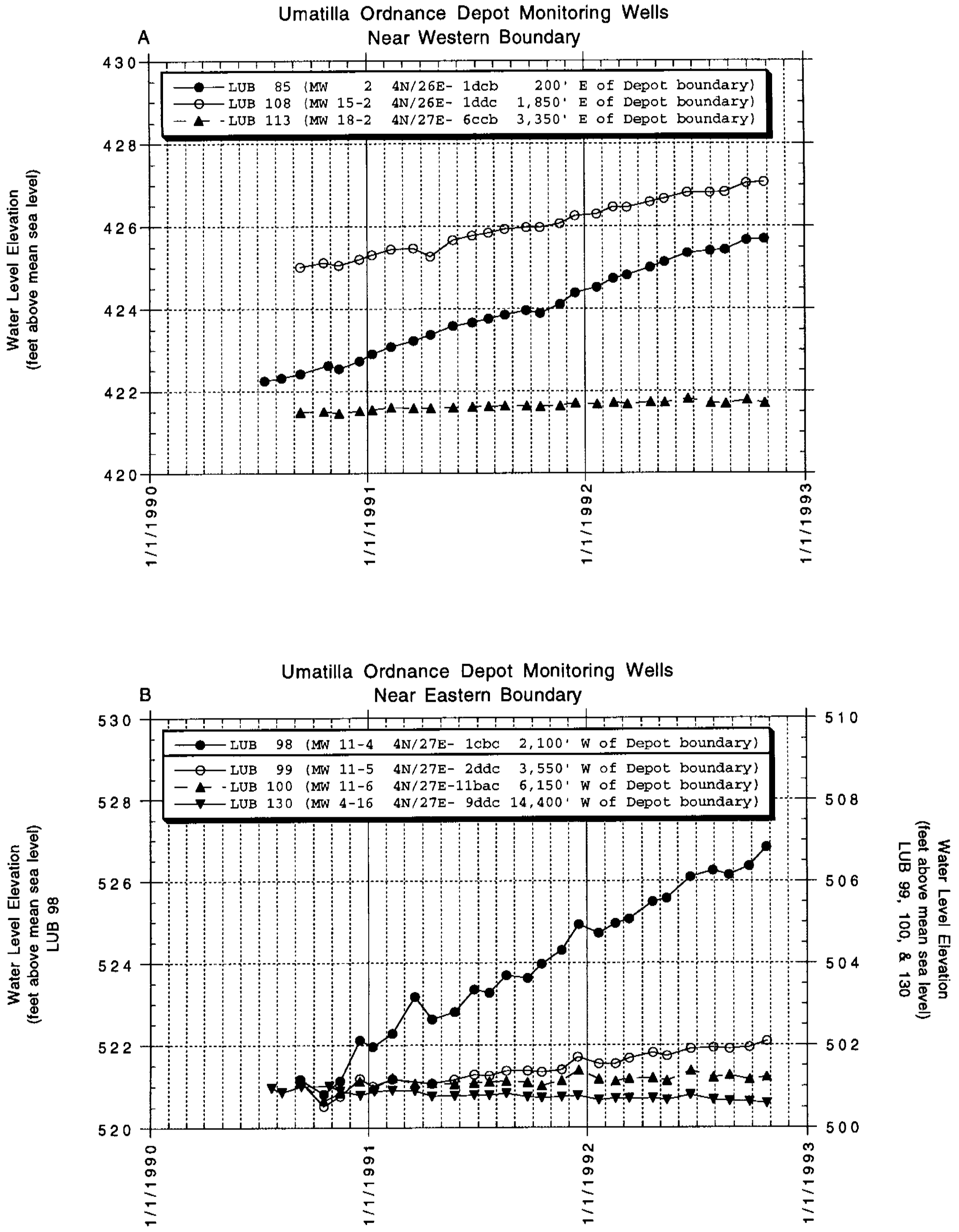


Figure 2.12 Seasonal hydrographs of monitoring wells screened in fine-grained flood deposits on the Umatilla Ordnance Depot. A, Wells near western boundary; B, Wells near eastern boundary

Water levels also indicate that discharge from the gravels to the Umatilla River occurs between Cottonwood Bend and Bridge Road. In this reach, the river penetrates the gravels at elevations coincident with the elevation of the water table (450 to 500 feet). This is consistent with surface water measurements which indicate that this stretch of the river gains water from groundwater discharge (Kreag, 1991). Pumpage discharge that lowers or reverses the hydraulic gradient of the alluvial aquifer toward the river will decrease the rate of discharge to the river. Alternatively, canal leakage will increase the gradient toward the river and increase the rate of discharge to the river.

Contaminant plumes for RDX (Royal Demolition Explosive) and nitrate/nitrite in coarse-grained sediments at the Washout Lagoons area of the Depot (section 15 of 4N/27E) show that contaminants have migrated to the south and southeast from their source at the lagoons (Dames & Moore, 1994b, figures 4-75 to 4-78). This suggests that the net yearly movement of groundwater in that area is to the southeast. This is consistent with discharge to the Umatilla River. Alternatively, most of this contaminant migration may have occurred prior to 1976, when pumping during the irrigation season was not offset by artificial recharge in the winter months.

In summary, flow directions vary seasonally in the coarse-grained flood deposits in the Ordnance area because of a complex interaction between pumpage east and south of the Depot, artificial recharge south of the Depot, and leakage from irrigation canals east and south of the Depot. Some northwesterly flow out of the gravels is likely, but the predominant direction of flow is to the east, with discharge to the Umatilla River.

Hermiston Area

Saturated coarse-grained flood deposits occur in a northeast-trending trough between the city of Hermiston and Hat Rock State Park (highlighted in yellow on Plate 2.4). The trough occupies a shallow syncline (Plate 2.2) which has been modified by erosion during the Missoula floods. Along the central and northern parts of the trough, sands and gravels rest directly on basalt and the saturated thickness is controlled by the elevation of the basalt surface. Along the trough axis, the saturated thickness increases from 40 feet in the east to 100 feet in the west. To the north and east, the saturated zone thins to zero as the surface of the underlying basalt rises gradually above the elevation of the water table. To the south, the saturated zone within the sands and gravels thins abruptly to zero as the contact with underlying fine-grained deposits rises sharply above the elevation of the water table on the terrace south of Hermiston. A similar thinning occurs to the east as the water table drops below the elevation of the contact with fine-grained sediments. In places, the water table intercepts land surface to form shallow ponds and swamps. The most notable examples are in Hermiston between Elm and Jennie Avenues (NW/NE 11-4N/28E) and northeast of Hermiston near the intersection of Diagonal and Locust roads (NW/NE 28-5N/29E). In both localities, land surface elevations are at, or slightly below, 440 feet.

In February 1991, measured groundwater elevations varied between 435 and 445 feet throughout most of the coarse-grained deposits in the Hermiston trough (Plate 2.4). As in the Ordnance area, some of this variation is probably due to uncertainties in land surface elevations at field-located wells. In August 1991, water levels were 1 to 3 feet lower in most wells (Appendix B), presumably in response to irrigation withdrawals during the summer (Plate 2.6). In contrast, August 1991 water levels were 2 to 3 feet higher in wells near the base of the south Hermiston terrace, adjacent to, and downgradient from, the A Line canal (in the northwest portion of 4N/29E and the southwest portion of 5N/29E). High summer groundwater levels in this area are believed to be caused by leakage from the A Line canal and its distributary ditches or, from deep percolation of water from flood-irrigated fields (see the section on groundwater recharge below).

The continuous recorder hydrograph for UMAT 3609 (5N/28E-35ccc) shows a seasonal water-level trend which is believed to be typical for the central part of the Hermiston trough (Figure 2.13). The annual water-level high occurs in winter and the low occurs in late summer. Rising water-levels from September through late winter correlate to decreasing pumpage, increasing rainfall, and decreasing evapotranspiration. Minor water-level rises during the spring and summer months correlate to short episodes of intense rainfall (Figure 2.13).

Local residents report a water table rise of several feet at the beginning of the irrigation season near canals in the northern part of the Hermiston trough. This phenomena was observed by the author in a sump north of Hermiston (NW 25-5N/28E) during several visits in late spring. Measurements in nearby wells were not frequent enough to document similar changes in the subsurface.

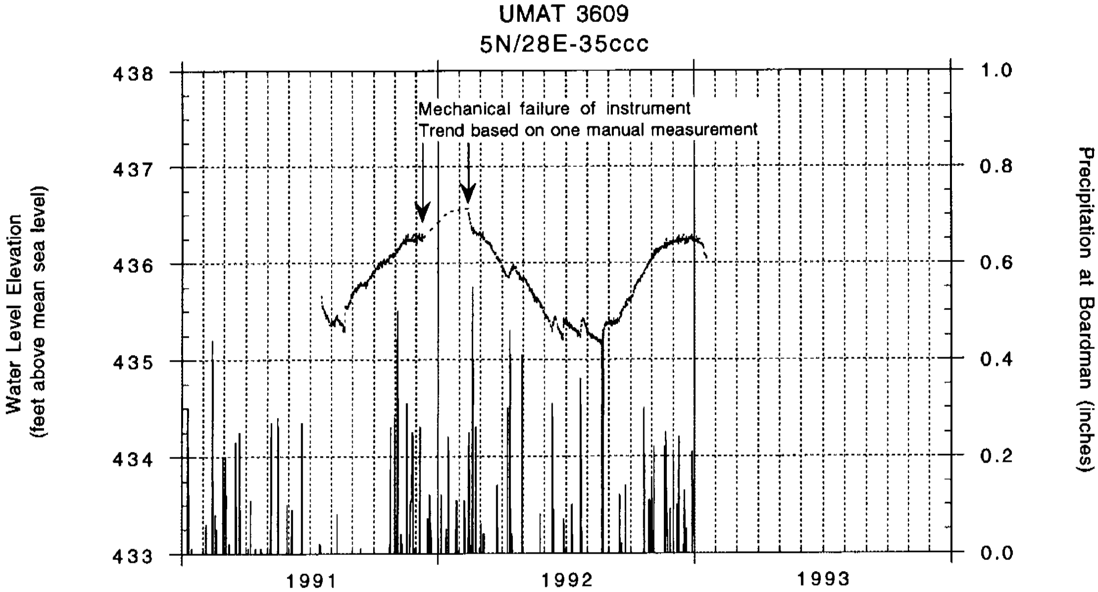


Figure 2.13 Continuous recorder hydrograph for well completed in coarse-grained flood deposits near Hermiston

Because hydraulic gradients are very low and well-head elevations are imprecise, the direction of groundwater flow in the Hermiston trough cannot be directly inferred from the water levels on Plate 2.4. Groundwater flow to the northeast cannot be precluded in the eastern one-third of the trough, an area which is drained to the Columbia River by Cold Springs Wash. Any such flow, however, would be restricted to a very narrow sediment-filled gap in the lower drainage of the wash. Because the land surface and the underlying basalt surface (Plate 2.2) slope gently to the southeast throughout most of the Hermiston trough, the predominant flow direction is inferred to be southwesterly, with discharge to the Umatilla River. Flowpaths in the western part of the trough are restricted to relatively narrow sediment-filled gaps located north and south of Hermiston Butte. Because of the low hydraulic gradients, local or seasonal flow directions may be highly variable, especially in the vicinity of high capacity wells or leaky canals.

Umatilla River Valley

Groundwater in the Umatilla River Valley occurs in undifferentiated catastrophic flood deposits and Holocene Alluvium. Groundwater levels near the river are at, or near, river level. The hydraulic connection between the river and the alluvial aquifer is illustrated by the water-level trends of several monitoring wells completed at the water table near the river (Figure 2.14). Seasonal water-level fluctuations range from 2 to 4 feet and correspond to the stage of the Umatilla River; the highest water levels occur in winter and spring, the lowest levels in summer and autumn. Spikes in June of 1991 correspond to flooding of the Umatilla River several weeks earlier, in late May (EMCON Northwest, 1992).

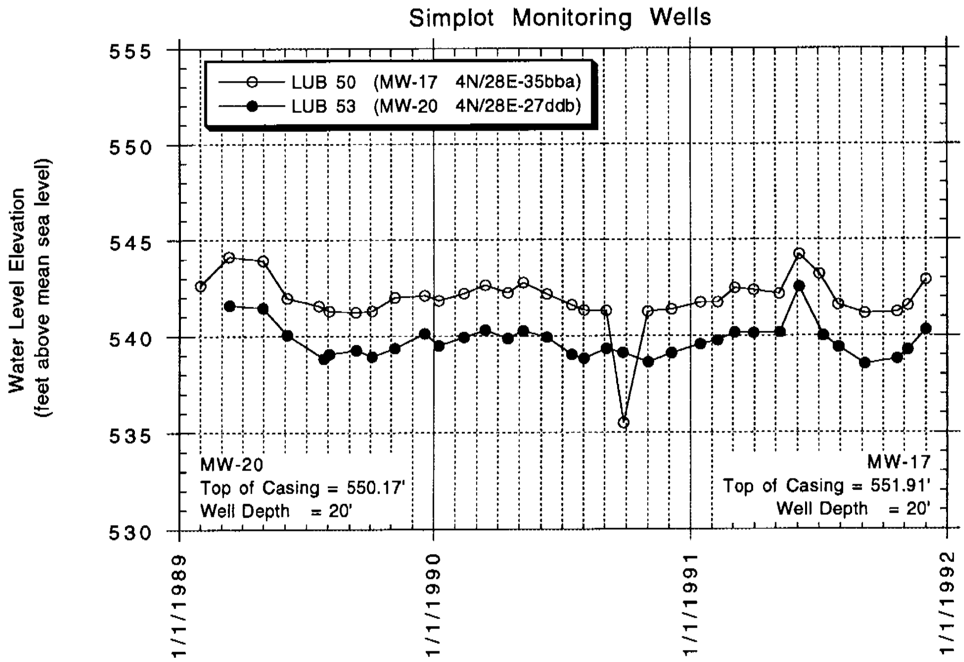


Figure 2.14 Hydrographs of wells completed in shallow unconfined water-bearing zones of the alluvial aquifer in the Umatilla River floodplain

Sixmile Canyon Area

Sixmile Canyon is a narrow gorge which cuts through the Elephant Mountain Basalt between Carty Reservoir and the Columbia River. The canyon contains up to seventy feet of silt, sand, and gravel which rest upon the upper surface of the Pomona Basalt (cross section A-A', Plate 2.3). Saturated thickness within the sediments ranges up to 35 feet. Groundwater flow is to the north with discharge to the Columbia River. The hydraulic gradient averages about 30 feet per mile.

Prior to the filling of Carty Reservoir in 1977, Sixmile Canyon was dry and groundwater was limited to a thin zone at the base of the sediments (Portland General Electric, 1973). The long-term hydrograph for LUB 28 (Figure 2.15A) shows that groundwater levels in the canyon sediments have risen up to 30 feet since the reservoir was filled. Similar rises have occurred in wells completed in the basal Elephant Mountain aquifer in nearby areas (Figure 2.15B). In general, the onset of water-level rise is earlier, and the rate and magnitude of rise is greater, in wells closer to the reservoir. These relationships suggest that the observed rises are caused by leakage from Carty Reservoir and that the affected area has increased over time. Portland General Electric (1992) estimates that reservoir losses to groundwater are about 4000 acre-feet per year. This is equivalent to 10 or 15 percent of the total reservoir capacity.

Rising groundwater levels are also believed to be responsible for the ponds which now occur on the floor of Sixmile Canyon (and its western tributary) in and north of sections 16 and 17 of 3N/24E. The ponds occur in closed depressions, up to 30 feet deep, and were first observed in 1982 (Portland General Electric, 1984; Portland General Electric, 1985). An analysis of air photos and topographic contours (Ella 7.5-minute quadrangle) shows that pond elevations in sections 8 and 17 of 3N/24E were within a few feet of groundwater elevations in LUB 28 (4N/24E-16bdc) in September, 1989.

Although Carty Reservoir is believed to be the main source of recharge water to the alluvial aquifer in Sixmile Canyon, Portland General Electric (1992) presents water quality data that suggests a component of recharge from irrigated lands to the west. Quarterly measurements in LUB 27 (4N/24E-30cda) prior to 1986 indicate that annual water level highs occurred in late winter or early spring and seasonal lows in late summer or early fall. This suggests that seasonal groundwater-level trends in the canyon are not controlled by recharge from irrigation water. Seasonal trends after 1986 are less certain because of a change to semi-annual measurements.

In the areas adjacent to Sixmile Canyon, alluvial groundwater is limited to a thin layer near the top of the Elephant Mountain Basalt. The available data indicates that water levels have not changed notably in these areas since Carty Reservoir was filled.

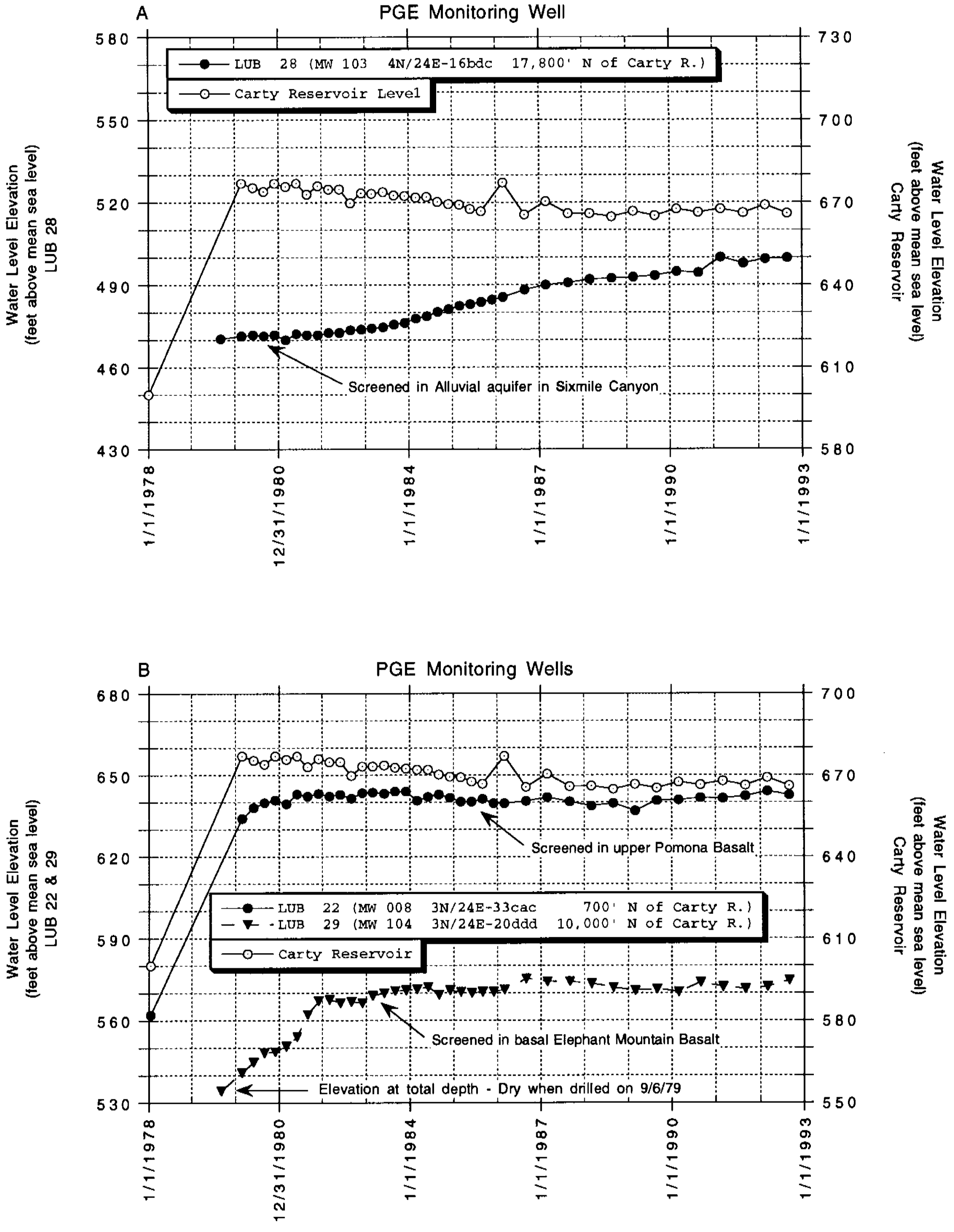


Figure 2.15 Hydrographs of monitoring wells near Sixmile Canyon showing rises in groundwater levels since the filling of Carty Reservoir. A, Alluvial well in Sixmile Canyon; B, Basalt wells west of Sixmile Canyon

Alkali Canyon Formation

The Alkali Canyon Formation is composed of poorly sorted clays, silts, sands, and gravels. The overall permeability of the unit appears to be low and well yields are capable of satisfying domestic needs only. Most of the formation lies above the regional groundwater table but scattered wells indicate the presence of some saturated zones at the base of the unit where it overlies the Columbia River Basalt Group. Beneath Finley Buttes, for example, saturated Alkali Canyon sediments occur several hundred feet below land surface. The saturated thickness ranges up to 40 feet but decreases to zero where local basalt highs rise above the water table (David J. Newton Associates, Inc., 1990).

Breccia/Fracture Zones at the Top of the Columbia River Basalt Group

The upper portions of Columbia River basalt flows are commonly scoriaceous and fractured. The occurrence of these brecciated or fractured zones at the top of the uppermost basalt flow is generally not noted on water well logs but is reported on many monitoring well logs. Reported thicknesses range up to 40 feet. Where overlain by saturated alluvial sediments, the breccia/fracture zones are likely to be hydraulically connected to the sediments, since both are relatively porous and permeable. Conversely, the uppermost breccia/fracture zone is hydraulically isolated from the first underlying basalt aquifer by the dense, relatively impermeable interior of the uppermost basalt flow. On this basis, the uppermost breccia/fracture zone is considered to be part of the alluvial aquifer.

The hydraulic connection between the uppermost breccia/fracture zone and the overlying alluvial sediments is illustrated by the behavior of adjacent monitoring wells completed in these zones at the Umatilla Ordnance Depot (Figure 2.16). One well (LUB 182) is completed exclusively in the uppermost breccia/fracture zone; the second (LUB 165) is screened at the water table in the overlying coarse-grained flood deposits. The hydrographs of both wells are virtually identical, showing the same response to seasonal pumping and recharge stresses that occur in the alluvial aquifer in the Ordnance area. Several pairs of similar wells at the Depot show the same behavior (Dames & Moore, Inc., 1992).

Hydraulic Properties

Table 2.1 shows a summary of hydraulic parameters derived from aquifer tests conducted in water-bearing units of the alluvial aquifer. For comparison, average conductivities from slug tests are also shown for wells on the Umatilla Ordnance Depot. Most of the data was collected from reports on file at the Oregon Water Resources Department. A single aquifer test was conducted in the coarse-grained catastrophic flood deposits during the current investigation; a summary of the test is presented in Appendix 2C.

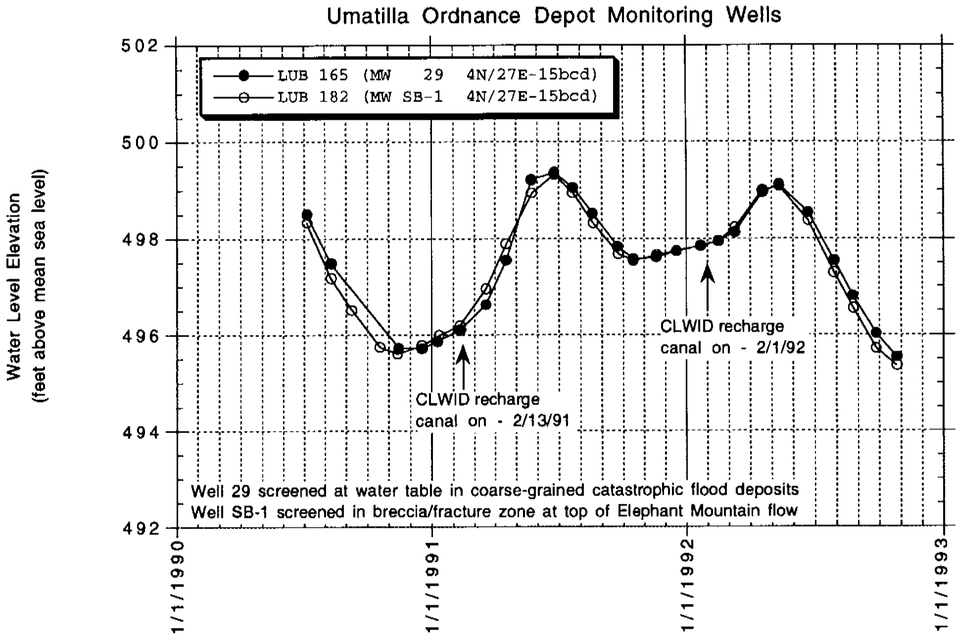


Figure 2.16 Hydrographs of adjacent monitoring wells completed at the water table in coarse-grained flood deposits and in the breccia/fracture zone at the top of the uppermost Columbia River Basalt flow on the Umatilla Ordnance Depot

The data in Table 2.1 show some scatter for hydraulic conductivity values in the alluvial aquifer. This is not unexpected since controlling factors, such as grain size and sorting, are known to vary locally and regionally in the aquifer. Some of the scatter can also be attributed to variations in testing methods and interpretive bias. Although it is beyond the scope of this report to critique the methods and assumptions of each of the tests, a review of the tests indicates that the reported values represent acceptable order-of-magnitude estimates of hydraulic conductivities in the alluvial aquifer.

High well yields and low hydraulic gradients suggest that hydraulic conductivities are high in the coarse-grained flood deposits. The rapid response of wells to artificial recharge and the widespread similarity in well behavior in the Ordnance area also indicate that conductivities are high. Based on these factors, and the data in Table 2.1, hydraulic conductivities for the coarse-grained flood deposits are assumed to be in the range of 1000 to 4000 feet per day. This is consistent with general estimates for clean sands and gravels (Freeze and Cherry, 1979). Storage coefficients for the coarse-grained flood deposits are assumed to range between 0.15 and 0.25.

Table 2.1 Summary of hydraulic parameters for the alluvial aquifer

Unit	Discharge	K gpd/ft*ft	K ft/day	S	Location	Method	Well	Source
Pscfc			2000-5000		Umatilla Ordnance Depot	Aquifer tests		Nick Easterly, Army Corp., personal comm.
Pscfc	>500 gpm	14960	2000	0.2	4N/27E-30	Aquifer test	MORR 683	This report, Appendix C
Pscfc	>500 gpm	9312	1245	0.24	4N/25E-02	Aquifer test	MORR 684	CH2M Hill, 1975
Pscfc	>500 gpm	9267	1239	0.37	5N/26E-27	Aquifer test	MORR 1250	CH2M Hill, 1975
Pscfc	>500 gpm	5131	686	0.21	5N/26E-31	Aquifer test	MORR 1252	CH2M Hill, 1975
Pscfc	<100 gpm	3067 - 13,389	410 - 1790		4N/27E-15bcd	Aquifer test	LUB 124	Dames and Moore, 1994b
Pscfc	<100 gpm	30,765 - 50,490	4113 - 6750		4N/27E-15bcd	Aquifer test	LUB 132	Dames and Moore, 1994b
Pscfc	<100 gpm	7802 - 29,351	1043 - 3924		4N/27E-15cab	Aquifer test	LUB 127	Dames and Moore, 1994b
Pscfc		4376	585		Umatilla Ordnance Depot	Average of multiple slug tests		Dames and Moore, 1994b
Pscff	>500 gpm	667	89 - 178	2.5 E-04	4N/29E-17	Aquifer tests	UMAT 2866	WRD files
Pscff		202	27		Umatilla Ordnance Depot	Average of multiple slug tests		Dames and Moore, 1994b

Pscfc: Coarse-grained catastrophic flood deposits
Pscff: Fine-grained catastrophic flood deposits

Little data is available on the hydraulic parameters of the fine-grained flood deposits. Steep hydraulic gradients and low yields suggest that hydraulic conductivities are low. Two aquifer tests have been conducted for UMAT 2866 (4N/29E-17), which produces from a 20 foot sand encased in "clay". Values from these tests suggest that hydraulic conductivities for the sand beds in the fine-grained deposits may range between 50 and 200 feet per day. Gravel beds are likely to have higher conductivities. Slug tests in fine-grained deposits on the Umatilla Ordnance Depot suggest that conductivities for flood silts and silty sands are less than 50 feet per day. General estimates for the hydraulic conductivities of silts and silty sands range from .001 to 10 feet per day (Freeze and Cherry, 1979).

Hydraulic properties of Holocene sediments are unknown but are expected to be similar to those of the catastrophic flood deposits because of the similarity in the sediments of the two deposits. Hydraulic properties of the Alkali Canyon Formation are also expected to be similar to those of the fine-grained flood deposits.

Recharge

Recharge to groundwater systems occurs when water infiltrates the land surface and percolates through soils and unsaturated materials to reach the water table. Potential sources of recharge include precipitation, canal leakage, stream leakage, reservoir leakage, and deep percolation of applied irrigation water.

Although a comprehensive accounting of recharge is beyond the scope of this project, rough estimates of recharge magnitude can be made for the major sources of potential recharge in the basin. These estimates are subject to large uncertainties and are presented solely to provide a sense of the relative magnitude of recharge from each source.

Soils in the Lower Umatilla Basin are typically sandy loams with moderate to high permeabilities (Johnson and Makinson, 1988). In many areas, these soils overlie coarse sands and gravels which are highly permeable. These conditions promote the rapid downward movement of any excess water that occurs at land surface. An example of rapid seepage in sandy soil was observed by the author in an area south of the Umatilla Ordnance Depot (SE/SE 30-4N/28E) when a one-mile length of 16-inch pipe was drained for repair in late March 1992. About 17,500 gallons of water was discharged from the pipe to a depression on the surface over a period of 1.5 hours (195 gallons per minute). After about 15 minutes of discharge, water began to accumulate in a shallow pond which grew to a maximum area of about 50 by 50 feet. Twenty minutes after discharge ended, all of the water in the pond had infiltrated the ground. This rapid infiltration of water is consistent with the known properties of the soils of the basin.

As will be shown below, the timing of water-level rises in wells near recharge sources indicates that recharge water can travel from the land surface to the water table in a period of time ranging from several days to several months.

From Precipitation

Average precipitation in the study area ranges from about 8.0 inches per year near the Columbia River to 10.0 inches per year at the southern boundary (Johnsgard, 1963). Much of this precipitation is lost to evaporation and uptake by plants (evapotranspiration). When precipitation exceeds evapotranspiration some of the surplus moisture is lost as runoff and some is used to recharge soil moisture. The remainder is available as groundwater recharge.

A rough estimate of potential recharge from precipitation can be made by calculating an average monthly water balance. At Hermiston, for example, Johnsgaard (1963) estimates that evapotranspiration exceeds precipitation except for the months of November through February; for these months, the average moisture surplus totals 3.4 inches, about 40 percent of the average annual precipitation. This is the maximum potential recharge. Actual recharge will be lower because of losses to runoff and soil moisture buildup. This analysis suggests that most precipitation recharge occurs in the winter months and that the average long-term recharge from precipitation is less than 3 inches per year.

Using a model developed by the U.S. Geological Survey, Davies-Smith and others (1988) estimate that long-term recharge from precipitation is less than 0.2 inches per year in the area covered by the present study. This suggests that 2 inches per year would be a liberal estimate of precipitation recharge.

The behavior of wells completed in the fine-grained flood sediments on the northern part of the Depot also suggests that 2 inches per year is a liberal estimate for recharge from precipitation. As discussed above, water levels in these wells show rises of up to 3 feet per year but, little or no seasonal fluctuations (Figure 2.12). Rises are greatest near the eastern and western boundaries of the Depot and decrease toward the interior. This is consistent with inflow from the east and west. Since precipitation is likely to be uniform across the Depot, the variation in water-level rises cannot be attributed to precipitation recharge. On the other hand, wells near the center of the Depot are the most likely candidates to exhibit the effects of precipitation recharge because they are remote from other potential recharge sources. The best candidates are shown in Figure 2.17. Of these, LUB 88 shows no annual change and LUB 87 shows an annual rise of about 0.25 feet. Month to month trends are similar in both wells and show no obvious correlation to monthly precipitation trends at Boardman. In both wells, minor water-level rises of less than 0.5 feet occur in December or January of some years. This is equivalent to 1.2 inches of precipitation recharge, assuming an aquifer porosity of 20%.

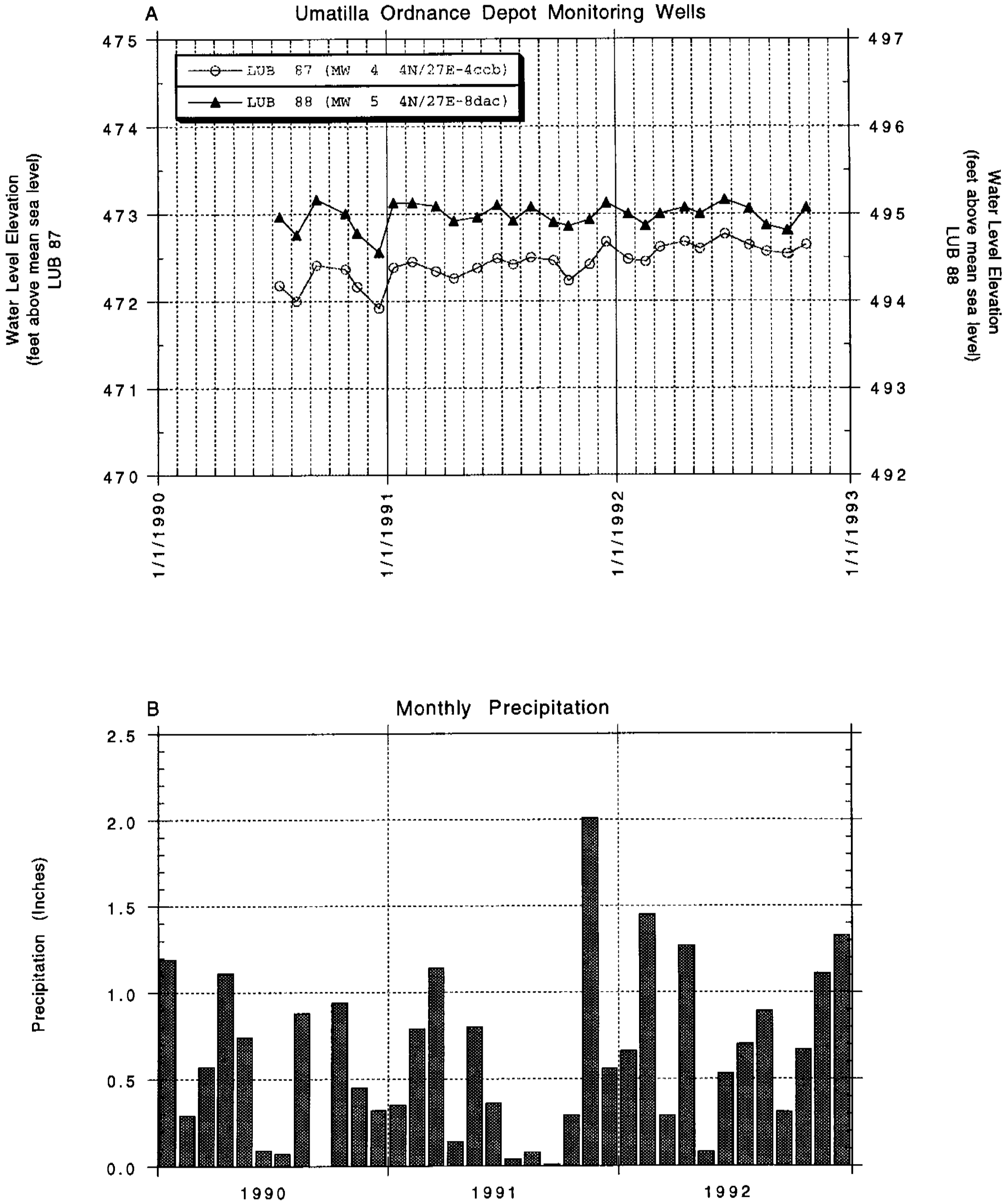


Figure 2.17 Comparison of water-level trends and precipitation in the interior of the Umatilla Ordnance Depot. A, Hydrographs of wells screened in fine-grained flood deposits; B, Monthly precipitation at Boardman

For comparative purposes, it is assumed that the average yearly recharge from precipitation falls within the range of 0.2 to 2 inches per year. This is the equivalent of 400 to 4000 acre-feet of recharge per township per year.

A conventional analysis suggests that precipitation recharge is unlikely outside of the winter months. However, as discussed above, the recorder hydrograph for UMAT 3609 (Figure 2.13) suggests that some precipitation recharge may occur during the spring and summer months. At this well, minor water-level rises in the spring and summer generally occur within two days following rainfalls of 0.3 inches or more. If these rises are caused by precipitation recharge, they indicate rapid rates of infiltration. If the surrounding soils are already near 100% saturation because of irrigation, 0.3 inches of rainfall may be sufficient to drive water downward to the water table.

From Canal Leakage

Approximately 130 miles of primary canals, and an unknown length of secondary canals and ditches, convey water for four irrigation districts in the basin (Plate 2.1). Most of the canals are unlined or have older linings which are reported to be in poor repair. In most areas, the canals traverse well-drained soils which are classified as fine loamy sand with moderate or "rapid" permeabilities (Johnson and Makinson, 1988). Although canal losses are known to be significant, no comprehensive study of losses has been conducted.

The Bureau of Reclamation estimates overall system losses of about 30% for the West Extension District, the only district with a lined major canal (LeAnn Ray, West Extension Irrigation District Manager, personal communication). Losses for the Stanfield and Westlands irrigation districts may be as high as 65% and losses for the Hermiston district may be even higher (Bill Porfily, former manager of Stanfield, Westlands, and Hermiston irrigation districts, personal communication) . These figures include all losses from the headgates to irrigated fields and do not differentiate between canal seepage, evaporation, and deep percolation of applied irrigation water.

The potential for canal leakage is illustrated by the artificial recharge project of the County Line Water Improvement District. The project was constructed in the early 1970s to recharge the alluvial aquifer in the Lost Lake area. The recharge project consists of an unlined canal which is about 2.5 miles long and 20 feet wide (Plates 2.1 and 2.4). A broad area at the western end of the canal is sometimes used as an overflow area and infiltration pond. Water is delivered to the southern end of the recharge canal by a pipeline which diverts water from the Westland High Line Canal near its terminus at Lost Lake. Annual water deliveries to the recharge canal have averaged about 5200 acre-feet per water year through 1993 (WRD files). Evaporation losses are believed to be relatively low because most of the water is delivered in the winter months. Assuming that most of the infiltration occurs through the floor of the canal, the infiltration rate is about 2000 acre-feet per canal mile per year. Assuming an average operating period of 150 days, this is equivalent to about 13 acre-feet per canal mile per day. These estimates are probably high since an unknown amount of water percolates through the infiltration pond at the western end of the canal. As noted above, nearby wells respond to recharge within several days of the filling of the canal. This is consistent with a rapid rate of infiltration.

Evidence for canal leakage can be seen on the hydrographs of various wells in the basin. The best examples are from shallow monitoring wells screened at the water table in the northern part of the Butter Creek floodplain. In this area, the floodplain is bordered and crossed by several canals of the Westland Irrigation District. Hunt Ditch, the southernmost canal, crosses the floodplain in section 8 of 3N/28E, about 2.5 miles south of Interstate 84. Figure 2.18A shows hydrographs for typical monitoring wells located north of the Hunt Ditch crossing. In these wells, water levels rise in the spring, peak in the summer, and fall to annual lows in the winter. Annual fluctuations of 10 to 15 feet across the floodplain suggest a high volume of recharge in the spring and early summer. These patterns do not correlate to precipitation (see Figure 2.17B) or to flow in Butter Creek, which is typically depleted by diversions beginning in May. In wells south of the Hunt Ditch crossing (Figure 2.18B), water-level highs occur earlier in the year, seasonal fluctuations are on the order of 5 feet, and the water table is above the elevation of the ditch (about 615 feet). Since irrigation practices and stream flow do not vary significantly north and south of Hunt Ditch, most of the annual water-level rise in the northern wells can be attributed to seepage losses from Hunt Ditch, the High Line Canal, and the A Canal. Water-level rises in January, February, and March may correspond to seepage loss from Butter Creek or to deep percolation of potato-processing plant effluent water prior to the irrigation season.

The Westland Irrigation District has long suspected substantial losses along a section of the A canal near Cottonwood Bend (Miller, 1985). In this area soils are thin and Pleistocene flood gravels are exposed at or near the surface. Measurements during the summer of 1994 indicate a loss of 7.5 cfs out of a total flow of 50 cfs over a 4 mile section (Carol Bradford, Westland Irrigation District manager, personal communication, 1995). This translates to a loss of 3.7 acre-feet per mile per day or about 550 acre-feet per mile per year, assuming a 150 day operating season.

Comparison values are available for the Umatilla Project Feed Canal. The Feed Canal diverts water from the Umatilla River near Echo and delivers it to Cold Springs Reservoir during the months of November through May. The canal is 24.5 miles long, has no secondary diversions, is unlined, and is gauged at both ends. The average diversion at Echo over 65 years of record is 69,810 acre-feet per water year (Oregon Water Resources Dept., 1988). Gauge readings for the period of December 6, 1993 to March 23, 1994 (107 days), indicate a transmission loss of approximately 13.25% (Pendleton Watermaster Office). This is equivalent to an average loss of about 9250 acre-feet per year or 380 acre-feet per mile per year. Since the canal operates mainly during the winter months, evaporation losses are considered to be small. Assuming that the canal operates for 150 days, seepage losses are about 2.5 acre-feet per mile per day. Similar canals operating in the summer would probably have somewhat higher evaporation losses and lower seepage losses.

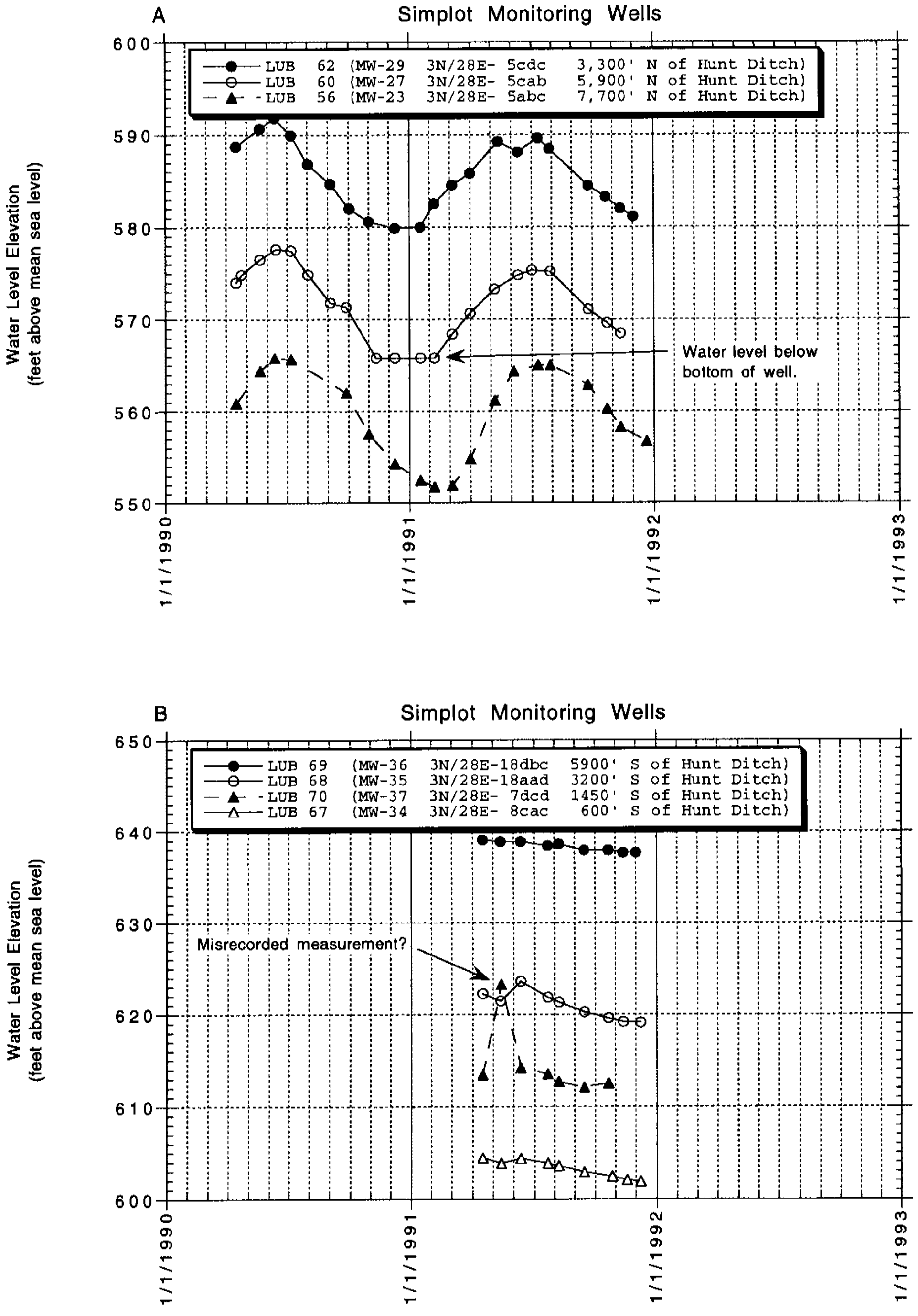


Figure 2.18 Hydrographs of monitoring wells screened in Holocene Alluvium in the Butter Creek floodplain. A, Wells north of Hunt Ditch; B, Wells south of Hunt Ditch

Soil conditions along the Feed Canal are typical for the main delivery canals in the basin. On this basis, seepage rates for the Feed Canal are assumed to be representative for other major canals. Seepage rates for the Westland A canal in the Cottonwood Bend area are assumed to represent an upper limit for losses from typical canals. These assumptions ignore other factors which influence seepage rates, such as canal width and depth and variations in soil permeabilities, but are considered to be reasonable as a first-order approximation of canal losses.

Estimates of yearly canal losses for the main delivery canals in the basin are shown in Table 2.2 The estimates assume a seepage rate of 2.0 acre-feet per mile per day, a rate slightly lower than that of the Feed Canal. The estimates also assume a five-month operating season. This equates to a loss of 300 acre-feet per mile per year. By this account, losses for the four districts total about 40,000 acre-feet per year. Of the total area downslope (downgradient) of canals in these districts, approximately 190 square miles (5.3 townships) are underlain by the alluvial aquifer. This equates to a canal recharge of about 7500 acre-feet per township in the affected areas, the equivalent of about 4 inches of rainfall per year

Table 2.2 Estimates of yearly canal losses for main delivery canals.

Irrigation District	Canal	Avg Yrly Diversion * (acre-ft)	Length** (miles)	Estimated Loss (acre-ft/yr)
Hermiston	U S Feed	69,810	25.0	7500
	A Line	50,000	10.0	3000
	Maxwell	18,680	10.0	3000
Stanfield	Furnish	36,550	30.0	9000
Westland	Westland	63,340	20.0	6000
	A***		8.0	2400
West Extension	West Extension	62,360	27.0	8100
Totals		300,740	130	39,000

* Oregon Department of Water Resources, 1988
** Based on digitized lengths from 1:100,000 scale maps
*** Excludes recently lined sections

As noted above, these estimates do not include an analysis of factors that would cause seepage to vary from place to place. They also ignore losses from lateral canals, ditches, and drains. If we assume that all errors have been on the liberal side for seepage, 150 acre-feet per mile per year (4000 acre-feet per township or 2 inches of rainfall per year) represents a conservative lower limit on canal losses. This is equivalent to a liberal estimate of annual recharge from rainfall. More than likely, recharge from precipitation is lower and recharge from canal seepage is higher.

For comparative purposes, canal losses have been shown in terms of acre-feet per township. All else being equal, however, the effective recharge from canals will vary from place to place because of variations in canal density. In addition, portions of some canals lie within a short distance of the Umatilla River. In these areas, canal losses may only affect a small portion of the aquifer before the water is discharged to the river. A qualitative impression of the canal impacts on the groundwater system can be gained by noting the distribution of canals on Plate 2.4.

Projects which reduce or eliminate canal seepage will impact groundwater recharge. For example, in order to maintain higher flows in the Umatilla River, the Bureau of Reclamation plans to decrease diversions to the Feed Canal and the Furnish Ditch (Phase II of the Columbia Basin Project). Replacement water will be pumped via pipeline from the McNary Pool on the Columbia River to the newly constructed Columbia-Cold Springs Canal. The canal, which is lined, will deliver water to Cold Springs Reservoir and to the lower section of the Furnish Ditch. This may decrease seepage recharge to the alluvial aquifer by up to 10,000 acre-feet per year.

Several irrigation districts are actively seeking funds to reduce seepage losses. The Westland District has already lined several miles of the A canal and replaced the F canal with pressurized pipes. These modifications were made in the late 1980s and may be partly responsible for water-level declines which have occurred since 1986 in the coarse-grained flood deposits of the Ordnance area. Additional conservation measures are likely to be implemented by all of the districts in the future. If discharge remains at historic levels, the overall effect of these conservation measures will be to decrease the amount of groundwater in storage. Conservation measures in the West Extension District are expected to have the least impact because losses are relatively low to begin with and, because the saturated thickness of the aquifer in the area is largely controlled by the elevation of the John Day pool of the Columbia River.

From Stream Leakage

A comparison of stream elevations (7.5-minute topographic maps), water levels in wells, and water table elevations (Plate 2.4) indicates that stream elevations are up to 20 feet higher than adjacent water table elevations in the lower Butter Creek valley north of sections 17 and 18 of 3N/28E and, in the Umatilla River valley between sections 19 and 30 of 4N/28E (Cottonwood Bend) and section 35 of 4N/28E. These relationships indicate that Butter Creek and the Umatilla River lose water to the underlying alluvial aquifer along these reaches. The rate of downward flow cannot be determined on the basis of the available data.

Although several reports infer that the uppermost water-bearing zones in these stream reaches are perched above the water table of the alluvial aquifer, no data is provided to document an underlying unsaturated zone (Sweet, Edwards & Associates, 1987; EMCON Northwest, Inc.). If no unsaturated zone is present, pumpage from nearby alluvial wells may increase the hydraulic gradient between the streams and the aquifer. This will increase the rate of stream leakage and decrease flow in the streams.

From Reservoir Leakage

Cold Springs and Carty reservoirs are the main water-storage facilities in the Lower Umatilla Basin. Cold Springs is located about six miles east of Hermiston and is operated by the Bureau of Reclamation. Carty Reservoir is operated by Portland General Electric (PGE) at its Boardman coal-fired generating plant site, about 12 miles southwest of Boardman. Although Carty Reservoir is west of the main productive part of the alluvial aquifer, leakage is well documented and the reservoir illustrates the potential, as well as the mechanisms, for leakage.

Carty Reservoir provides cooling water for the Boardman Coal-Fired Plant and receives some plant effluent discharge. The reservoir lies behind the escarpment formed by the southern terminus of the Elephant Mountain flow and fills a swale which was probably created by the Missoula floods. The reservoir dam is constructed across the head of Sixmile Canyon at the edge of the escarpment (Plate 2.2 and cross section A-A', Plate 2.3). Reservoir capacity ranges from 26,000 acre-feet at low pool elevation (667 feet) to 38,300 acre-feet at high pool elevation (677 feet). Maximum reservoir depth ranges from 67 to 77 feet. Water to fill and maintain the reservoir is pumped via pipeline from the Columbia River at the mouth of Willow Creek. Prior to the filling of Carty Reservoir in 1977, Sixmile Canyon was dry and groundwater occurred only at the base of the sediments in the canyon (Portland General Electric, 1973). The long-term hydrograph for LUB 28 (Figure 2.15A) shows that groundwater levels in the canyon have risen progressively since the reservoir was filled. Similar rises have occurred in confined aquifers at the base of the Elephant Mountain Basalt and the top of the Pomona Basalt (Figure 2.15B). Portland General Electric (1992) estimates that reservoir losses to groundwater total about 4000 acre-feet per year (11 acre-feet per day), the equivalent of 10 to 15 percent of the total reservoir capacity. The proportion of losses to the sediments versus the basalt flows is unknown.

Seepage to the sediments in Sixmile Canyon may occur beneath the toe of Carty dam or beneath wing dams on the east and west sides of the reservoir. Indirect seepage to the sediments probably occurs through breccia/fracture zones at the base of the Elephant Mountain and the top of the Pomona basalts. These zones, exposed in the floor of the reservoir and beneath sediments in the reservoir and Sixmile Canyon, provide a conduit for transporting groundwater from the reservoir to the alluvial aquifer in Sixmile Canyon (cross section A-A', Plate 2.3). The rapid rise in water levels in the basal part of the Elephant Mountain flow and the upper upper part of the Pomona flow after the filling of Carty Reservoir suggests that these zones are relatively permeable.

Leakage is also documented at Cold Springs Reservoir. Cold Springs was constructed in 1908 to store Umatilla River water for the Hermiston Irrigation District. River water is delivered to the reservoir via the Feed Canal during winter and spring and released through the A Line Canal during the irrigation season. Reservoir capacity is about 50,000 acre-feet and pool elevation varies from about 570 to 623 feet. The minimum pool level occurs at the end of the irrigation season and the maximum level occurs in late spring.

Cold Springs dam is an earthfill embankment constructed across a narrow gorge in Cold Springs Wash near the southern margin of the Pomona Basalt (Plate 2.2 and cross section E-E', Plate 2.3). An adjoining wingdam extends south to the Feed Canal, a distance of about 2000 feet. The northern part of the dam in Cold Springs Wash abuts against the Pomona Basalt, which forms the northern barrier for the reservoir. Along the northern shore, the surface of the basalt lies above elevations of 600 feet except in an erosional saddle on the northwest shore. The Pomona basalt also occurs along the southern dam abutment up to elevations of about 580 feet, just above the outlet level for the A Line Canal. South of Cold Springs Wash, the surface of the Pomona Basalt dips to the south and alluvial sediments form the southwestern bank of the reservoir. At the damsite, Cold Springs Wash cuts through about 100 feet of the Pomona Basalt. About 40 feet of alluvial sediments overlie the basalt in the wash at the base of the dam. The water table in these sediments occurs within several feet of land surface. When the dam was built, the sedimentary fill was removed and the underlying basalt was trenched and filled with a small concrete berm to prevent seepage through the sediments at the base of the wash (Acree, 1988).

Seeps are common along the southern dam abutment and have been reported since the reservoir was first filled (Acree, 1988). Some of these seeps occur in Cold Springs Wash at the southern toe of the dam. Others occur above the A Line Canal at the contact between the Pomona Basalt and the overlying alluvial sediments. About 3500 feet downstream from the dam, a spring occurs in the floor of the wash. The owner of the spring reports (Acree, 1988) that flow is constant throughout the year at a rate of 1000 gallons per minute (4.4 acre-feet per day) but this has not been confirmed by independent measurements.

Piezometers installed by the Bureau of Reclamation (Acree, 1988) indicate that seepage from the reservoir occurs through the alluvial sediments which underlie the southern wing dam but not through the dam itself. Seepage also occurs through breccia/fracture zones at the top of the basalt. Figure 2.19 shows hydraulic heads for a representative pair of piezometers installed in the alluvial sediments and the upper basalt surface beneath the southern wing dam. The piezometers are nested at a single well site. As seen in the figure, a substantial mound of groundwater builds up in the aquifer as the reservoir fills. Nearby piezometers indicate a maximum rise of 20 feet. A vertical component of hydraulic gradient is indicated by lower hydraulic heads at depth. This is consistent with recharge from the reservoir.

The rate of seepage loss from Cold Springs Reservoir to the alluvial aquifer cannot be calculated from the available data. Several years of gauge records document the inflow and outflow of water through canals but a complete water budget would require an analysis of evaporation losses and knowledge of inflow from Despain Gulch and Cold Springs Canyon.

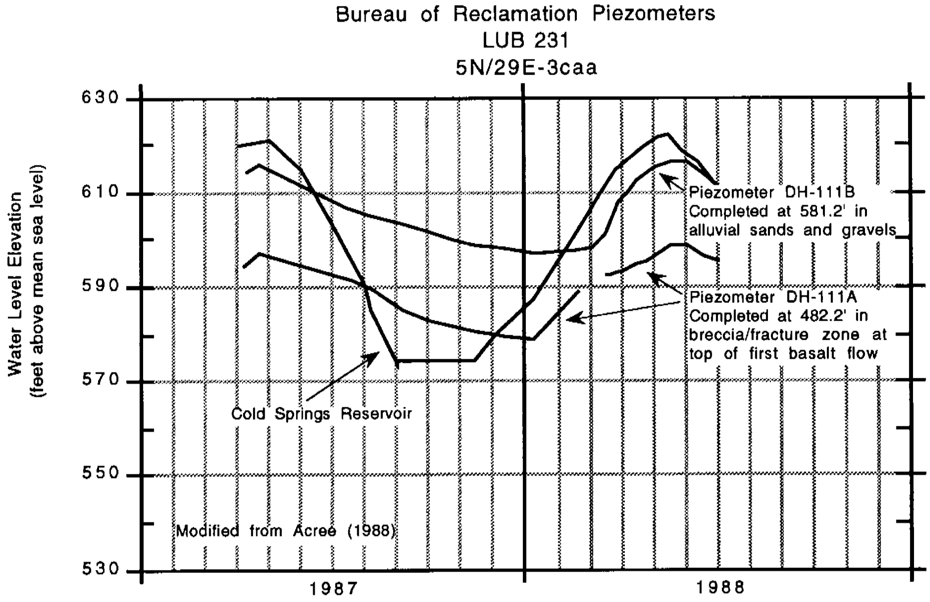


Figure 2.19 Hydrographs of paired piezometers completed near the water table in the alluvial aquifer and in the breccia/fracture zone at the top of the uppermost Columbia River Basalt flow near Cold Springs Dam.

Seepage at Cold Springs Reservoir is controlled by the geometry of the Columbia River Basalt flows. Only minor seepage occurs along the north abutment of the dam (Acree, 1988) which sits directly on the basalt surface in Cold Springs Wash. In addition, piezometers completed in basalt at the base of the dam show little response to changing reservoir levels. These factors suggest that the interior of the Pomona flow is relatively impermeable to the flow of water. Seepage is possible under the southern wing dam because permeable alluvial sediments occur beneath the dam south of Cold Springs Wash (Plate 2.2). The basal elevation of the sediments is controlled by the "topography" of the underlying basalt surface which forms a northeast-trending trough centered about 0.6 miles south of Cold Springs Wash. At the outlet for the A Line Canal, the base of the sediments occurs at an elevation of about 580 feet, 43 feet below the maximum reservoir level. One-quarter mile to the southwest, the base of the sediments drops to an elevation of about 490 feet, 133 feet below the maximum reservoir level. The base remains near this level for another one-half mile to the southeast where the basalt surface begins to rise gradually to the southeast. Throughout this area, the silts, sands, and gravels which overlie the basalt provide a conduit for the flow of water from the reservoir to the alluvial aquifer.

A similar geometry occurs along the northwestern shore of Cold Springs Reservoir where a saddle in the basalt surface drops the base of the alluvial sediments to slightly below 600 feet elevation. Above this elevation, the sediments form the northern bank of the reservoir. These sediments, and the upper brecciated surface of the Pomona flow, form a potential northwesterly pathway for the seepage of water from Cold Springs when the reservoir level rises above 600 feet elevation. No well data is available to confirm seepage along this pathway.

Another potential pathway for seepage from Cold Springs Reservoir is through breccia/fracture zones at the contact between the Pomona Basalt and the underlying Umatilla Basalt. These zones are exposed at the southern margin of the Pomona flow which appears to occur beneath a cover of alluvial sediments in the reservoir (Plate 2.2 and cross section E-E', Plate 2.3). The geometry between the reservoir and the southern margin of the Pomona flow is analogous to that between Carty Reservoir and the southern margin of the Elephant Mountain flow. Although well data is not available to confirm seepage along this pathway, the analogy with Carty Reservoir suggests that seepage is likely to occur.

From Deep Percolation of Irrigation Water

Deep percolation occurs when irrigation water infiltrates beyond the root zone and becomes available for groundwater recharge. The potential for deep percolation exists wherever irrigation water is being applied to the land surface. The occurrence of deep percolation is controlled by factors such as soil permeability, soil moisture content, depth of the root zone, and the rate and timing of water application.

All other factors being equal, the potential for deep percolation is related to the rate at which water is applied to the land surface. Application rates are controlled by the method of irrigation and by the water management strategies of individual irrigators. Within the study area, irrigation methods include the flooding of fields, the use of various sprinkler systems (hand lines, wheel lines, and center pivots), and the use of drip irrigation systems. The relative potential for deep percolation is high for flood irrigation, less for sprinkler irrigation, and very low for drip irrigation.

A survey of irrigation districts indicates that flood-irrigated lands total about 10% of the Stanfield and Westland districts, about 40% of the West Extension district, and as much as 50% of the Hermiston district (Bill Porfily, Carol Bradford, LeAnn Ray, former and current district managers, personal communications). The remaining lands are irrigated by sprinkler systems. Center pivots are common on large plots in the districts and are the dominant sprinkler system used outside of the districts.

Areas of potential deep percolation correspond to irrigated lands which overlie the alluvial aquifer. According to files at the Oregon Water Resources Department, approximately 188,000 acres of irrigated lands are listed on valid water rights in the study area (Plate 2.6). This corresponds reasonably well to an estimate by DEQ (this report) of 180,000 acres of irrigated land based on 1992 LANDSAT photos. Current information is not sufficient to calculate the total contribution of deep percolation to recharge of the alluvial aquifer. However, based on irrigation methods, the relative potential is considered highest within the Hermiston and West Extension irrigation districts, lower in the other districts, and lowest outside of the districts.

Evidence for deep percolation of irrigation water is seen in various places around the basin. Examples are discussed below.

Deep percolation is probably the major source of recharge in the area around the northeast corner of the Umatilla Ordnance Depot. In that area, groundwater occurs in predominantly fine-grained flood deposits dominated by silt and clay, with minor interbeds of sand. Unconfined groundwater occurs in shallow water-bearing zones and confined groundwater occurs in deeper water-bearing zones. Local recharge is indicated by the presence of a groundwater mound (Plate 2.4). A comparison of adjacent wells completed in shallow and deep water-bearing zones shows that water-levels are higher in the shallow zones (Figure 2.20). This indicates a downward component of hydraulic gradient consistent with local recharge. The similarity in the trend and magnitude of water-level changes in these wells suggests that they are responding to the same stresses. Large-capacity pumping wells are not located in the area (Plate 2.6) and the hydrographs do not show any pumping influences. This suggests that recharge is the principal factor controlling water levels in both zones. The rapid increase in water levels in both wells in late February of 1991 suggests that recharge water moves downward relatively rapidly in spite of the predominantly fine-grained nature of the sediments.

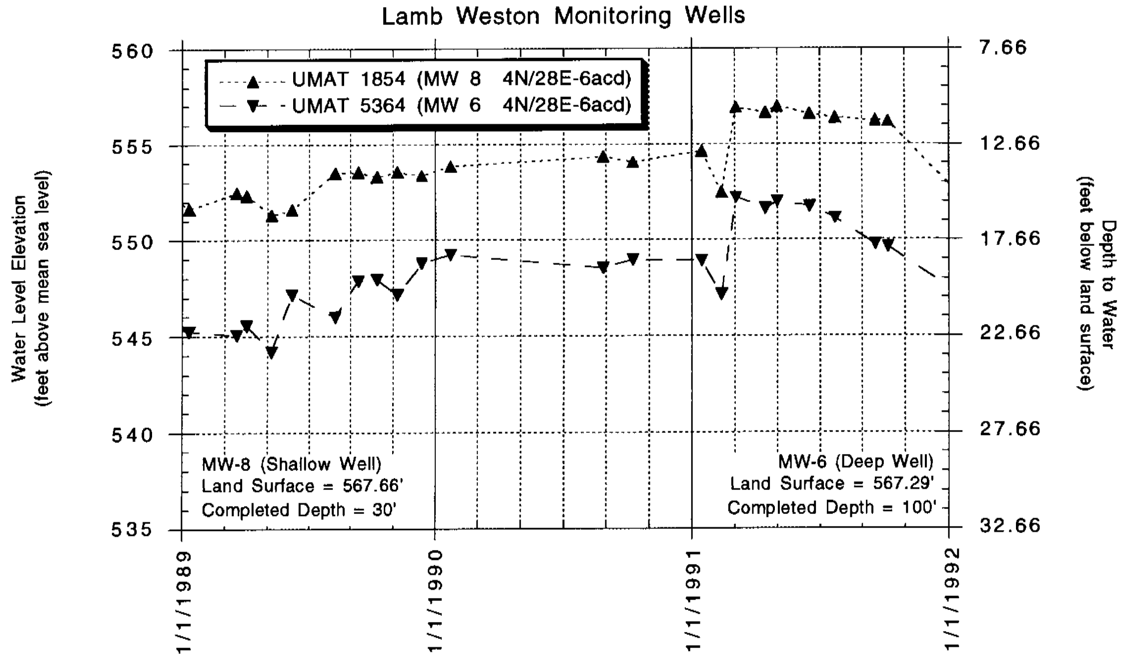


Figure 2.20 Hydrographs of adjacent wells completed in shallow unconfined and deeper confined water-bearing zones within fine-grained catastrophic flood deposits northeast of the Umatilla Ordnance Depot

Potential recharge sources near the northeastern boundary of the Depot include precipitation, leakage from the Westland A Canal, leakage from an unlined pond in the southeast corner of section 1 of 4N/27E, and deep percolation of irrigation water. As discussed above, hydrographs in the northeastern corner of the Depot (Figure 2.12B) show annual water-level rises that decrease with distance from the eastern boundary of the Depot. This indicates that recharge rates are higher to the east. Since precipitation is likely to be uniform across the area, it can be eliminated as a major recharge source for the mound. Although the Westland A Canal flows through the area on the eastern side of the mound, the elevation of the canal (about 558 feet) is at least 20 feet lower than the highest part of the mound. In addition, this section of the canal is an unlikely recharge source because it was lined in the late 1980s when highway I-82 was built. The pond in the southeast corner of section 1 of 4N/27E lies at an elevation of approximately 600 feet, about 20 feet above the highest part of the mound, but is located about one-half mile south of the center of the mound. At less than 4 acres in size, the pond seems an unlikely source for such widespread recharge effects. This suggests that deep percolation of irrigation water is the principal source of recharge over the mound. Lands immediately overlying the center of the mound have been used for the year-round disposal of waste water (through irrigation sprinklers) from a local food-processing plant since 1972. The applied acreage has increase from about 320 acres in 1972 to about 800 acres at present. Records at DEQ (DEQ Water Quality File 48780) indicate that, until recently, water was applied to these fields at rates greater than needed for crop cultivation. In addition, much of the water was applied in the winter months when evapotranspiration was minimal. These conditions, which are highly favorable for deep percolation, suggest that much of the recharge for the groundwater mound has come from land application of food-processing waste water at this site.

Deep percolation is also a likely source of recharge on the terrace immediately north of the Umatilla River between highway 207 and the Hinkle rail yards (sections 26-28 and 33-34 of 4N/28E). Groundwater in this area occurs in predominantly fine-grained flood deposits. Well logs document a shallow unconfined water-bearing zone separated from one or more deeper confined water-bearing zones by laterally discontinuous beds of silt or clay. Various reports (Sweet, Edwards & Associates, 1983, 1985, 1987; EMCON Northwest, Inc., 1992) refer to the shallow zone as a perched groundwater body but no evidence is presented to document an unsaturated zone at its base. The boring log (WRD files) for LUB 46 (4N/28E-28ddc) indicates that confining beds of gravelly silt and silt between the upper and lower water-bearing zones are saturated throughout.

Figure 2.21 shows hydrographs for wells completed in the shallow unconfined water-bearing zone and the deeper confined water-bearing zones on the terrace north of the Umatilla River. Higher water-levels in the shallow zone indicate a downward component of hydraulic gradient consistent with local recharge. The deeper confined zones show pumping impacts from nearby irrigation and industrial wells (Plate 2.6), most notably in the summer. In contrast, the shallow unconfined zone shows no obvious pumping impacts. Water levels in the shallow zone are highest in summer and autumn and lowest in winter and spring.

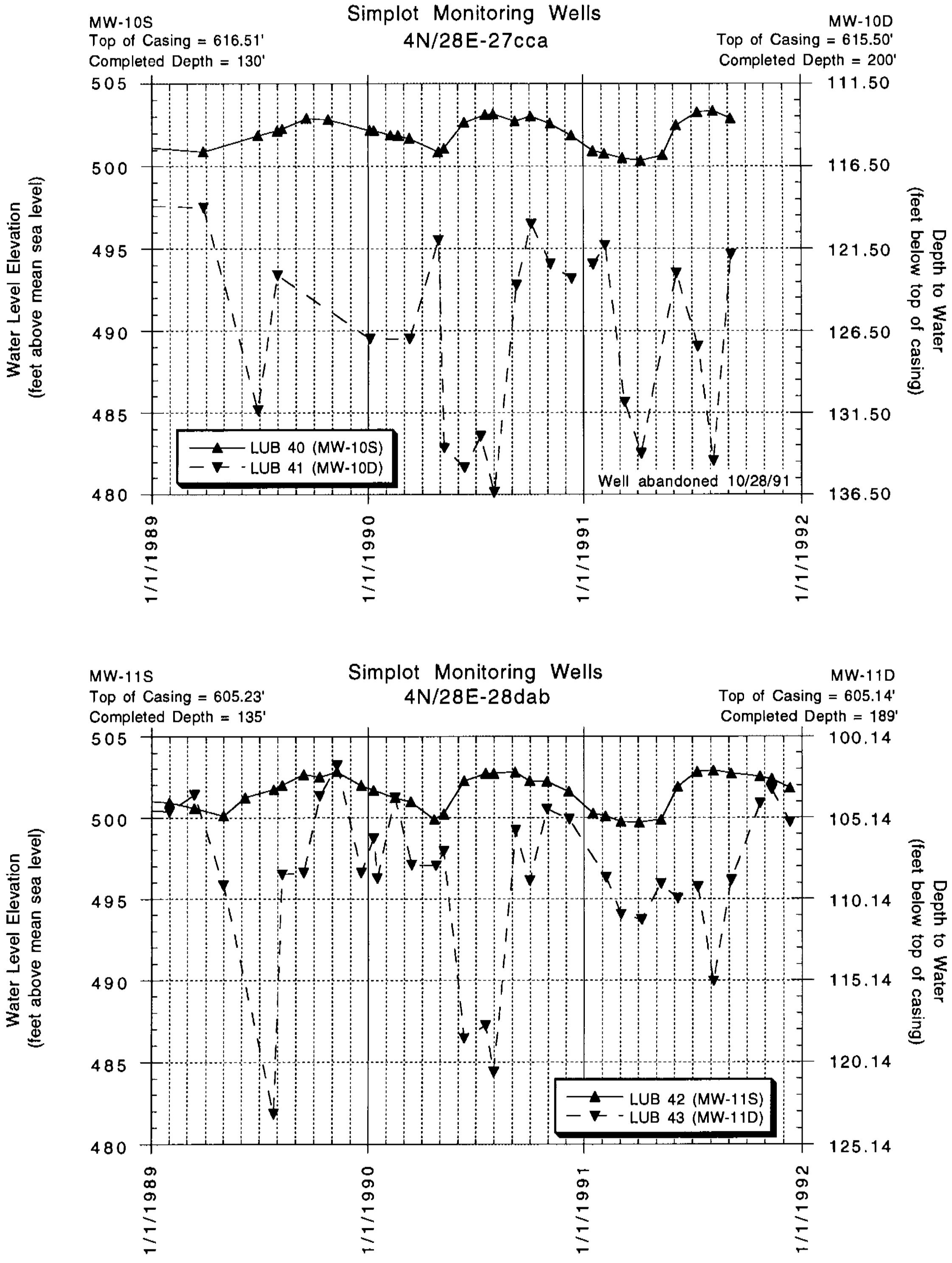


Figure 2.21 Hydrographs of paired wells completed in shallow unconfined and deeper confined water-bearing zones within fine-grained catastrophic flood deposits on the terrace north of the Umatilla River.

This suggests that the dominant factor controlling water levels is canal leakage or deep percolation of irrigation water. The presence of elevated nitrates in the shallow zone (EMCON Northwest, Inc., 1992) suggests that deep percolation is an important source of recharge but recharge from nearby canals cannot be precluded. The nearest canals include the Maxwell Canal (about one-half mile to the east at and elevation of 529 feet), the Feed Canal (about one mile to the northeast at an elevation of 628 feet), and the A Line Canal (about 1.5 miles to the northwest at an elevation of 555 feet). All three canals occur at higher elevations than the shallow water-bearing zone on the terrace. Apart from pumping effects, water-level trends in the deeper zones are similar to trends in the shallow zone. This suggests that both zones are recharged by the same sources.

Evidence for deep percolation is also seen in the hydrographs of several monitoring wells in section 4 of 3N/28E, between Butter Creek and Emigrant Buttes (Figure 2.22A). Water levels in these wells show seasonal fluctuations that correlate in part to leakage from the nearby Hunt Ditch (compare with Figure 2.18A but note the difference in vertical scale). An additional source of recharge is indicated by the observation that seasonal trends in these wells are superimposed on a rising annual trend ,whereas water-level trends directly associated with canal leakage (Figure 2.18A) are falling over the same time period. The seasonal water-level fluctuations in Figure 2.22A do not correlate to precipitation (Figure 2.22B). In addition, the rising annual trends occur during a period of declining annual rainfall (Figure 2.2). This suggests that deep percolation is the source of the additional recharge. The surrounding acreage is irrigated with effluent water from a food processing plant but the timing and rate of water applications is not known.

The above examples are all associated with lands irrigated with effluent water from food-processing plants. In at least some of these areas, water has been applied at rates which exceeded crop needs and at times outside the irrigation season (DEQ, this report). Because of this, these areas may not be representative of most irrigated lands in the basin. Therefore, evidence of deep percolation on other irrigated lands is presented below.

For example, deep percolation is probably a major source of recharge in the area west and southwest of the Umatilla Ordnance Depot. More than 30,000 acres of land are irrigated by center pivots on these lands in townships 3N/26E and 4N/26E. Lands on the Depot are not irrigated. As discussed above, the bending of contours across the western Depot boundary (Plate 2.4) and the pattern of water-level rises in wells adjacent to the boundary (Figure 2.12A) indicate that groundwater is flowing onto the Depot from the southwest. This indicates that recharge rates are higher on lands west of the Depot. Potential recharge sources in the area are limited to precipitation, leakage from the West Extension canal, and deep percolation of irrigated water. As discussed above, precipitation recharge is expected to be uniform (and low) on or off the Depot. The West Extension canal is an unlikely source of recharge since it lies at a lower elevation (about 390 feet) than most of the affected area of the aquifer. This suggests that deep percolation is the probable cause of higher recharge rates west of the Depot.

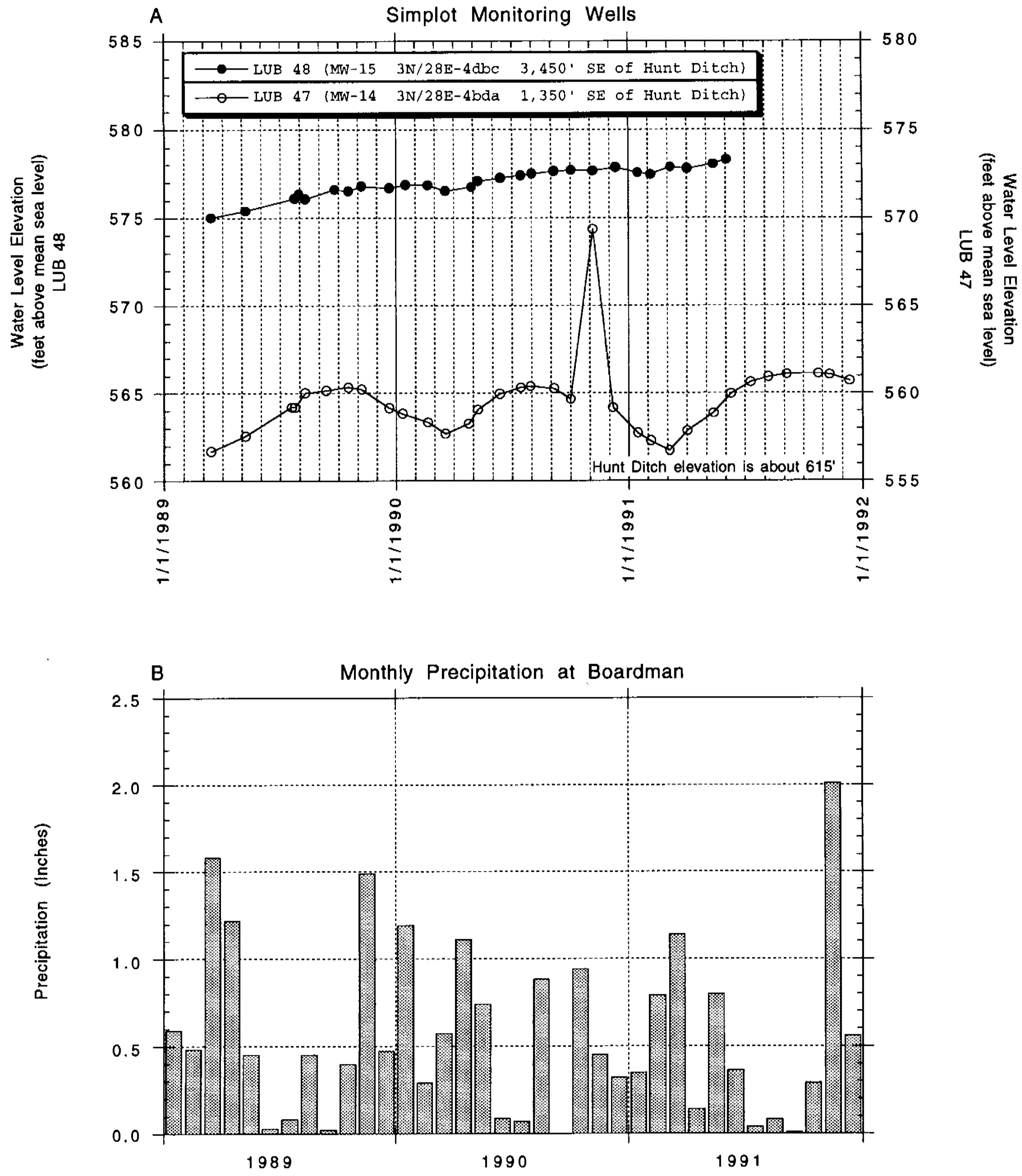


Figure 2.22 Comparison of water-level trends and precipitation in the area between Butter Creek and Emigrant Buttes. A, Hydrographs of wells screened in fine-grained flood deposits; B, Monthly precipitation at Boardman.

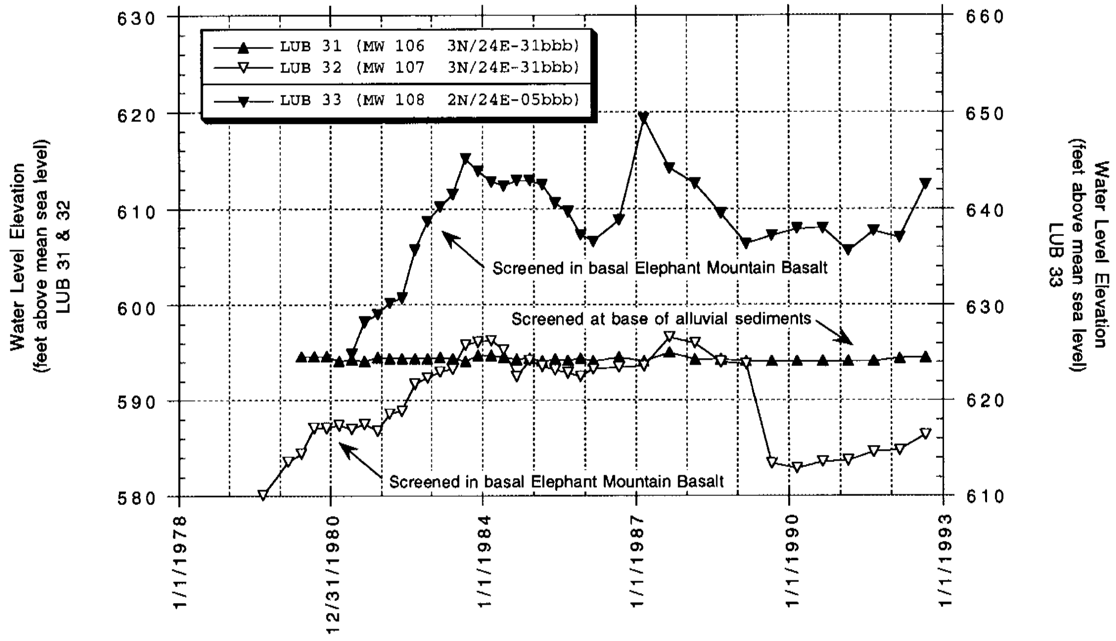
Water-level rises at the western boundary of the Depot averaged over 1.5 feet per year between July 1990 and September 1992. The maximum rise was 1.85 feet per year. Because annual water-level rises increase progressively from the interior to the western boundary of the Depot, annual water-level rises west of the Depot are likely to be even higher. This cannot be verified by measurements, however, because of a lack of wells to the west. On this basis, 1.5 feet per year is assumed to be the minimum rise caused by deep percolation recharge. Assuming a porosity of 20% for the alluvial sediments, this is equivalent to about 3.5 inches of recharge per year. Assuming that application rates range from 24 to 36 inches per year (typical rates for low pressure center pivots in the area, Pumphrey and others, 1991), this equates to a deep percolation loss of 10 to 15 percent of the applied water. Not enough data is available to determine if this figure is typical for losses from center pivot systems. Taken as a whole, however, the example suggests that deep percolation is possible even in areas of center pivot irrigation.

The duration of water-level rises on lands west of the Depot is unknown because of a lack of long-term hydrographs, but these lands were originally developed for irrigation in the 1970s. If water-level rises have occurred at a steady rate between 1982 and 1992, the overall rise in the water table would be at least 15 feet. The available data suggests that the water table is now within a few feet of land surface near the West Extension Canal in areas west and northwest of the Depot. If the water-table continues to rise due to deep percolation losses, or if leakage from the canal is substantial during the irrigation season, the water table may intersect the land surface. This is believed to be the cause of ponded water and flooded septic systems which have been reported over the last few years in areas immediately northwest of the Depot. Local residents report that these lands were historically dry but this was not confirmed by independent sources. Additional water-levels from Depot monitoring wells and a survey of the locations and timing of ponding are needed to confirm this mechanism.

Some of the lands west of the Depot are currently being converted from center pivot to drip irrigation systems for the cultivation of poplar trees. The total number of acres to be converted is unknown but the effect may be visible over time in the hydrographs of Depot monitoring wells if large land areas are involved. At present, it is not known if the Depot plans to continue monthly water-level measurements in any or all of its wells.

Evidence for deep percolation in alluvial sediments is also seen in an area irrigated by center pivots immediately west of Carty Reservoir and Sixmile Canyon. In this vicinity, the Elephant Mountain Basalt ranges from 25 to 40 feet thick. The basalt flow is overlain by 5 to 10 feet of alluvial sediments which are in turn capped by 5 to 10 feet of windblown silt and sand (section A-A', Plate 2.3). Prior to the filling of Carty Reservoir in 1977, little or no groundwater was present in the alluvial sediments overlying the Elephant Mountain Basalt or in the breccia/fracture zone at the base of the basalt flow (Portland General Electric, 1992). Hydrographs in Figure 2.23A document water-level trends in these zones in the area northwest of Carty after the reservoir was filled. Two of the wells are screened adjacent to a confined aquifer at the base of the Elephant Mountain Basalt (Figure 2.23B) and display a rising water-level trend that correlates to the filling of the reservoir. The third well (LUB 31) is adjacent to one of the deep wells (LUB 32) and is completed in the sediments which overlie the basalt. Measurements from the shallow well show that a thin layer of groundwater has been present at the base of the sediments since at least 1980, the approximate date at which irrigation of the adjacent lands was first begun. Water levels in the sediments have been relatively constant over time and show no relationship to the filling of the reservoir. This suggests that deep percolation is the source of the groundwater in the alluvium.

A PGE Monitoring Wells



B Well Construction Diagrams

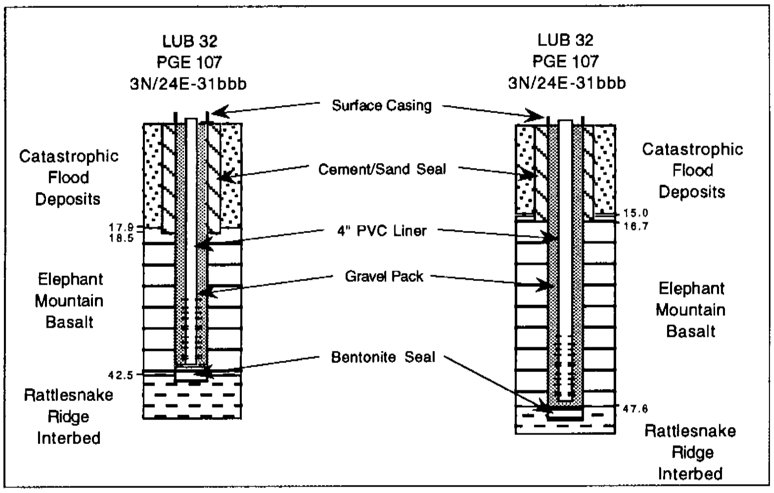


Figure 2.23 Water-level trends and construction details of monitoring wells northwest of Carty Reservoir. A, Hydrographs of alluvial and basalt wells; B, Well construction diagrams of basalt wells.

Although water levels in the deep wells in Figure 2.23A correlate to the filling of Carty Reservoir, the chemistry of groundwater from these wells indicates a component of recharge from agricultural sources (Portland General Electric, 1992). This discrepancy is believed to be caused by well construction features. Both deep wells have a sand/cement seal which extends no more than 5 feet into the top of the Elephant Mountain Basalt (Figure 2.23B). Gravel packs expose the remainder of the basalt to the well bore. This construction is not likely to prevent alluvial groundwater from seeping into the well bore through the breccia/fracture zone at the top of the basalt flow.

This example provides additional evidence that some deep percolation recharge can occur in areas of center pivot irrigation. It also illustrates a mechanism by which alluvial water can migrate into the bores of wells which are nominally completed in basalt aquifers. This is believed to be a common occurrence in many wells in the study area because of well construction practices. The water quality implications of these practices are discussed below in the section on discharge to the shallow basalt aquifers.

Economic factors have encouraged many irrigators in the study area to reduce their per acre water consumption. This has resulted in a gradual shift to sprinkler systems and an increased use of center pivots over time. Recent conservation trends include drip irrigation and the use of sophisticated water-management techniques. Water budgets are now commonly established for individual plots using satellite images, aerial photographs, daily weather data, crop water requirements, and neutron probes. In this manner, water use is adjusted daily to apply only that amount which is optimal for the growth of crops. All of these trends will decrease deep percolation of irrigation water and reduce the amount of recharge to the alluvial aquifer over time.

In summary, evidence for deep percolation of irrigation water is found in various areas of the basin. Percolation recharge may be as great as 15 percent of the applied water in areas irrigated by center pivots. Proportionately higher recharge rates are expected in areas irrigated by wheel lines, hand lines, and flooding of fields. If 2.4 inches per year (a 10 percent loss for 24 inches of applied water) is assumed to be a minimum recharge rate for the 180,000 acres of irrigated lands in the study area, the minimum annual recharge from this source would total about 36,000 acre-feet per year. Over time, the component of recharge from deep percolation is expected to decrease as the use of flood irrigation decreases, as the use of drip irrigation increases, and as water management programs become more common on individual farms.

Flow Directions and Velocities

Interpreted flow directions for the alluvial aquifer are shown on Plate 2.4. As a first approximation, flow was assumed to be perpendicular to the contours, a condition that is strictly true for isotropic aquifers only. In areas where data is sparse, or the contour interval is too coarse, flow directions were determined by analyzing local hydrogeologic factors, as discussed in the earlier sections of this report. The flow patterns on the map reflect conditions in late winter when pumping is at a minimum. Average groundwater flow velocity along a given flow path can be estimated from a modification of Darcy's Law which states that the velocity of groundwater is equal to the hydraulic conductivity times the hydraulic gradient divided by the effective porosity of the aquifer (Freeze and Cherry, 1979).

Table 2.3 shows estimated velocities based on a probable range of hydraulic parameters in the study area. The effective porosity of the coarse-grained deposits was assumed to be equal to the storage coefficient as determined by aquifer tests. A conservative effective porosity of 0.05 was assumed for the fine-grained deposits. Greater values of effective porosity will yield lower velocities.

Table 2.3 Estimated groundwater flow velocities in the alluvial aquifer.

Water-bearing Unit	Hydraulic Conductivity ft/day	Hydraulic Gradient ft/mile	Effective Porosity	Average Linear Velocity		
				ft/day	ft/year	mi/yr
Pscfc	1000	2	0.2	1.8939	691.8	0.1310
	4000	2	0.2	7.5758	2767.0	0.5241
Pscff	0.01	50	0.05	0.0019	0.7	0.0001
	0.1	50	0.05	0.0189	6.9	0.0013
	1	50	0.05	0.1894	69.2	0.0131
	10	50	0.05	1.8939	691.8	0.1310
	100	50	0.2	4.7348	1729.4	0.3275

Assuming a hydraulic gradient of 2 feet per mile (.0004), velocities in the coarse-grained flood deposits are estimated to range from 2 to 8 feet per day or 0.13 to 0.52 miles per year. Assuming a gradient of 50 feet per mile (.0095), velocities in the fine-grained deposits are estimated to range from 0.002 to 2 feet per day or 0.0001 to 0.13 miles per year. Velocities within sand and gravel beds in the fine-grained deposits are likely to fall somewhere in between.

These are rough estimates which are presented only to give a sense of relative flow velocities through the various aquifer materials. A variety of simplifying assumptions underlie the estimates. The actual flow velocity of a given particle of water may vary greatly because of local variations in hydraulic conductivity and porosity. In addition, pumping and recharge can locally alter hydraulic gradients and flow directions during the year, especially in the vicinity of aquifer boundaries. This is well documented in the coarse-grained flood deposits near the Umatilla Ordnance Depot. For example, the above estimates and the flow lines on Plate 2.4 suggest that groundwater will travel from the center of the Depot to the Umatilla River within a period of 10 to 40 years. However, seasonal water-level measurements in Depot wells indicate that flow directions vary by up to 180 degrees during the year, in response to off-site pumping and recharge. The net direction of water movement in this system is difficult to predict but the net displacement of a given particle of water is likely to be much less than the range of 0.13 to 0.52 miles per year. This probably explains why contaminant plumes on the Depot have not migrated far from their source areas.

It is beyond the scope of this study to predict the effects of transient pumping and recharge in any particular area. However, a general idea of the potential impact of these stresses can be gained by comparing the flow patterns on Plate 2.4 with the locations of canals and the density of high-capacity wells which produce from the alluvial aquifer (Plate 2.6).

Discharge

Water exits the alluvial aquifer by discharge to streams, by evapotranspiration from wetlands, by discharge to underlying basalt aquifers, and by withdrawal from wells. Evapotranspiration may be important in areas where the water table is near land surface but is probably a minor source of discharge for the aquifer as a whole. Not enough data is available to determine the rates of discharge to streams and basalt aquifers but it is possible to outline areas where such discharge is likely to occur. Estimates of withdrawals by wells can be made with a fair degree of confidence.

To Streams

As noted above, the Columbia River fully penetrates the alluvial aquifer in most places between Boardman and McNary Dam. Under natural conditions, groundwater flow directions are to the north and the aquifer discharges to the river along this reach.

Water-level contours (Plate 2.4) indicate that the alluvial aquifer discharges to the Umatilla River throughout most of its reach in the study area. An exception occurs between sections 19 and 30 of 4N/28E (Cottonwood Bend) and section 35 of 4N/28E, where the river loses water to the underlying aquifer (see the above section on recharge from streams). An analysis of return flows to the river (Kreag, 1991) suggests that groundwater discharge may be minimal except for a stretch between the Dillon Canal East Drain and Bridge Road (river mile 19.9 to 8.8). Discharge in this stretch of the river is manifested by perennial seeps and springs which occur between Cottonwood Bend and Bridge Road and seasonal springs which occur during the irrigation season near Bridge Road. Measurable spring flow at Minnehaha Springs and Bridge Road ranges from 3.5 cfs (cubic feet per second) in late spring to 12.8 cfs during the summer (Kreag, 1991). This is equivalent to about 7 to 25 acre-feet per day or about 2500 to 9000 acre-feet per year. These are conservative estimates of discharge to the river since additional unmeasurable spring flow and seepage (through the bed of the river) are not accounted for. Kreag (1991) estimates that this unaccounted component of discharge may range from 35 to 60 cfs (about 70 to 120 acre-feet per day) during the summer.

Downstream of Bridge road, the Umatilla river cuts progressively through the alluvial aquifer until it exposes the top of the underlying Pomona flow at Three Mile Dam (Plate 2.2 and cross section F-F', Plate 2.3). This suggests that discharge from the alluvial aquifer is also occurring along this reach of the river. Since springs are not noted in this stretch, discharge must occur by seepage through the bed of the stream.

To Shallow Basalt Aquifers

The potential for discharge to shallow basalt aquifers exists wherever the margins of basalt flows are exposed beneath saturated sediments of the alluvial aquifer. The approximate locations for the principal margins of Saddle Mountains Basalt flows are shown on Plate 2.2 and on the cross sections of Plate 2.3. Margins shown east of Service Anticline are not well constrained but the general relations hold nonetheless. Additional flow margins are likely along the flanks of Service Anticline, between Umatilla Butte and Emigrant Buttes, but could not be mapped with any degree of confidence.

The efficiency of discharge to a basalt aquifer depends upon a variety of factors including the permeability of the sediments, the permeability of the exposed margin of the basalt flow, and the hydraulic head in the sediments and the basalt flows. All else being equal, the potential for discharge to basalt aquifers is likely to be greatest in areas where high permeability sediments overlie flow margins

Not enough data are available to determine rates and volumes of discharge to shallow basalt aquifers, but geometric relationships indicate that the alluvial aquifer is the main source of recharge to the shallow basalt aquifers. This will be discussed in more detail in the section on basalt aquifer recharge.

To Wells

Table 2.4 summarizes well withdrawals from the alluvial aquifer within the study area. The distribution of wells is shown on Plate 5. Total withdrawal is estimated between 65,000 and 98,000 acre-feet per year. Irrigation is the largest category of use and accounts for 51,000 to 85,000 acre-feet of withdrawal per year. Domestic pumpage is relatively insignificant at about 1800 acre-feet per year. Wells for the City of Boardman and the Umatilla Fish Hatchery are not included in the total because much of their water probably comes from the Columbia River by induced infiltration. Boardman uses a collector well with laterals that extend partly beneath the Columbia River. The hatchery also uses several collector wells in addition to four high-capacity wells that are located near the river. Based on water chemistry, CH2M Hill (1992) estimates that 60 to 80 percent of the water produced by Boardman's collector well comes from the Columbia River. The remainder comes from the alluvial aquifer.

Total pumpage in the early 1980s was estimated by Davies-Smith and others (1988) at about 25,000 acre-feet per year for the alluvial aquifer. This estimate is considerably lower than the conservative estimate of 65,000 acre-feet per year shown in Table 2.4. The Davies-Smith total, however, does not include withdrawals from the alluvial aquifer along the Boardman-Umatilla strip. This probably accounts for a significant portion of the difference between the two estimates. A small part of the difference is probably due to the issuance of new permits (mostly for commercial and industrial uses) since 1982. Neither of these factors is likely to account for the majority of the difference. The remaining discrepancy must be due to errors in either or both of the estimates.

Table 2.4 Summary of well withdrawals from the alluvial aquifer.

Category	Discharge acre-ft/yr	Comments
Domestic Wells	1750†	Assumes 500 gallons per day per well
Irrigation - Primary	36,000 - 54000	Assumes 2-3 acre-ft/yr/acre
Irrigation - Supplemental	15,500†† - 31,000	Assumes 1-2 acre-ft/yr/acre
Miscellaneous	9,332	Mostly commercial and industrial use permits
City of Hermiston	1,811	City well #5
City of Irrigon	291	City well #2
Total	64,684 - 98184	
City of Boardman	1,108	Ranney collector adjacent to Columbia River
Umatilla Fish Hatchery	8,881	Wells and collectors adjacent to Columbia River

†Includes all wells less than 200 feet deep
††Includes County Line Water Improvement District recharge permit for 5339 acres

Although many assumptions underlie the above estimates, the figures are presented to provide a general sense of the overall magnitude of well withdrawals in the study area. The methods used for estimating well withdrawals are summarized below.

Withdrawals from domestic wells were estimated by assuming that all wells less than 200 feet deep produce from the alluvial aquifer. This probably overestimates the number of alluvial wells because the depth to basalt is less than 100 feet in some areas. It was also assumed that well logs on file at the Water Resources Department represent only 50% of the actual wells in the study area (see Groundwater Development). It was further assumed that domestic consumption averages 500 gallons per day per well.

Pumpage from irrigation wells was estimated using the Water Rights database at the Water Resources Department. The total number of acres permitted for primary and supplemental irrigation was summed for all wells (and sumps) which produce from the alluvial aquifer. Pumpage was estimated by assuming a duty of 2 to 3 acre-feet per year for primary rights and 1 to 2 acre-feet per year for supplemental rights.

Withdrawals from miscellaneous permitted wells were also estimated using the Water Rights database. Most of the wells in this category are permitted for commercial or manufacturing use and are associated with food-processing facilities. It was assumed that each well was used to the full capacity permitted on the water right. This probably overestimates actual usage.

Pumpage from municipal wells and from wells at the Umatilla Fish Hatchery were obtained from monthly water-use reports on file at the Water Resources Department.

Groundwater Supply

Under natural conditions, the average annual discharge from an aquifer is in equilibrium with the average annual recharge. Under these conditions, the volume of water in storage is constant, and water levels in the aquifer are stable. Artificial recharge or discharge can disrupt this stability and lead to changes in storage. Under favorable conditions, a new equilibrium will be reached and water levels will stabilize at a different level. If artificial discharge is too great, equilibrium may not possible and water levels will decline until the aquifer is depleted.

Although a comprehensive groundwater budget is beyond the scope of the current study, a general evaluation of groundwater supplies in the alluvial aquifer is possible on an area by area basis.

The principal productive areas of the alluvial aquifer occur within three shallow troughs which are filled with coarse-grained flood deposits (Plate 2.4). The limited extent of the coarse-grained sediments limits the effective size of the groundwater resource in each area. However, conditions which affect groundwater supplies also vary in each area.

In the Ordnance area, the saturated coarse-grained deposits are bounded on all sides by predominantly fine-grained sediments. Recharge sources are limited and the aquifer has been extensively developed as a source of irrigation water. Water-level declines between 1960 and 1976 and between 1986 and 1993 (Figure 2.9) indicate that discharge was greater than recharge during these time intervals. If the current imbalance continues, water levels will continue to decline. Additional development of groundwater in this area cannot be sustained unless recharge can be increased to compensate for the new withdrawals.

In the Boardman-Umatilla area, the alluvial aquifer is hydraulically connected to the Columbia River and the river determines the base level of the water table. If river levels are maintained over time, long-term storage will remain stable. Large increases in annual pumpage from the aquifer will induce water to flow from the river into the aquifer. In this sense, groundwater supplies in the Boardman-Umatilla strip are relatively unlimited but are developed at the expense of the Columbia River.

The alluvial groundwater resource in the Hermiston area is similar in size and geometry to that of the Ordnance area. In Hermiston, however, pumpage is lower and the density of canals is higher. The existing data indicate that groundwater levels are stable and that annual recharge is in balance with annual discharge. This suggests that some additional groundwater development can be sustained. Because canal leakage and deep percolation of irrigation water are the principal sources of recharge in the area, future conservation measures by the Hermiston Irrigation District and decreased use of the Feed Canal to deliver water to Cold Springs Reservoir may impact groundwater supplies. This may be compounded by additional pumpage as the population continues to grow in the area. At present, major pumping withdrawals are limited to the City of Hermiston's well #5 (UMAT 1771, 4N/28E-3dba) and a dozen or so high-capacity irrigation wells to the north and northeast of Hermiston (Plate 2.6). In the future, the city plans to use alluvial groundwater from their well #5 to recharge the deeper basalt aquifers during the winter months. It would be prudent to monitor groundwater levels in the alluvial aquifer to determine the nature and extent of changes in groundwater storage, if any, over time.

Groundwater in the alluvial aquifer is also developed from laterally discontinuous sand and gravel beds (within predominantly fine-grained flood deposits) on the terrace between Hermiston and Stanfield. Well logs, water levels, well yields, and aquifer test data indicate local confinement, moderate transmissivities, and low storage capacities. This is reflected in the large pumping drawdowns observed in monitoring wells which are completed in these zones (Figure 2.21). Relatively stable water levels in the area indicate that discharge is currently balanced by recharge.

Groundwater in the Umatilla River Valley is hydraulically connected to the Umatilla River. Groundwater levels adjacent to the river are at, or near, river level. Additional pumpage capacity is available but pumpage will decrease stream flow by decreasing the rate of groundwater discharge to the river or, by inducing water to flow from the river into the aquifer.

Shallow Basalt Aquifers

Water-bearing zones within Columbia River basalts are largely limited to thin breccia or fracture zones at the top or base of individual flows (Figure 2.6). The dense interiors of flows are believed to be relatively impermeable and confine groundwater to discrete tabular aquifers. Data from well logs indicate that productive aquifers do not occur at the top or base of every flow or at all localities of a given flow. This is consistent with exposures in road cuts which show that the thickness of individual breccia zones may vary considerably over short distances. In general, breccias and fracture zones account for less than 10% of the thickness of a flow. Assuming an average porosity of 10%, only about 1% of the total flow volume is available for the storage of groundwater. Because these aquifers are confined, only a fraction of the stored water is available for withdrawal by wells. This is because water is released from confined aquifers by expansion of water and by compression of the framework of the aquifer; neither mechanism is capable of releasing much water. Because of their low storage potential, Columbia River basalt aquifers are particularly vulnerable to overdraft, as evidenced by declining water levels in of many of the deeper basalt aquifers of the Umatilla Basin (Sceva, 1966; McCall, 1975; Bartholomew, 1975; Norton and Bartholomew, 1984; Zwart, 1990).

Three shallow aquifers occur within flows of the Saddle Mountains Basalt. From upper to lowermost, these are the Basal Elephant Mountain aquifer, the Basal Pomona aquifer, and the Basal Umatilla aquifer. Each aquifer unit includes water-bearing zones at the base of the named flow and at the top of the underlying flow (Figure 2.4). Although a thin interbed of silt and clay separates the two water-bearing zones in many areas, in practical terms they form a single aquifer. An exception to this generality occurs west of the Umatilla Ordnance Depot where the Selah interbed thickens to greater than 150 feet and probably effectively isolates the water-bearing zone at the base of the Pomona from the zone at the top of the underlying flow.

As discussed in earlier sections of this report, the geometry of Saddle Mountains Basalt flows is reasonably well defined based on surface exposures and subsurface correlations (Plates 2.2 and 2.3). The regional dip of the flows is to the north, largely controlled by the Dalles-Umatilla Syncline. Each of the flows is breached in downdip areas by the Columbia River, some at more than one locality. Margins of each flow are also exposed in updip areas beneath saturated alluvial sediments. From a geometric perspective, the aquifers in these flows are hydraulically connected to the Columbia River and the alluvial aquifer.

A limited amount of water-level data was collected from wells completed in the shallow basalt aquifers during the course of this investigation. Most of the reported data are from wells which are completed in a single aquifer. Many wells in the basin commingle water from several basalt aquifers. Hydraulic heads in commingling wells represent some combination of the heads of several aquifers and are probably unreliable for determining hydraulic gradients and flow directions. Several generalities can be made from the available dataset.

Water-level elevations in the uppermost basalt aquifer are typically a few feet or a few tens of feet lower than levels in the alluvial aquifer (Plate 2.4). In addition, water-level elevations in the shallow basalt aquifers generally decrease with depth (see Dames and Moore, 1994b for example). Because of this falling-head-with-depth relationship, any interconnections between the shallow aquifers will result in the downward movement of water.

Water-level trends in the basalt aquifers are illustrated by hydrographs of wells completed in the basal Pomona aquifer at the Umatilla Ordnance Depot (Figure 2.24). Seasonal lows occur in the summer in response to pumping withdrawals. Seasonal highs occur in the winter. At this locality, the amplitude of seasonal change is about 10 feet. Seasonal amplitudes at other localities are likely to vary depending upon the density of pumping wells and the cumulative pumping rates. Although the nearest wells which pump water from the basal Pomona aquifer are located several miles to the east, seasonal pumping effects at the Depot are on the order of 10 feet. This suggests that hydraulic conductivities are moderately high and storage capacities are low.

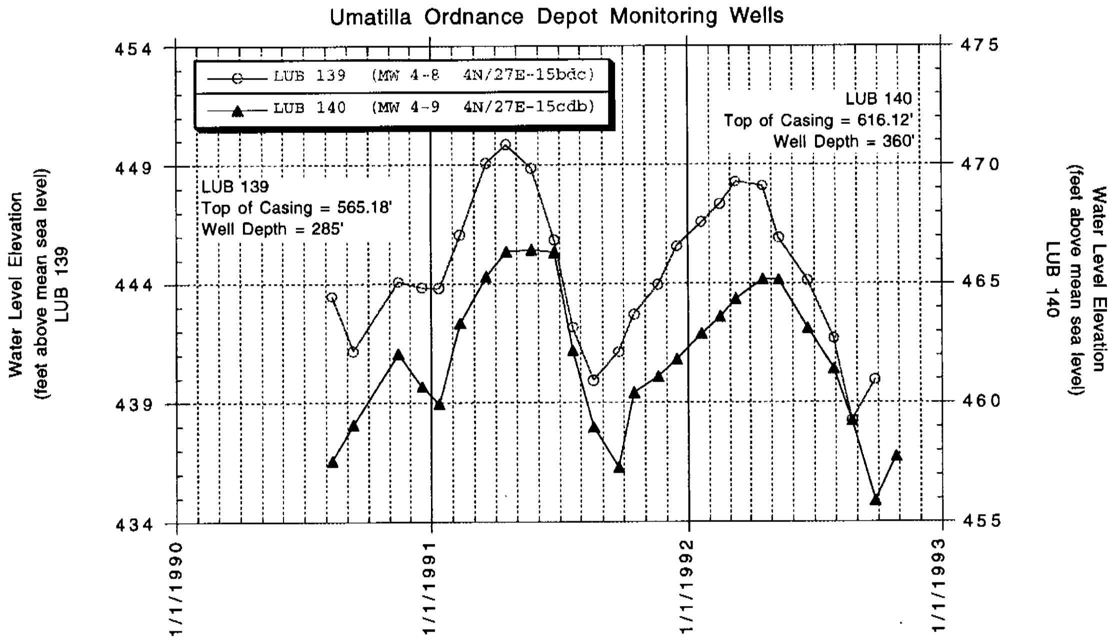


Figure 2.24 Hydrographs of monitoring wells completed in the basal Pomona aquifer on the Umatilla Ordnance Depot.

Aquifer Properties

Reliable values for the hydraulic properties of the shallow basalt aquifers and their associated interbeds are lacking. Aquifer tests were conducted in several wells completed in the basal Pomona aquifer on the Umatilla Ordnance Depot (Dames and Moore, 1992) but a review of the tests suggests that the data was compromised by the pumping of wells adjacent to the Depot. Packer tests and constant-head slug tests in boreholes at Portland General Electric's Boardman coal-fired plant indicate hydraulic conductivities of about 0.06 to 3.0 feet per day for the Elephant Mountain Basalt, 0.0003 to 0.3 feet per day for the brecciated upper portion of the Pomona Basalt, and 0.00003 to 0.003 feet per day for the dense interior of the Pomona Basalt. Tests also indicate hydraulic conductivities of 0.003 to 0.6 feet per day for the Rattlesnake Ridge interbed, and 0.0003 to .003 feet per day for the Selah interbed (Shannon and Wilson, 1972a; 1973a). Packer and slug tests evaluate small disturbed rock or sediment volumes in the immediate vicinity of well bores and may not reflect the bulk permeabilities of these materials under natural conditions. Using specific capacity data, Davies-Smith and others (1988) estimate a permeability of 18 feet per day for water-bearing zones in the Saddle Mountains Basalt. Vertical hydraulic conductivities are estimated to be several orders of magnitude lower. Estimates of storage coefficients for the water-bearing zones in the Saddle Mountains Basalt range as high as .003 (Davies-Smith and others, 1988).

The above data indicate that hydraulic conductivities in the shallow basalt aquifers are comparable to those of the fine-grained sediments in the alluvial aquifer. The rapid rate of water-level rise in the basal Elephant Mountain aquifer after Carty Reservoir was filled suggests that these values may be conservatively low.

Recharge

Because the interiors of the basalt flows are relatively impermeable, effective recharge to the shallow basalt aquifers is probably limited to areas where the margins of the basalt flows are exposed to recharge waters. Recharge rates cannot be determined from the present data but areas where recharge is likely to occur can be established.

From the Alluvial Aquifer

Within the study area, updip margins of the upper two basalt flows generally occur beneath a cover of alluvial sediments (Plates 2.2 and 2.4). Effective recharge to the basalts is probably limited to areas where these sediments are saturated. This is supported by the observation that in areas updip from the Columbia River, saturated portions of the shallow basalt aquifers are generally limited to areas which are overlain by the alluvial aquifer. These factors suggest that most of the recharge to these aquifers comes from groundwater that is discharged from the alluvial aquifer. Therefore, the water quality of the shallow basalt aquifers will be influenced by the water quality of the alluvial aquifer.

From Reservoirs and Streams

The upper surface of the Pomona flow is exposed beneath Carty Reservoir and in the bed of the Umatilla River between Three Mile Dam and the Columbia River. Leakage from Carty Reservoir to the basal Elephant Mountain aquifer (breccia/fracture zones at the base of the Elephant Mountain and the top of the underlying Pomona) is well documented. Leakage from the Umatilla River is highly probable.

Recharge from the Columbia River is also possible wherever the basalt aquifers are breached by the river. However, throughout most of the study area, hydraulic gradients in the basalt aquifers are sloped toward the river. Because of this, recharge from the river is probably limited to areas where well withdrawals are sufficient to locally reverse the gradient near the river.

Recharge from the Columbia River cannot be demonstrated in the study area but is illustrated by an example from several miles to the west, in the vicinity of Arlington. At the western boundary of the study area, the axis of the Dalles-Umatilla syncline leaves the path of the Columbia River and swings to south (Swanson and others, 1981). Because of this, the basalt flows dip to the south between the river and Arlington. After the John Day dam was completed in 1968, water levels in the City of Arlington's municipal well rose about 60 feet over a period of about 12 years (Figure 2.25). Apparently, the rising pool behind the dam inundated a breccia zone in the basalts which was previously above river level. This allowed water to migrate downdip toward Arlington where it was captured by the open (uncased) borehole of the municipal well.

From the Alluvial Aquifer Through Wells

As discussed in earlier sections of this report, some recharge to the shallow basalt aquifers also comes from alluvial groundwater which migrates through the bores of wells which have inadequate seals. A typical domestic supply well in the basalts has an 18 foot seal at the surface and a steel casing which extends from land surface to the top of the uppermost basalt flow (see cross sections on Plate 2.3 for examples). In most instances the casing rests on the basalt surface or penetrates only a few feet into the basalt. The remainder of the well consists of an open hole which penetrates one or more basalt aquifers. The lack of a seal into the dense interior of the first basalt flow may allow water from the alluvial aquifer to migrate into the well bore through breccia or fracture zones which occur at the top of the basalt. The volume of water that enters a borehole through this mechanism will probably vary locally depending on conditions at the surface of the basalt. In most cases, the rate of inflow will probably be low. If the alluvial aquifer is contaminated, a small rate of inflow may only degrade the water in and near the well bore. A large rate of inflow may produce a contaminant plume in the basalt aquifer. If significant inflow occurs through many wells, a large portion of the aquifer may be contaminated. At least one driller has reported some success in cleaning up domestic water wells in the Boardman area by placing a grout seal completely through the first basalt flow. This suggests that, in at least some cases, contamination of the basalt aquifers is limited to the vicinity of the well bore.

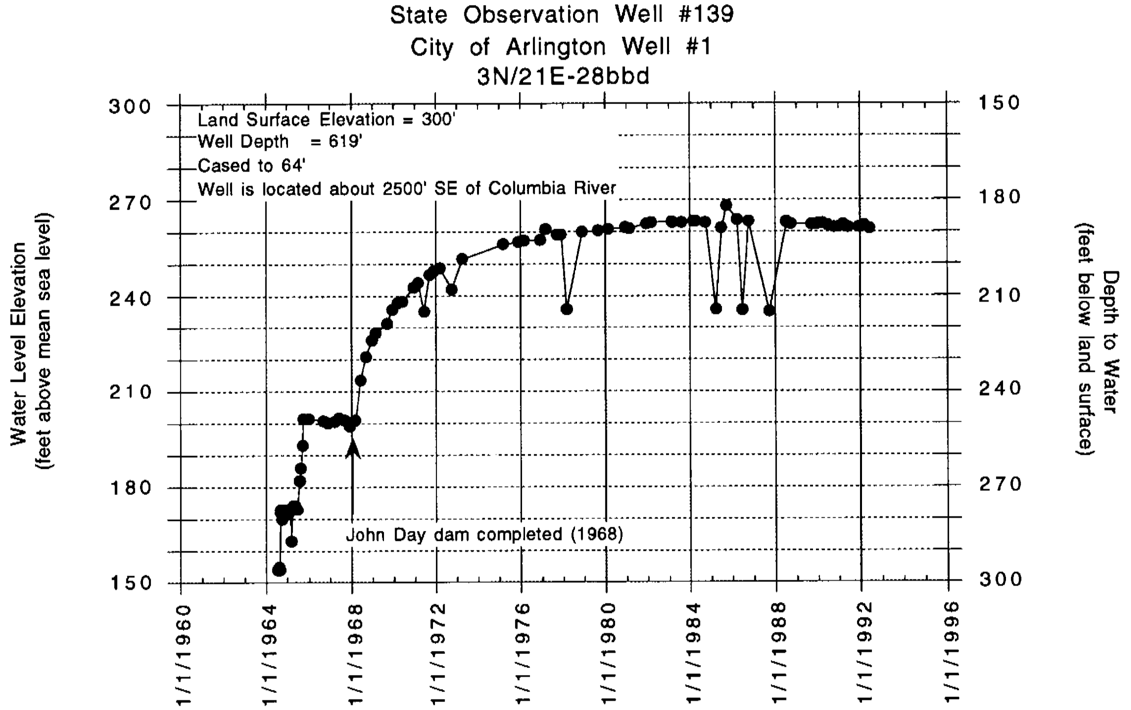


Figure 2.25 Hydrograph of the city of Arlington's municipal well #1 showing a rise in water level associated with the completion of the John Day dam

Flow Directions and Velocities

Although not enough data was collected from each of the shallow basalt aquifers to contour flow directions, the available data indicate that flow is generally parallel to the regional dip of the basalt flows (Plates 2.2 and 2.4). Throughout most of the study area, regional dips are to the north and groundwater flow is toward the Columbia River. Hydraulic gradients appear to range from 25 to 50 feet per mile.

Assuming a hydraulic conductivity of 18 feet per day and an effective porosity of 10%, the average groundwater flow velocity in the shallow basalt aquifers is estimated to range between about 1 and 2 feet per day, or 350 to 700 feet per year. These estimates are subject to considerable uncertainty.

Discharge

Water exits the shallow basalt aquifers by discharge to the Columbia River, by withdrawal from wells, and by discharge through well bores to other basalt aquifers.

Although shallow basalt groundwater flow is toward the Columbia River, effective discharge to the river is probably limited to areas where basalt flows are breached by the river. Because the three shallowest basalt flows are breached at various localities within the study area, efficient hydraulic connections probably exist between the shallow aquifers and the river. However, discharge rates cannot be calculated using available data.

Pumpage discharge from the shallow basalt aquifers was not estimated for the current study but sufficient data are available to make such an estimate.

Many wells in the study are completed in more than one basalt aquifer. Because hydraulic heads are commonly different in the various aquifers, this practice allows groundwater to migrate between aquifers. The magnitude of discharge by this mechanism is unknown but it may be significant in areas of high well density because of the limited storage capacity of the shallow basalt aquifers. The commingling of aquifers in wells also provides a pathway for contaminants to travel between aquifers.

Groundwater Supply

The limited thicknesses and storage capacities of the shallow basalt aquifers suggest that development potential is somewhat limited. Low hydraulic conductivities and storativities also increase the likelihood of interference between wells.

Groundwater supplies in the shallow basalt aquifers are expected to be relatively stable in downdip areas where aquifer elevations are near the level of the Columbia River. Because each of the shallow aquifers is breached by the river, pumpage is likely to be buffered by recharge from the river.

Where aquifer elevations rise above the level of the river, groundwater supplies are more prone to depletion by pumping. The most susceptible areas are likely to be near updip flow margins, especially where the overlying alluvial aquifer is thin or, where the basalts are overlain by predominantly fine-grained sediments with low hydraulic conductivities.

Excessive water-level declines have recently occurred in many wells completed in the shallow basalt aquifers in and around sections 8, 9 and 17 of 4N/28E (Marc Norton, WRD, personal communication). This is an area of rapid development immediately west of Hermiston which has more than 100 wells completed in shallow basalt aquifers. Declines over the past few years have resulted in many well deepenings. In most instances, the upper basalt aquifers have not been sealed off when these wells were deepened. Because hydraulic heads decline with depth in the area, the open wellbores will allow groundwater to migrate from the shallow zones into the deeper zones. This practice is likely to exacerbate water-level declines in wells which have not been deepened. Because the deeper basalt aquifers in the area are also declining because of irrigation pumpage (Norton and Bartholomew, 1984), water supplies from these zones may not be reliable in the future.

In most of the study area, long-term water-level trends are unknown in the shallow basalt aquifers because of a lack of data. However, limited data collected between 1990 and 1993 suggest that water levels are somewhat stable in many areas. For example, two years of record at the Umatilla Ordnance Depot (Figure 2.24) show a decline of about two feet per year in the basal Pomona aquifer (Dames and Moore, 1994b). However, this trend cannot be extrapolated into the future with any degree of confidence.

The proposed lowering of the John Day pool will probably have only a small impact on groundwater supplies in the shallow basalt aquifers within the study area. A drop in pool level will lower the base level at which discharge occurs and cause a small increase in hydraulic gradients within the aquifers. Near the river, water levels may drop the full distance that the pool is lowered, but this will only be a small fraction of the height of the water-column in a well. South of the river, water levels will drop only a fraction of the pool drawdown distance. Alternatively, a steepening of the hydraulic gradient will lead to a greater rate of discharge to the river.

Summary and Conclusions

A shallow unconfined to locally confined aquifer occurs in the alluvial sediments of northern Morrow and Umatilla counties between the cities of Boardman, Umatilla, and Echo. Multiple confined aquifers occur in the Columbia River Basalt flows which underlie the sediments. Shallow groundwater occurs in four discrete aquifers. From upper to lowermost, these are informally identified as the alluvial aquifer, the basal Elephant Mountain aquifer, the basal Pomona aquifer, and the basal Umatilla aquifer.

The principal water-bearing zones in the alluvial aquifer occur in sands and gravels deposited by catastrophic floods during the Pleistocene Epoch. The main productive areas occur in three east to northeast-trending shallow troughs which are largely filled with sands and gravels. Boundaries within each trough limit the size of the groundwater resource.

The available evidence indicates that water readily infiltrate the soils of the basin and travels rapidly through the unsaturated silts, sands, and gravels which overlie the alluvial aquifer. Because of this, the aquifer is highly susceptible to contamination from activities at the land surface.

Canal and ditch leakage are the principal sources of recharge to the alluvial aquifer. Deep percolation is probably an important source of recharge in areas which are irrigated by flooding or with low efficiency sprinkler systems. Some deep percolation also occurs in areas irrigated by center pivot systems. Recharge from reservoirs and streams may be substantial in some areas. Recharge from precipitation may be minimal. Local water-level highs near the northwest corner of the Depot and on the terrace between Hermiston and Stanfield indicate areas of sustained local recharge.

Between the Umatilla Ordnance Depot and Boardman, groundwater flow in the alluvial aquifer is uniformly to the northwest toward the Columbia River. South and east of the Depot, flow directions are more variable and flow is generally toward the Umatilla River. In the area east of the Depot, the topography of the underlying basalt surface is a major factor which controls flow directions. Flow directions are also influenced by the seasonal pumping of high-capacity wells and by pulses of recharge from canals. Average flow velocities may be as low as 0.0001 miles per year (0.002 feet per day) in the silts and silty sands and as high as 0.50 miles per year (8 feet per day) in the sands and gravels. Net displacement of water over a year's time may be considerably less because of seasonal variations in hydraulic gradients and flow directions.

Substantial quantities of groundwater are discharged from the alluvial aquifer by wells. In the Ordnance area, pumpage and other discharge has exceeded recharge since 1986 and groundwater levels are declining several feet per year. Pumpage discharge between Boardman and Umatilla is buffered by recharge from the Columbia River. Groundwater supplies in this area are relatively unlimited but are developed at the expense of the Columbia River. Pumpage in the Hermiston area is currently less than annual recharge but the capacity for additional development is unknown.

The shallow basalt aquifers of the basin are hydraulically connected to the alluvial aquifer and the Columbia River. Recharge is mostly from the alluvial aquifer but some recharge may be induced from the Columbia River by wells near the river. Therefore, water quality in the shallow basalts is affected by the quality of water in these sources.

The lack of deep seals in many wells probably allows water from the alluvial aquifer to migrate downward to aquifers in the underlying basalt flows. The commingling of basalt aquifers through open boreholes also provides a pathway by which water can migrate from shallow to deeper basalt aquifers. These pathways may be responsible for some of the contamination that is found in the shallow basalt aquifers.

Chapter 3

Land Use and Nitrogen Loading

in the
Lower Umatilla Basin Groundwater Management Area

Northern Morrow and Umatilla Counties
Oregon

Gerald H. Grondin
Oregon Department of Environmental Quality

Ivan Camacho
Oregon Department of Environmental Quality

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Chapter 3: Land Use and Nitrogen Loading

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CHAPTER 3: LAND USE AND LOADING

Abstract

Lower Umatilla Basin groundwater is very vulnerable to contamination from many different land uses given the basin's soil conditions and hydrogeologic properties. The potential for a land use to contaminate groundwater with nitrate-nitrogen or another constituent relates to loading. Groundwater contamination can occur whenever water (or another liquid) and nitrate (or another contaminant) released exceeds or bypasses:

- removal by crops or other vegetation;
- removal by evaporation; and
- soil capacity to prevent deep percolation.

Nitrate-nitrogen contamination is the most widespread groundwater contamination problem in the basin, but it is not the only problem. This investigation focused on nitrate nitrogen. It explored how much nitrogen each land use releases to the environment, and how much may percolate to deep groundwater. Investigated activities include:

- irrigated agriculture,
- food processing,
- livestock,
- domestic sewage systems,
- military activities,
- solid waste disposal sites,
- electricity generation,
- groundwater recharge projects,
- underground storage tanks,
- hazardous waste handlers, and
- accidents.

Project review found the greatest potential for historic and/or current nitrate loading to groundwater related to irrigated agriculture, food processing, livestock operations, domestic sewage systems, and military activity. A much lower nitrate loading potential exists for the other activities.

Nearly all of the investigated activities could potentially contaminate groundwater with other constituents, in addition to nitrate. Many of the investigated activities are intermixed, occurring in some of the same locations. Future activities also present a concern. Any new contaminants loading by population growth, agriculture, or industrial activities could affect groundwater quality.

Introduction

Background

The land uses within the approximately 550-square-mile Lower Umatilla Basin Groundwater Management Area are best described as diverse, changing and growing.

Water availability, new technology and economic fluctuations have greatly influenced agricultural activities. Food processing and other industries have located and expanded in the area. Military activities, including munition storage, maintenance, destruction and target bombing practices, have occurred in large areas within the basin. Many hazardous and solid waste sites as well as environmental cleanup and accident sites are also located in the groundwater management area.

Population has grown, especially in the Hermiston and Boardman areas. As a result, private wells and septic systems service many residents who live outside city boundaries and their service areas.

All of these activities occurred in a basin where soil conditions and hydrogeologic conditions make groundwater very vulnerable to contamination.

Local Soils

Soil characteristics and chemical behavior in the environment are important influences to consider when assessing groundwater contamination risks. Appendix 3A presents a general discussion about the behavior of nitrogen in the environment (the nitrogen cycle) and soil influences upon nitrogen transport. Additional information about groundwater contamination risks related to Oregon soils and selected chemicals include Kerle and others (1994a, 1994b) and Huddleston (1994). Oregon State University Extension Service maintains the relevant information in soil sensitivity and pesticide properties databases (Vogue, 1994).

Soil surveys for Umatilla and Morrow Counties indicate that basin soils consist of well-drained, fine sandy, and sandy loams (USDA/SCS, 1976, 1988). The soils are low in clay and nutrients and contain little organic matter. Soil pH typically ranges from 6.5 to 7.8 in near surface soil and up to 9.0 in deeper soil. The soil permeability rates from moderate to high permeability, and the available water holding capacity ranges between approximately 0.7 to 3 inches of water per foot of soil (see Appendix 3A).

With sufficient moisture, nitrate-nitrogen leaching in Lower Umatilla Basin soils becomes a moderate to high risk for contaminating groundwater. Under dryland conditions however, the risk of leaching nitrate-nitrogen from basin soils and contaminating groundwater drops to low and very low.

This investigation assessed nitrate-nitrogen groundwater contamination risks of Lower Umatilla Basin soils by using the Oregon Water Quality Decision Aid publication (State University Extension, 1993). The assessment considered local soil characteristics, available moisture, and the depth of groundwater. Nitrate leaching from basin soils to contaminate groundwater rated primarily as a moderate to high risk with sufficient moisture, and a low to very low risk under dryland conditions (Table 3.1).

Table 3.1 Assessed risk of nitrate-nitrogen leaching from Lower Umatilla Basin soils and contaminating groundwater given local soil characteristics.

Soil	Leaching Potential		Groundwater Contamination Risk	
	Dryland	Irrigated	Dryland	Irrigated
Adkins WET	Very Low	High	Very Low	High
Koehler	Very Low	High	Low	High
Pedigo	Very Low	Moderate	Very Low	Moderate
Powder	Very Low	Moderate	Very Low	Moderate
Quincy	Very Low	High	Low	Very High
Quinton	Very Low	High	High to Very High	
Sagehill	Very Low	Low to Moderate	Low	Low to Moderate
Shano	Very Low	Low	Low	Low
Winchester	Very Low	High	Low	Very High

Extracted from Oregon Water Quality Decision Aid, H. Huddleston and others (1993) and used in Oregon HOME*A*SYST, Worksheet #10, Site Evaluation, Oregon State University Extension Service (1993).

Loading Relationship to Groundwater Contamination

The Lower Umatilla Basin's soil conditions and hydrogeological properties make local groundwater vulnerable to contamination from many different land uses. As land uses continue to expand and evolve, other contaminants may potentially leach through basin soils to contaminate groundwater.

This investigation focused on nitrate-nitrogen. Groundwater sampling confirmed that extensive basin areas have nitrate groundwater concentrations near or exceeding the U.S.E.P.A. drinking water standard of 10 mg/L (Plates 4.2 and 4.3).

The potential for a land use to contaminate groundwater with nitrate-nitrogen or other constituents relates to loading. Loading refers to the quantity of water and concentration of nitrate being released to the land.

Groundwater contamination can occur whenever water (or another liquid) and nitrate-nitrogen (or another contaminant) is released and exceeds or bypasses:

- removal by crops or other vegetation
- removal by evaporation
- soil capacity to prevent deep percolation

Good management practices can reduce or prevent the loss of nitrate or other contaminants to groundwater. This investigation reviewed the history of nitrogen released to the environment by different land uses in the basin and how much may percolate to deep groundwater. Table 3.2 provides a summary of local land use practices and nitrogen released.

Table 3.2 Practices and nitrogen related to basin land uses.

	Practices				**Nitrogen**
Activity or Land Use	*Land Application*	*Ponds or Lagoons*	*Solid Waste*	*Infiltration*	
Irrigated Agriculture	Yes				> 20.5 million lbs. applied to crops in 1990 (limited information)
Livestock	Yes	Yes	Yes		> 3.4 million lbs./yr produced in 1980s > 780,000 lbs. land applied some years (limited information)
Food Processing	Yes	Yes			More than 1 million lbs./yr produced since early 1980s
Sewage Treatment	Yes	Yes		Yes	> 140,000 lbs. municipal land applied 1993 9,100 lbs. municipal infiltration beds 1993 4,700 lbs./yr. large on-site system 113,000 lbs./yr. septic systems
Military		Yes	Yes		85 million gallons of explosive washout water to unlined ponds in 1950s-1960s, causing contamination (nitrogen content unknown)
Industrial	Yes	Yes	Yes		Little or none (limited information)
Landfills		Yes	Yes		Insufficient information, possible impact/loading from Depot landfill.
Underground Storage Tanks				Yes	Little or none
Accidents	Yes			Yes	Little or none

Local Land Uses and the Potential for Groundwater Contamination

Irrigated Agriculture

Introduction

Since the 1920s, irrigated agriculture has expanded and changed in the Lower Umatilla Basin. Total available irrigated agriculture acreages in the basin increased from approximately 85,500 acres (134 square miles) in 1965 to nearly 180,000 acres (281 square miles) by 1992 (Table 3.3). Low rainfall and low soil fertility have created the need to irrigate and fertilize most basin crops.

The combination of nutrients (nitrate, phosphorus, etc.) and water applied in irrigated agriculture creates the potential for those nutrients to leach to groundwater. Results from this investigation's evaluation of groundwater chemistry analyses links some of the basin's highest nitrate-nitrogen concentrations to irrigated agriculture.

Any contamination from the approximate 180,000 acres of crops grown in the basin is considered to come from a "nonpoint source." Since the impacts of irrigated agriculture to the environment are dispersed, they are subject to less regulation and monitoring than point sources which interact with the environment at readily identifiable locations. As a result, this investigation found little existing information about nitrogen and other chemical use and fate in the Lower Umatilla Basin related to irrigated agriculture.

Table 3.3 Total irrigated agriculture acreage estimates for the Lower Umatilla Basin.

Period	OWRD Primary Irrigation Water Rights[a] (total acres)	Adjusted OWRD Primary Irrigation Water Rights[b] (total acres)	LANDSAT Photo/GIS Derived (total acres)
1986 - 1992	260,255	233,695	179,880[d]
1976 - 1985	251,556	224,996	171,181[e]
1966 - 1975	200,178	195,058	141,243[f]
1956 - 1965	85,488	85,488[c]	85,488[c]

[a]: Values presented in this column are from the Oregon Water Resources Department Water Rights Database. The values are for primary irrigation water rights, and they reflect the total acreage at the end of each period. These values include acreages yet to be developed.

[b]: Values in this column were derived by using the values in the first column and subtracting undeveloped acreages readily observed on a LANDSAT photograph.

[c]: Undeveloped acreage was not easily identified on the LANDSAT photograph. So, no adjustment of total acres was made.

[d]: This value was derived with the aid of OSU Experiment Station and Morrow County ASCS staff. Irrigated areas by crop were outlined on a LANDSAT photo. The outline was transferred to a map. The map was reviewed and corrected. Then, the map was entered into an electronic Geographic Information System (GIS). The GIS provided the acreage for each crop category. These acreages were totalled yielding the number shown.

[e]: This number was derived by: (179,880) - (233,695 - 224,996) = 171,181 and assumed a constant percentage difference between rates in column 2.

[f]: This number was derived by: (171,181) - (224,996 - 195,058) = 141,243 and assumed a constant percentage difference between rates in column 2.

Irrigated Agriculture: A Groundwater Contamination Source

National Contamination

Groundwater contamination by agricultural chemicals from nonpoint agricultural sources in the United States has been documented. The literature includes Saffigna and Keeney (1977), Spalding and others (1978), Exner and Spalding (1979, 1990), Gormly and Spalding (1979), Hallberg and Hoyer (1982), Spalding and others (1982), Detroy and Kuzniar (1988), Detroy and others (1988), Detroy and others (1990), and the Malheur County Groundwater Management Committee (1991). Most of the groundwater contamination in these studies occurred in cultivated areas underlain by well-drained soils with groundwater five to 30 feet below ground surface (Spalding and Kitchen, 1988).

Regional Contamination

Irrigated agriculture was identified as the primary source of the contamination in Northern Malheur County, Oregon (Malheur County Groundwater Management Committee, 1991). Reconnaissance groundwater sampling in 1985 found nitrate+nitrite-nitrogen concentrations exceeding the 10 mg/L drinking water standard in 34 percent of 107 samples. The maximum concentration found was 49 mg/L. The pre-emergent herbicide, dacthal di-acid, was found in 67 percent of 81 samples analyzed. Subsequent sampling found similar results.

Spalding and others (1982) used nitrogen isotopes to identify sources of nitrate-nitrogen groundwater contamination for the Burbank-Wallula, Washington area, northeast of the Lower Umatilla Basin. They identified a variety of land uses as contributors to the groundwater contamination. However, nitrogen fertilizers and mineralized soil nitrogen from cultivated fields were identified as the dominant contamination source.

Irrigated Agriculture: Factors Affecting Nitrate Leaching

By the early 1980s, nitrate leaching was identified as a problem in most irrigated sandy soils by Lembke and Thorn (1980), Watts and Martin (1981), and others. Research about factors influencing nitrate leaching from irrigated crop soils includes Viets and Hageman (1971), Wendt (1976), McNeal (1976), Letey and others (1978, 1979), Hergert (1986), Spalding and Kitchen (1988), Kalkhoff and others (1992), and others.

Existing research indicates that the method, amount, and timing of irrigation affects nitrate-nitrogen leaching. Watts and Martin (1981) noted irrigation scheduling minimized deep percolation and nitrate-nitrogen leaching. They concluded that irrigation based upon soil moisture requirements or evapotranspiration was the most practical water management method for controlling nitrate-nitrogen leaching.

Research shows nitrogen fertilizer amounts applied to crops also affect nitrate-nitrogen leaching. Spalding and Kitchen (1988) found increased amounts of applied nitrogen fertilizer beyond 100 pounds per acre correlated to increased amounts of extractable nitrate-nitrogen in the unsaturated zone sampled 6 to 60 feet below irrigated farm land (Table 3.4). Hergert (1986) noted that matching nitrogen fertilizer rates more closely to crop yield requirements could substantially reduce nitrate-nitrogen leaching from sprinkler irrigated sandy soil to groundwater.

Table 3.4 Nitrate-nitrogen measured in the unsaturated zone beneath farmlands.

Nitrogen Applied to Farmland (lbs/acre/year)	Nitrate-Nitrogen Measurements for the Unsaturated Zone Between 6 and 60 Feet Beneath the Farmlands		Calculated Nitrate-Nitrogen Concentration in the Top 25 Feet of Groundwater If All the Nitrate-Flushes From the Unsaturated Zone and Mixes Completely With the Top 25 Feet of Groundwater (mg/L)
	Total Nitrate-Nitrogen (lbs/acre)	Average Nitrate-Nitrogen in the Pore Water (ug/L)	
0	131	4.04 ± 2.4	7.7
100	154	3.77 ± 0.9	8.9
200	270	7.30 ± 1.9	16.0
300	721	19.40 ± 13.0	42.0
400	1,260	35.10 ± 16.4	74.0

Source: Spalding and Kitchen (1988)

A review of IRZ Consulting (1993), Hergert (1986), and Letey and others (1978, 1979) indicates both nitrogen application and irrigation need proper management to prevent nitrate-nitrogen leaching below the crop root zone. For example, IRZ Consulting (1993) observed no significant leaching of nitrate below the root zone where good irrigation and soil fertility management was practiced in the Lower Umatilla Basin. Letey and others (1978, 1979) found a weakened correlation between nitrate leached from commercial farm soils and fertilizer applied when fertilizer and water application were considered separately.

Precipitation also contributes to residual nitrate-nitrogen leaching from crop soils during the non-growing season (Hergert, 1986, Detroy and others, 1988, 1990).

Investigation Concern about Pesticides

Although this investigation focuses on nitrate-nitrogen contamination, pesticides are also a concern. Some pesticides have been detected in groundwater from a few basin locations (Appendix 4G). Dacthal was detected recently. It may become a greater problem. Dacthal di-acid was found in 67 percent of 81 samples analyzed in northern Malheur County, Oregon in a study conducted in the late 1980s.

Irrigated Agriculture: Local History

The following discussion is primarily a summary of personal communications with A. Youse, R. Kopecz, L. Fitch, B. Warkenton, F.V. Pumphrey, and D. Wysocki as well as information found in Pumphrey and others (1991) and IRZ Consulting (1993). Table 3.5 provides a chronological overview.

Before 1945

Early Lower Umatilla Basin settlers raised livestock and produced limited crops. Local farmers organized ditch companies and irrigation districts. Shortly after 1900, the West Extension, Hermiston, Stanfield, and Westland districts existed, and the U.S. Bureau of Reclamation began constructing the Umatilla Project. Many dryland acres were converted to irrigated crops after water became available. Flood and furrow irrigation were the standard methods used during this period. By the 1920s, available Umatilla River water for summer irrigation was fully appropriated. Livestock manure was used as a soil amendment and nutrient source for crops (Kopecz, 1994).

Table 3.5 Chronological overview of the major agricultural events in the Lower Umatilla Basin.

Period	Irrigation	Agricultural Production	Location	Water
1910-1919	Dry-land agriculture. Early irrigation methods (no land leveling, flood), farms next to Umatilla river	Small acreage farms until wheat prices stimulate cultivation of sub-marginal lands. Producers grow mostly alfalfa, grains, vegetables, fruits. Dairy and sheep industry begins (1915's) with manure as fertilizer.	NW Umatilla/ NE Morrow Counties	
1920-1939	Dry and irrigated agriculture. More demand for irrigation technology and water supplies. Some well drilling for irrigation uses occurred. The Umatilla River fully appropriated.	Large areas under wheat production. Alfalfa continues as the major crop, with water shortages limiting to two or three cuttings. Cuttings increased when additional water was obtained (from McKay creek). Turkey and chicken became important commodities.	Northern Morrow/ Western Umatilla Counties. With water, Umatilla, Stanfield, Echo and Boardman flourish.	With the Reclamation Act of 1905, BLM forms the Umatilla Project with water districts set for the West Extension, Hermiston, Stanfield and Westland. Small farms in LUB consolidated. Many farmstead wells are abandoned or used for stock only, reverting to grazing (Post-world war I).
1940-1959	Groundwater as a source for irrigation began. 1930's Drought: Incentives for well-drilling.	LUB agriculture diversifies to include large poultry farms and many crops that require irrigation. Sprinkler irrigation begins. Irrigated alfalfa, wheat and field corn were grown in rotation on small acreage (80 A). Other crops included peas, beans, carrots and fruits. Intensive commercial fertilizer use begins soon after World War II. Fertilizer industry expands. Dairy industry is strong		
1960-1979	Groundwater uses include industrial, domestic and municipal. Potato processing plants begin. Columbia river diversion for irrigation occurs (John Day and McNary's Dams construction began).	Early center pivots first in late 1960's. Potato as a high value crop is welcome in LUB. Potato production becomes significant. Large scale watermelon production begins. Fruit trees and other cash crops are grown. Nitrogen fertilizer on the rise. Dairy industry declines.		High groundwater withdrawals prompted the declaration of critical groundwater areas: Ordnance (gravel and basalt), Butter Creek and Stage Gulch.
1980-1989	Efficient water-management, irrigation scheduling is introduced.	Nitrogen fertilization increases more than irrigation in the past 40 years as producers use available technology. Potato production increases to meet high demand. The area is a major wheat producer region in the West US. Center pivot irrigation use at its peak.	Stanfield becomes a center of potato production.	Nitrates in domestic wells first detected in 1984 (Oregon Health Division sampling).
1990s	Center pivot technology continues to be refined. Water shortage issues affecting agriculture arise.	BMP's practices are to be adopted to improve and protect the groundwater quality of LUB. Center pivot technology continues to be refined. Potato continues to be a high value crop.	Center pivots expand throughout LUB	DEQ declared LUB a Groundwater Management Area based on nitrate levels in groundwater. The LUB GWMA local citizen committee looks at potential contributors: N-fertilizer, food processing, animal and industrial waste, domestic septic systems

Source: Personal communication (A. Youse, ODA; R. Kopecz, L. Fitch, B. Warkenton, F.V. Pumphrey, D. Wysocki, OSU; J. Anderson, Morrow Co. N.R.C.S.); IRZ Consulting, 1993; Pumphrey and others, 1991

Lower Umatilla Basin groundwater development began as a limited source of irrigation water during the 1930s and 1940s. Drought conditions during the 1930s prompted U.S. Government incentives for well drilling. Water from McKay Creek was also allocated for irrigation during this critical water period. Despite these water developments, drought and full appropriation of Umatilla River water limited agricultural land development during this time.

1945-1960s

After World War II, intensive commercial fertilizer use and sprinkler irrigation began. Small acreage farmers began rotating crops of alfalfa, wheat and field corn. Other crops included peas, beans, carrots and fruits.

1960s-1970s

The basin experienced an irrigation expansion "boom" during the 1960s and 1970s. The use of nitrogen fertilizer become more intensified during the irrigation expansion. Along with more irrigation, the use of water become more efficient. Wheeled and center pivot irrigation systems were introduced in the basin. Columbia River water became available via pumping and lift stations. Groundwater (including basalt aquifers) was developed for irrigation. Corporate farming began and dryland farms were converted to irrigated wheat and row crops.

Economics and limited water--both from groundwater and surface water--eventually slowed the boom. In some areas, groundwater use exceeded groundwater recharge, prompting the Oregon Water Resources Department to restrict or reduce groundwater use by declaring Critical Groundwater Areas within the basin.

1970s-1980s

The basin continued as a major regional wheat producer. The introduction of center pivot technology coincided with a new demand for potatoes. Intensive potato production in the Lower Umatilla basin increased, using more nitrogen fertilizer and pesticide per acre and in total quantity than other basin crops. Irrigation scheduling for efficient water management was introduced to the basin during this period.

1990s

Total irrigated crop acreage in the Lower Umatilla Basin was approximately 180,000 acres (281 square miles) by 1992 (Table 3.3, Plate 3.1). Of this total acreage, about half produced irrigated wheat and potatoes. Center pivots--which were also used for fertilizer applications--irrigated nearly 90 percent of the total irrigated area (IRZ Consulting, 1993). Many of the farms using center pivots employed some form of irrigation scheduling service (IRZ Consulting, 1993).

About 11 percent (20,000 acres) of the total irrigated area was gravity irrigated. Soils--sands and coarse silt loams--at these sites permit rapid infiltration and make efficient water distribution in the fields difficult. A summary of water and fertilizer use by crop and by irrigation method is presented in Table 3.6.

Crop rotation--growing a series of different crops in a sequence to improve crop and soil quality--has been an on-going practice in the Lower Umatilla Basin. Rotated crops include alfalfa, field corn, potatoes and wheat in a variety of sequence combinations. One rotation may take eight to twelve years.

Irrigated agriculture in the Lower Umatilla Basin continues to change. At least two large farms have been purchased to grow poplar trees for paper production. Drip irrigation has begun at some of these farms.

Table 3.6 Amount of irrigation water used and fertilizer nitrogen applied to Lower Umatilla Basin irrigated agriculture in 1990: comparison between irrigation types.

Crop	System of Irrigation	Amount of Water Used (Range: in/yr).	Evapotranspiration for 9 out of 10 years (inches)	Nitrogen Fertilizer Used (Range: lbs/Ac/yr)[a]
Alfalfa Hay	Sprinkler, Center Pivot, Flood	22-48	34	24
Field Corn	Sprinkler, Center Pivot, Furrow	20-36	29	225-230 (190 = average)
Potatoes (Harvested in September)	Center Pivot, Sprinklers	22-42	31	250-410 (350 = average)
Pasture	Sprinkler, Flood	20-30	41	0-225 (60 = average)
Watermelon	Drip/Wheel Roll, Furrow	3-14 drip 20 other		96-180
Winter Wheat	Center Pivot, Wheel Roll	18-30	25	130-275 (194 = average)

a: Source is Pumphrey and others, 1991.

Irrigated Agriculture: Local Nitrogen Use and Potential Loading

Determining the nitrogen use for the approximately 180,000 acres of basin cropland is difficult. Specific crops are grown on specific acreages on a rotational basis, with each type of crop requiring various amounts of nitrogen. Basin irrigated agriculture does not report crop type, acreage or nitrogen use unlike some other basin land uses.

This investigation has developed a likely range of nitrogen applied to irrigated agriculture, beginning with a very conservative estimate for 1975. That calculated estimate assumes nitrogen applied to irrigated basin crops has annually exceeded 7 million pounds total since 1975 (Appendix 3B). This estimate multiplies 1975 acreage with a nitrogen application rate of 50 pounds per acre. This application rate is very low when compared to application rates in Table 3.6. This estimate appears even more conservative when compared to the basin project analysis of Pumphrey and others (1991). This analysis indicates nitrogen applied to basin irrigated crops in 1990 as exceeding 20.5 million pounds on nearly 132,500 acres.

Nitrogen may remain in the soil after the growing season (see Table 3.7). That nitrogen could leach beyond the crop root zone. A review of the IRZ Consulting (1993) and del Nero (1994) reports indicate nitrogen does penetrate beyond the root zone at some irrigated crop fields within the Lower Umatilla Basin. However, the IRZ Consulting (1993) investigation also indicates nitrogen leaching beyond the crop root zone in the Lower Umatilla Basin can be prevented when water and nitrogen applications are timed and limited to actual crop need.

Ritter (1989) and Vitosh (1991) indicate nitrogen loss to deep percolation at agricultural fields in the U.S. can range from 1 to more than 50 percent depending upon the amount of nitrogen applied, the time of application, soil texture, and the amount and timing of water applied.

Although nitrogen loss to deep percolation in unknown in the basin, a conservative figure applied to the estimated ranges of nitrogen application provides an example. Figuring a five percent nitrogen loss of the 7 million pounds nitrogen applied since 1975, deep percolation from basin fields may have exceeded 350,000 pounds of nitrogen annually. Using the same five percent loss for Pumphrey's estimated 1990 application of more than 20.5 million pounds, at least one million pounds of nitrogen may have been lost to deep percolation.

Table 3.7 The average annual nitrogen budget for intensively managed Lower Umatilla Basin crops.

	ALFALFA (HAY)	FIELD CORN, GRAIN	PASTURE	POTATO-TUBERS	WATER-MELONS	WINTER WHEAT (GRAIN)
YIELD	6.5 T	185 Bu	3 T	480 cwt	16 T	123 Bu
N REQUIRED, LB/A	360	190	190	295		190
N APPLIED/PRESENT:						
N IN CROP RESIDUE, LB/A	40	60	30	90		60
N APPLIED, LBS/A	25	280	110	350	140	195
N RELEASED FROM SOIL, LB/A	300	60	40	80	80	75
N AVAILABLE, LB/A	365	400	180	520	220	330
N OUTPUT:						
DE-NITRIFICATION, LB/A	0	25	0	40	10	10
RESIDUE, LB/A	0	50	0	10		50
N REMOVED, LBS/A	320	130	160	205	130	130
N REMAINING IN PROFILE, LB/A	45	195	20	265	80	140

From "Lower Umatilla Basin Water Management Area Crop Production Practices and Groundwater Quality, May 1991; and individual contact with L. Fitch, OSU Hermiston Ag. Research and Extension Ctr, and V. Pumphrey, Retired Professor, OSU.

Food Processing

Introduction

The food processing industry began small in the Lower Umatilla Basin and expanded quickly in response to the economic demand for processed foods, particularly potato products.

The industry produces large volumes of nutrient and salt-rich wastewater daily. Facilities have spent time and money to improve their wastewater management.

Wastewater has been land applied to crops or pasture and stored in unlined or lined ponds. Sometimes fresh water is used to supplement wastewater. Some solid food waste has been fed to livestock.

Food Processing Wastewater: A Local Groundwater Contamination Source and Concern

Food processing wastewater management through the 1980s has caused some local nitrate-nitrogen groundwater contamination and concern. For example, nitrate-nitrogen contamination of groundwater related to J.R. Simplot Co. sites was reported in 1978. A subsequent investigation in 1984 and 1985 found 30 percent of the nitrogen land applied via wastewater leached beyond the root zone at monitored fields (Sweet, Edwards and Associates, Inc., 1987). Barlow and Dillenberger (1990) included wastewater land application as a possible groundwater contamination source at a Port of Morrow site. In 1988, DEQ staff concluded that nutrient overloading from wastewater land application by the former Columbia Sun, Inc. threatened groundwater quality (DEQ Water Quality File 18702).

When some food processors upgraded facilities to improve efficiency, the amounts of wastewater or nutrients increased. An example can be found in A.E. Staley Manufacturing Co., whose 1990 upgrade increased process wastewater by 40 percent. A.E. Staley increased their total land application area and arranged for consultants to assess leaching losses in the land application soils.

Food Processing Wastewater: Management

Improving food processing wastewater management has followed a pattern of trial and error.

Wastewater management during the 1970s and 1980s included using unlined storage ponds, exceeding crop nitrogen needs, and not considering soil moisture or the growing season (DEQ Water Quality Files 4870, 70590, 81590, 18702). Additionally, some facility upgrades or expansions increased wastewater amounts and/or nitrogen concentrations beyond what existing land application sites could accommodate (DEQ Water Quality Files 18702 and 81590, Barlow and Scott, 1991, Barlow, Scott and Urban, 1992).

Eventually, groundwater contamination became a growing concern. Facilities gradually improved their wastewater management, and DEQ successively revised facility water quality permits with compliance schedules for reducing nutrient loading. Examples are documented in DEQ Water Quality Files 9584, 18702, 48780, 70590, 81590, Barlow (1990), Barlow and Dillenberger (1990), Barlow, Scott and Urban (1992), Barlow and Tipton (1993), Columbia Sun (1992), CH2MHill (1990, 1991a, 1991b, 1992), Port of Morrow (1991), Portwood and Rankin (1993), Ruby (1993), Ruby and Barlow (1991), Ruby, Scott, and Urban (1992), and Urban and Scott (1991).

The most common approach to improving wastewater management involved successive expansion of land application acreage. Nearly every food processing facility has increased land application acreage, with the large operations expanding from a few hundred acres to more than 2000 acres over the past decade (Appendix 3C, Plate 3.2). The acreage needed is figured according to the agronomic rates for both water and nitrogen of the crop being irrigated by the wastewater.

Other wastewater management improvements include using lined ponds, developing or increasing winter wastewater storage, and monitoring wastewater, freshwater, chemicals, crops, soils, and groundwater. Examples are found in Barlow (1990), Barlow and Dillenberger (1990), Barlow and Tipton (1993), CH2mHill (1991b), Columbia Sun (1992), Port of Morrow (1991), Portwood and Rankin (1993), Ruby (1993), Ruby and Barlow (1991), Urban and Scott (1991), and DEQ Water Quality File 70590.

Efforts to improve wastewater management have been executed using information provided by consultants. For example, early on it was believed by the industry and their consultants that year-round land application would not affect groundwater quality. Even recently, various industry reports have concluded that the season of applying process wastewater is relatively unimportant to nitrogen loading, that travel time to groundwater is long (11 to more than 30 years), and that the basalt aquifer is not hydraulically connected to the overlying alluvial aquifer (Barlow, 1990, 1991, Barlow and Dillenberger, 1990, Barlow and Scott, 1991a, 1991b, Ruby and Barlow, 1991, Barlow, Scott and Urban, 1992, Barlow, Urban, and Scott, 1992, Ruby, Scott and Urban, 1992). These conclusions are not born out by this investigation or by the presence of high nitrate values beneath some of the land application sites. This investigation found travel times from the land surface to groundwater to be 1-18 months. It also concluded that there is a hydraulic connection between the alluvial and basalt groundwater systems.

Food Processing History

Before 1945

Turkey slaughter houses operated in Hermiston from the 1920s through the 1950s and in Stanfield during the 1940s (Kopecz, 1994). A Hermiston cannery cooperative served local farming families by canning fruits, vegetables and fish from the 1920s through the 1950s. Any wastewater was discharged to city sewers (Kopecz, 1994).

1945-1960s

Very little vegetable food processing occurred in the basin before 1970 (Fitch, 1994, Kopecz, 1994). Potato fresh pack sheds such as Walchli Potato and Bud Rich operated in the Hermiston area during the 1960s. They produced little or no wastewater (Fitch, 1994). Kosmos Potato, the basin's first specialty potato processor, operated during the 1960s and 1970s (Fitch, 1994).

Meat slaughter houses operated north and northeast of Hermiston and in Stanfield (Fitch, 1994).

1970s-1980s

Large-scale potato processing for fast food and other uses settled into the region east of Boardman and south of Hermiston during the 1970s. The potato processing plants expanded to dominate all local food processing activities during the 1980s. Many facilities generate large volumes of nutrient and/or salt rich wastewater daily.

Potato processing wastewater some caused local nitrate-nitrogen groundwater contamination during this period (Sweet, Edwards and Associates, Inc., 1987). Wastewater management included land application at limited acreages, during all seasons, nutrient amounts exceeding crop needs, and storage in unlined ponds as noted earlier.

1990s

Today, the facilities are expanding their land application areas, building or expanding lined wastewater storage, scheduling wastewater application to meet crop nutrient and water needs, and increasing monitoring of crops, nutrients, water, soils, and groundwater as noted earlier.

Food Processing Nitrogen Loading

Estimated land application area and nitrogen loading for food processing facilities for selected periods are presented in Table 3.8, with individual facilities presented in Appendix 3C. The total wastewater land application acreage has expanded from nearly 825 acres in 1977, to nearly 7,500 by 1992. Nitrogen land application rates generally decreased after 1991. The rates ranged from 14 to more than 2,500 pounds per acre per year from the 1970s through 1991. Since 1991, the application rates have ranged from 3 to nearly 680 pounds per acre per year. The decrease coincided with application area expansion.

This investigation did not determine nitrogen lost to deep percolation. However, recent consultant estimates of nitrate-nitrogen escaping annually to deep percolation range from 10 to 27 pounds per acre (Barlow, 1990, Barlow and Scott, 1991a, 1991b, Barlow, Urban, and Scott, 1992). A mid-1980s Cascade Earth Science investigation found 30 percent of the nitrogen land applied via wastewater leached beyond the root zone at the fields monitored (Sweet, Edward and Associates, Inc., 1987).

The process wastewater also contains salt which crops do not use. Salt application rates currently range in excess of 3,000 to nearly 30,000 pounds per acre per year at some sites (Appendix 3C).

Future salt and nitrogen loading could be affected by several proposed power cogeneration facilities that would coordinate with food processors to blend cooling tower water with food processing wastewater (Barlow and Tipton, 1993, IDA-West Energy Company, 1993). With any changes to the chemistry of the wastewater, food processors will need to adjust their wastewater management techniques accordingly.

Table 3.8 Approximate food processing industry total land application area and total nitrogen loading in the Lower Umatilla Basin for selected periods.

Period	Total Acreage (acres)	Total Nitrogen or TKN Loaded[a] (total pounds/yr)	Average Nitrogen or TKN Loading Rate (pounds/acre-yr)
1977 - 1980	824	-	-
1981 - 1984	2,097	>1,074,361[b]	>512[b]
1985 - 1989	2,805	2,506,446	894
1991 - 1992	7,492	1,591,898	212

Values in this table were derived from Table 3.9.

[a] Values in this column should be considered approximate values only

[b] These values are missing nitrogen loading by Port of Morrow.

Livestock

Introduction

Livestock, both historically and currently, are a potential source of groundwater contamination. Various livestock operations have been present in the Lower Umatilla Basin since approximately 1900 (Kopecz, 1994, Reed-no date). Livestock production has contributed to the local economy and provided valuable crop nutrients.

Livestock Waste: A Groundwater Contamination Source

Groundwater contamination by livestock waste has been documented in the U.S. (Stewart and others, 1967; Spalding and Fulton, 1988; Spalding and others, 1982.)

Livestock waste contains valuable nutrients. The nutrient content and other waste characteristics depend upon the animal species (Table 3.9). Nitrogen is the primary livestock waste component that contaminates groundwater (Goldberg, 1989). However, elevated chloride concentrations often accompanies that contamination (Spalding and Fulton, 1988). Phosphorous and potassium are often retained in the soil layer or other unsaturated material above groundwater (Goldberg, 1989).

How livestock waste contaminates groundwater depends on the management of waste stockpiles, waste ponds, and/or land application sites. At least one confined animal feeding operation in the basin has occasionally had problems with managing animal waste (DEQ Water Quality File 81591, J-U-B Engineers, Inc., 1987, 1989). Proper waste management can prevent most problems. Leakage from self-sealing lagoons can be expected, given basin soils. High nitrate-nitrogen concentrations detected around one self-sealing lagoon indicates seepage from local unlined lagoons is occurring (see Chapter 4). Additionally, high nitrate concentrations and some organic nitrogen detected near other livestock facilities, as well as some nitrogen isotopic analyses, indicate livestock operations have contributed to the basin's groundwater contamination (see Chapter 4).

Table 3.9 Nutrients in livestock manure at the time of land application.

Specie	Dry Matter	Ammonium-Nitrogen	Total Nitrogen	P_2O_5	K_2O
	percent	------------ Pounds per Ton Manure-----------			
Swine	18	6	10	9	8
Beef (concrete lot)	52	7	21	14	23
Beef (dirt lot)	15	4	11	7	10
Dairy	18	4	9	4	10
Sheep	28	5	18	11	26
Poultry	45	26	33	48	34
Turkey	22	17	27	20	17
Horse	46	4	14	4	14

Source: Livestock manure management for efficient crop production and water quality preservation, Publication WQ 12, 1992; Michigan State University, Cooperative Extension Service.

Managing Livestock Waste

Animals confined to feedlots and other small areas produce waste that is often collected, stored, and land applied to crops or pasture. This investigation found limited information about annual waste management for basin facilities.

Generalized Lower Umatilla Basin confined animal waste management includes the following. Waste is drained or washed down out of the animal holding area or pens or it is excavated after drying. Liquid waste may contain manure, stormwater runoff, animal feed and water. Sludge is separated from the wastewater at some facilities. Sludge and wastewater are temporarily stored at stockpiles and self-sealing evaporative ponds or lagoons until removed, sold, or land applied to crops and pasture. The ponds and lagoons are cleaned seasonally (J-U-B Engineers, 1987, 1989, DEQ Water Quality File 81591, ODA CAFO General Permit File Facility ID Numbers 12903, 103222, 36630).

Some waste management problems have been observed at two large cattle feedlots. Staff involved in this investigation observed several feet of manure accumulated on bare ground in animal pens adjacent to a deep unlined Feedville Road ditch nearly full with animal waste runoff at C & B Livestock, Inc. C & B is a feedlot with a cattle population fluctuating between 12,000 and 25,000 head.

J.R. Simplot Co., a feedlot designed for 32,000 cattle, but operating with 20,000 head average, stockpiled manure on bare ground and used manure to fill low lying areas when crop land became unavailable for land application of waste from 1983 to 1987 and possibly after 1989 (J-U-B Engineers, Inc., 1987, 1989, DEQ Water Quality File 81591). Additionally, J.R. Simplot's groundwater monitoring indicates that seepage from self-sealing, evaporative, unlined lagoons is responsible for elevated nitrate-nitrogen concentrations in local groundwater (DEQ Water Quality File 81591, Chapter 4).

Livestock History

A summary of the basin's livestock history is presented in Figure 3.1. The location of current and historic livestock operations are shown on Plate 3.3. The locations were obtained from DEQ water quality permit files and field visits to sites identified by OSU Extension Service staff, OSU Experiment Station staff, and local residents. Many livestock facilities may be missing from Plate 3.3 due to the difficulty of obtaining a complete list of historic and active facilities.

Before 1945

Livestock operations have been present in the Lower Umatilla Basin since approximately 1900 (Kopecz, 1994). Dairies began operating in the basin around 1915 and grew into an important industry by World War II (Kopecz, 1994). Turkey and chicken operations became established in the Lower Umatilla Basin during the 1920s (Pumphrey, 1994). Sheep and hogs also were introduced early to the area.

Livestock manure has been valued and used in the Lower Umatilla Basin since the early settlements. Very little, if any, commercial fertilizer was applied to crops from 1910 to 1930 (Kopecz, 1994). Instead, manure additions to the soil provided necessary crop nutrients and improved the soil tilth, water holding capacity, and resistance to wind erosion.

1945-1960s

Beef cattle operations in the Lower Umatilla Basin grew in importance after the 1950s (Fitch, 1994). Many dairy operations closed or consolidated into beef operations when Oregon required sanitation improvements (Kopecz, 1994). Manure use for crops declined after World War II when the local dairy industry declined and produced less manure.

The rise and decline of hog operations in the Lower Umatilla Basin nearly parallels the history of Lower Umatilla Basin dairies. Canadian competition and other economic factors caused hog operations in the basin to decline (Kopecz, 1994, Pumphrey, 1994).

From 1945 through the 1960s, several large turkey facilities operated in the basin. Two facilities that remained active until the late 1960s operated with 45,000 and 90,000 turkeys, respectively (Kopecz, 1994, Fitch, 1994). Then, turkey operations in the basin declined due to economic conditions (Kopecz, 1994).

1960-1980s

Beef cattle remained active in the basin in the 1960s and 1970s. Permits for handling livestock waste were issued to four confined animal operations in the 1980s including two cattle feedlots, a dairy, and a hog facility (DEQ Water Quality File 81591, ODA CAFO General Permit File Facility ID Numbers 12903, 103222, 36630). Two fish hatcheries operated by Oregon Department of Fish and Wildlife received waste discharge permits from DEQ in the 1980s (DEQ Water Quality Files 64478, 107454).

1990s

Some sheep ranches and a few dairies remain in operation within the basin and a number of beef facilities currently operate across the Lower Umatilla Basin (Plate 3.3). The local cattle beef industry sustains continued manure use in the Lower Umatilla Basin. Of the facilities permitted in the 1980s, the hog facility ceased operation and one large cattle feedlot suspended operation for several years beginning mid-1991 (DEQ Water Quality File 81591, J-U-B Engineers, Inc., 1994).

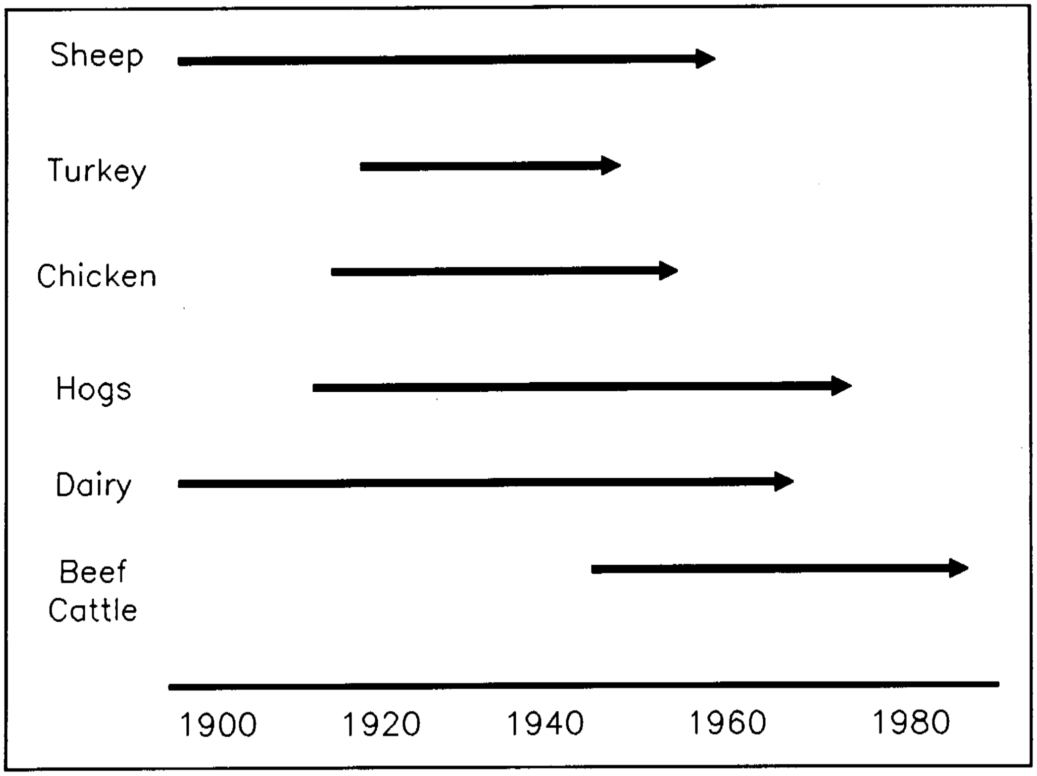

Figure 3.1 Approximate Operational Period for Several Livestock Commodities in the Lower Umatilla Basin.
(Source: Fitch, 1994, Pumphrey, 1994, and Kopecz, 1994).

Livestock Waste Nitrogen Loading

Information necessary to calculate basin nitrogen loading from livestock waste is very limited. Some 1980s information exists for two large beef cattle operations (averaging a total of 38,500 head), one large hog operation (averaging 13,500 head) and one dairy (averaging 200 head)(see Appendix 3D). Waste management at the facilities included waste removal from confined animal areas, waste storage in unlined ponds or stockpiles, and land application. The amount of waste stockpiled, stored in ponds and land applied varied by year.

Project calculations summarized in Appendix 3D indicate that basin livestock probably produced more than 3.4 million pounds of total nitrogen per year during the 1980s. However, nitrogen loss during storage possibly decreased the total nitrogen available for land application to about 780,000 pounds per year.

The total animal waste application acreage varied during the 1980s, while the amount of waste and total nitrogen remained relatively constant. The total acreage varied between 1,350 acres some years and more than 14,350 acres other years (Appendix 3D). The actual acreage utilized each year was not obtained.

Actual nitrogen load application rates were not determined due to insufficient information. However, limited data for three facilities indicates annual nitrogen application from livestock waste during the 1980s may have exceeded 15.7 to 78.2 pounds per acre. Consultants for one of these facilities recommended applying 300 to 450 pounds per acre (J-U-B Engineers, Inc., 1987, 1989). That facility occasionally stockpiled waste at a 10-acre site during years when no land application acreage was available. Nitrogen annually stockpiled possibly exceeded 35,000 pounds per acre.

Nitrogen leaching to deep percolation from land application, pond, stockpile and animal yard sites was not determined due to insufficient information.

Domestic Sewage

Introduction

Domestic sewage facilities can be separated into one of three types: municipal, large on-site, or individual on-site systems. Municipal sewage treatment systems serve cities with higher population densities. Large on-site systems serve small communities or large facilities while individual on-site systems generally serve single rural residences outside existing sewage treatment system connections.

Domestic sewage wastewater and sludge management at these facilities can include treatment, discharge to surface water, storage in ponds, land application, burial, or subsurface discharge through infiltration beds, sandfilters, drainfields or disposal wells.

All domestic sewage is regulated through a combination of local, state and federal laws which have been administered by the State Sanitary Authority until 1969, DEQ since 1969 and county agencies under contract to DEQ.

Municipal Domestic Sewage: A Groundwater Contamination Source

Infiltration to groundwater by some basin municipal sewage treatment facilities has been a concern. The Irrigon and Echo facilities have documented examples of infiltration to groundwater.

Irrigon uses a two-acre, 10-bed rapid infiltration basin system to treat and discharge the community's domestic wastewater. Nitrogen concentrations have been reported as high as 52 mg/L in the percolate below the infiltration beds (SCM Consultants, Inc., 1990). Groundwater sampling data submitted by Irrigon indicates the nitrogen concentration in groundwater upgradient of the treatment system may be higher than in the percolate from the infiltration beds (DEQ Water Quality File 42490, Chapter 4).

Seepage from the City of Echo's sewage treatment lagoons occurred from 1976 to 1985 due to incomplete construction. Approximately 85 percent of the sewage in the first cell escaped to the subsurface and at least one domestic well may have been impacted (DEQ Water Quality File 26200).

On-Site Domestic Sewage: A Groundwater Contamination Concern

North American septic systems have caused elevated nitrate-nitrogen and/or chloride in soils and groundwater (Salvato, 1972, Viraraghaven and Warnock, 1976; Brown and others, 1979, Chen, 1988, Robertson and others, 1991). A groundwater investigation for the Burbank-Wallula, Washington area, northeast of the Lower Umatilla Basin, found septic systems contributed less nitrate-nitrogen to local groundwater than other sources (Spalding and others, 1982).

Oregon examples of septic systems contaminating groundwater include mid-Multnomah County, Santa Clara/River Road, Clatsop Plains, LaPine and Irrigon. Most of these areas were required to build and use a sewer system. The City of Irrigon experienced groundwater contamination from Irrigon area septic systems in 1977 and 1978. Three hepatitis outbreaks involving 17 people prompted the Oregon Health Division to declare an "Imminent Health Threat" to Irrigon's groundwater supply (DEQ Water Quality File 42490). In 1978, City of Irrigon samples confirmed drinking water contamination and linked it to inadequately treated sewage percolating through shallow coarse soils (sand and gravel) to groundwater (DEQ Water Quality File 42490).

This investigation has concluded that individual septic systems are contributing to elevated nitrate-nitrogen in groundwater along the Columbia River between Irrigon and Umatilla and other areas (see Chapter 4). Some ares with a high density of septic systems have lower concentrations in groundwater due to dilution from local surface water. The Diagonal Road vicinity near Hermiston is a good example (see Chapter 4). Concentrations could increase with any changes to nearby canals operations.

A large on-site domestic sewage collection and treatment system serves the Administration Area of the U. S. Army Umatilla Depot Activity west of Hermiston (DEQ Water Quality File 91000). Nitrate-nitrogen concentrations in groundwater greater than 10 mg/L have been detected in the Administration Area. Ritchie and others (1992) identify crop and animal operations south of the Depot as the likely source.

Municipal Domestic Sewage: Waste Management

Municipal sewage treatment facilities generally have a limited operating life, with construction and improvements usually introduced to keep up with population growth, correct problems, and meet new regulations. Municipal plants either discharge treated wastewater to nearby surface water, land apply it to vegetation or allow it to infiltrate into groundwater. The solid waste, or sludge, is usually land applied, although it may also be disposed of in a landfill.

Municipal sludge is generally applied within agronomic rates. However, sludge may have a variety of potential contaminants in varying concentrations, so sludge is regulated by its most limiting factor. For example, if heavy metals are the most concentrated contaminant, sludge application may not achieve agronomic rates as it is applied at the safest rate for heavy metals.

Over the past three decades, basin municipal sewage treatment plants have shifted to more land application and less direct discharge to surface water. As part of this shift, municipal facilities have also introduced more ponds, stricter land application controls and consideration of the types of vegetation receiving land application of sludge and wastewater (DEQ Water Quality Files 9104, 26200, 38212, 84405). The land application loading for each facility is presented in Appendix 3E. Facility locations are shown on Plate 3.4.

Portland and Washington County's Unified Sewerage Agency ship sewage sludge to the Lower Umatilla Basin where it is land applied at Madison Ranch south of Hermiston. Sludge is applied within agronomic rates (DEQ Water Quality Files 70725, 90770). The land application loading for each facility is presented in Appendix 3E.

On-Site Domestic Sewage: Waste Management

Most basin large on-site facilities discharge domestic sewage water to drainfields or bottomless sand filters (DEQ Water Quality Files 91000, 100128, 100132, 03745, 105049). Some facilities may provide additional treatment through the use of recirculating sand filters prior to discharge. At least one system uses a lined faculative lagoon, and another continues to use dry wells (DEQ Water Quality Files 64710, 103746). Sewage sludge is often removed and treated off-site. At least one facility has buried its sludge at a landfill (DEQ Water Quality File 91000). Loading for each facility with a water quality permit is presented in Appendix 3F. Facility locations are shown on Plate 3.5.

Owners of individual on-site septic systems are responsible for maintaining their own systems. Proper maintenance includes removing solids from the septic tank at least once every five years.

Domestic Sewage History

In the basin, six cities operate municipal sewage treatment plants. Other facilities include six large on-site systems on file at the DEQ Water Quality Division and 4,375 individual septic systems identified by this investigation. Some sewage treatment facilities within the Portland metropolitan area currently export sludge for land application in the basin.

Before 1970

Individual on-site sewage systems offered the first basin sewage treatment. Hermiston provided one of the first municipal sewage treatment systems for the area, replacing it in 1951 (DEQ Water Quality File 38212). Stanfield constructed a sewage treatment system in 1952 as did Boardman before 1967 (DEQ Water Quality Files 9104, 84405). The Oregon Department of Transportation (ODOT) constructed public rest areas at two Interstate 84 locations, west of Boardman and west of Stanfield, by 1967 (DEQ Water Quality Files 64710, 105049).

1970s-1980s

The City of Echo started constructing and using of a sewage lagoon treatment plant in 1976, which remained incomplete until 1985 due to lawsuits and funding problems. Sewage seepage occurred during that period. Echo's current NPDES permit allows discharge of treated wastewater to the Umatilla River from April through December (DEQ Water Quality File 26200).

The City of Umatilla's current wastewater treatment facility was constructed in 1980. It replaced a treatment plant built in 1974 that had also serviced the community of McNary. This facility was built to serve a population of 10,000 in Umatilla and Port of Umatilla industries. Umatilla's NPDES permit allows wastewater discharge to the Columbia River (DEQ Water Quality File 90659).

In 1980, a Boardman facility capable of serving 4,000 people began operation. The facility includes wastewater storage in a lined lagoon and land application on a 40-acre site. Boardman's 1981 and 1987 WPCF permits required groundwater monitoring in the land application area (DEQ Water Quality File 9104).

In 1981, the city of Hermiston began using its current sewage treatment plant by servicing 10,000 people. The facility was constructed to service a population of 25,000. The NPDES permit, issued for the facility in 1983 and 1989, allows wastewater discharges either to the Umatilla River or by land application to vegetation. The 1989 permit added requirements to monitor influent and sludge as well as develop a sludge management plan. Hermiston land applies its sludge (DEQ Water Quality File 38212, Caldwell, 1993).

Irrigon addressed the late 1970s hepatitis outbreak and sewage contamination of groundwater by constructing a controversial sewage treatment system in 1989. Individual on-site septic tanks discharge to a two-acre, 10-bed rapid infiltration basin treatment area. The system failed to meet its WPCF permit requirements (DEQ Water Quality File 42490, SCM Consultants, Inc., 1990, D'Eagle, 1994).

Several large on-site disposal systems failed or were improved during this time. A lined lagoon replaced the Boardman public safety rest area's sewage disposal system in 1977 (DEQ Water Quality File 64710). The Hinkle Railroad Inn made efforts to correct problems with its septic system and drainfield in 1986 (DEQ Water Quality File 100132). The Shady Rest Mobile Home Court and the Vista Estate Mobile Home Court systems have failed. Improvements to the systems were accompanied by a DEQ requirement to connect to an approved sewer system when it becomes available (DEQ Water Quality Files 103745 and 100128).

1990s

Individual on-site septic systems continue to be commonly used outside of municipal areas. One large on-site system, the Stanfield rest area replaced septic systems with recirculating gravel filters in 1992 (DEQ Water Quality File 105049).

The City of Stanfield began upgrading its sewage treatment facility in 1993. It added a storage pond to spray-irrigate wastewater at its sludge land application site. By 1994, treated effluent was expected to be discharged to the Stage Gulch Irrigation Ditch from November to March and spray irrigated from April-October (DEQ Water Quality File 84405). Discharge to the Stage Gulch Irrigation Ditch may influence groundwater quality. Consultants have identified the unlined ditch as a local groundwater recharge source (Barlow, Scott, 1991, Barlow, Scott, Urban, 1992). Stanfield's sewage treatment facility is currently not required to conduct or report any groundwater monitoring.

In 1989, DEQ authorized land application of the City of Portland's Columbia Boulevard Wastewater Treatment Plant Triangle Lake Lagoon sludge at an agronomic rate to Madison Ranch property west of Butter Creek Highway and south of Interstate 84 (DEQ Water Quality File 70725). Land application began in March 1990, stopped after June 1991, and restarted in July 1992 (DEQ Water Quality File 70725). Sludge quality, a concern when Portland detected dioxin in the sludge in 1988, was declared safe in March 1991 by the U.S. Department of Agriculture (DEQ Water Quality File 70725, The Oregonian, 1991).

DEQ declined the City of Portland's 1990 requests to increase the sludge land application to greater than agronomic rates. However, DEQ did allow increasing the sludge application rate from 5.0 to 6.5 dry tons per year (150 pounds of nitrogen per acre per year) as long as dioxin was kept within an acceptable level. The land application of sludge operates under a DEQ authorization that includes limits on land application areas and rates, soil testing and a fallow period before livestock grazing or feed harvesting (DEQ Water Quality File 70725).

The Unified Sewerage Agency (USA) operates multiple wastewater treatment facilities in Washington County, Oregon. DEQ approved land applying digested, dewatered, cake sludge year-round to 803 acres at Madison Ranch in August 1993 (DEQ Water Quality File 90770). USA currently seeks to land apply its sludge year-round on 325 additional acres at Madison Ranch. The non-irrigated land application area could significantly expand if Madison Ranch purchases approximately 9,700 acres of dry land west of the Ranch (Richwine, 1994).

Domestic Sewage Nitrogen Loading: Municipal

The total acreage available to land apply treated municipal waste in the Lower Umatilla Basin expanded from less than 400 acres before land application of Portland and Washington County sludge to more than 2,700 acres by 1993. The historic and recent average annual land application rates for nitrogen from domestic sewage ranged from none applied to nearly 215 pounds per acre (Table 3.10, Appendix 3E).

Some deep percolation of municipal sewage wastewater does or did occur in the basin. The City of Irrigon discharges sewage wastewater to the subsurface via infiltration beds within a 2-acre area. The average nitrogen loading from the infiltration beds to the subsurface apparently increased from about 2,200 pounds per acre in 1990 to about 4,500 pounds per acre in 1992 (Appendix 3E). One City of Echo sewage treatment lagoon cell, that was at least partially sealed, reportedly lost 85 percent of the lagoon influent to subsurface seepage from 1976 until the lagoon's completion in 1985 (DEQ Water Quality File 26200). The average nitrogen loading from the lagoons to the subsurface in 1983 was about 195 pounds per acre (Appendix 3E).

Domestic Sewage Nitrogen Loading: On-Site

The large on-site sewage treatment systems identified by this investigation primarily discharge wastewater to the subsurface via drainfields or bottomless sand filters. One facility also uses dry wells and another uses a faculative lagoon with occasional land application. Deep percolation of nitrate-nitrogen from these systems appears to annually exceed 4,700 pounds over an area exceeding 10 acres (Table 3.11, Appendix 3F)

This investigation assumed all units identified outside sewer service areas are active and use individual on-site systems which discharge directly to the subsurface via drainfields. The annual average nitrate-nitrogen discharge from each household was calculated as 26 pounds per year per system, derived from local municipal sewage treatment facility data, literature and DEQ on-site system experiments. Deep percolation of nitrate-nitrogen from these systems may annually exceed 113,000 pounds for the entire basin, and range from 0 to about 6,200 pounds within square mile sections (Table 3.12, Appendix 3G).

Plate 3.5 shows the distribution density of all the unsewered units for each square mile. The highest densities occur near Hermiston, Boardman and Irrigon.

Table 3.10 Estimated nitrogen loading in the Lower Umatilla Basin by municipal sewage treatment facilities during 1992-1993.

Facility	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
City of Boardman[a] (1993)	Poplar trees	10	Nitrogen	pounds/acre-year	-	-	69
City of Echo[b]	Sludge land application area	54.5?	Nitrogen	Pounds/acre-year	0	0	0
City of Hermiston (1992)	Poplar trees and Wadekamper Ranch	161	Nitrogen	pounds/acre-year	139	6	22
City of Irrigon (1992)	Infiltration beds	2	Nitrogen	pounds/acre-year	-	-	4,550[c]
City of Stanfield (1993)	Sludge land application area	48	Nitrogen	pounds/acre-year	-	-	16
City of Umatilla (1992)	Current sludge land application area	7.7[d]	Nitrogen	pounds/acre-year	-	-	212
City of Portland Sludge (1992)	Madison Ranch	1809	Nitrogen	pound/acre-year	-	-	75
Unified Sewerage Agency Sludge (1993)	Madison Ranch	630	Nitrogen	pounds/acre-year	-	-	-[e]

See Appendix 3E for estimated nitrogen loading tables for individual facilities.

[a] City of Boardman land applied wastewater to 40 acres of alfalfa from 1986 - 1990. No land application occurred in 1991 or 1992.

[b] From 1976 to July 1985, the City of Echo lagoons lost approximately 85 percent of the influent to subsurface seepage.

[c] This value reflects nitrogen leaving the infiltration bed to the subsurface after nitrogen reduction/losses in the beds.

[d] Historic sludge land application area was an 80 acre site.

[e] Land application began in September 1993.

Sources: DEQ files: 26200, 42490
DEQ Northwest Regional Office Staff
DEQ Pendleton Office Staff
SCM Consultants, Inc (1990)
Beyeler (1993)
Richwine (1994)

Table 3.11 Estimated nitrogen loading in the Lower Umatilla Basin by selected large on-site sewage treatment systems.

Year	Facility	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1978 - Present	Hinkle Railroad Inn (drainfield)	2.41	Nitrate-N	pounds/acre-year	551[a]	-	-
1993[b]	OR Dept of Transportation Boardman Rest Area (land application area)	5	Nitrogen	Pounds/acre	-	-	60
1993	OR Dept of Transportation Stanfield Rest Area West Bound (drainfield)	0.17	Nitrate-N	pounds total	-	-	244
1993	OR Dept of Transportation Stanfield Rest Area East Bound (drainfield)	0.17	Nitrate-N	pounds total	-	-	244
1991	Shady Rest Mobile Home Park (bottomless sand filter)	0.19	Nitrate-N	pounds total	-	-	441
1990	US Army Umatilla Depot Activity Administration Area (drainfield)	0.23	Nitrate-N	pounds total	-	-	2,483
1986	Vista Park Mobile Home Park (drainfield)	4.13	Nitrate-N	pound/acre	-	-	752

See Appendix 3F for estimated nitrogen loading tables for individual facilities.

[a] Value is based on the maximum discharge allowed by WPCF permit number 100195

[b] The only land application event since the facility began operating in 1977.

Facilities operating with drainfield values came from using available discharge flow information and by using a 40 mg/l nitrate-nitrogen concentration for drainfield effluent percolating by groundwater. The 40 mg/l nitrate-nitrogen concentration came from EPA (1980) and DEQ (Ronayne et al., 1982) literature as well as recent work conducted by DEQ employee Henning Larsen.

Sources: DEQ files: 100132, 105049, 103745, 91000, 100128
DEQ Pendleton Office Staff
Bochsler and Hansen (1990)
Joleen Odens (1994)

Table 3.12 Estimated annual total nitrate-nitrogen loading from domestic septic systems in the Lower Umatilla Basin.

Units	Units Counted[a]	Estimated Annual Nitrate Loading[b] (pounds/year)
Homes/Mobile Homes	4,015	103,846
Public Places (Churches, Schools, Parks, Public Buildings)	40	1,035[c]
Work Places (Business, Shop/Industry)	320	8,277[c]
Grand Total	4,375	113,157[d]

[a] Units outside of sewer services areas identified from Morrow and Umatilla County Records. Some units may not be occupied. Other units may be serviced by large on-site systems.

[b] Estimate calculations used 25•8,644 pounds of nitrate-nitrogen per year per unit. This value was derived from using an average 213.3 gallon per day wastewater discharge rate for households/small businesses and 40 mg/l average nitrate-nitrogen concentration in septic tank effluent percolating to groundwater. The wastewater discharge rate for households/small businesses was calculated from Lower Umatilla Basin sewage treatment facility data. The 40 mg/L average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne et al., 1982) literature as well as recent work conducted by DEQ employee Henning Larsen.

[c] The total amount of nitrate-nitrogen loading for these units may be larger than the estimates shown. The total population served by these units was not determined from the sources reviewed. However, some of these units may be inactive, out buildings without toilet facilities, or units with an alternate sewage treatment system.

[d] The column total differs from the number shown by 1 pound/year due to errors introduced by rounding numbers to a whole number.

Military Sites

Introduction

A variety of military activities involving metals, ammunition, bombs and chemical agents have occurred over 180 square miles at two Lower Umatilla Basin facilities since 1941. These activities have involved the U.S. War Department, Army, Army Air Corp, Navy, and Air Force. The Oregon Department of Veteran's Affairs acquired 91 square miles in 1963, which it later leased to Boeing and the Port of Morrow. The currently active military areas are 30.8 square miles at the U.S. Army Umatilla Depot Activity and 58.3 square miles at the U.S. Navy Boardman Bombing Range (Dawson and others, 1982, Mahannah and others, 1993, Hafley, 1992, DEQ Environmental Cleanup File 1030).

The bombing range originally covered 150 square miles until 1960 (see Plate 3.6). Environmental concerns primarily relate to military ordnance. Bombing practice from 1942 to 1960 left unexploded bombs, practice bombs, incendiary bombs, artillery shells, rockets, and 50 caliber ammunition at target sites. Additionally, World War II war games littered a 36-square-mile area inside the range with military ordnance (Hafley, 1992, DEQ Environmental Cleanup Site File 1030). Inspection, assessment, and cleanup activity has occurred at range sites outside the current Navy bombing range since 1989. In 1992, DEQ environmental cleanup staff concluded these sites pose a minimal threat to the surrounding population and the environment (Hafley, 1992, DEQ Environmental Cleanup Site File 1030).

Military site cleanup primarily involves the 30.8 square mile U.S. Army Umatilla Depot Activity between Hermiston and Boardman, Oregon (Plate 3.6). The U.S. government owns 17,054 acres, and 2,674 acres is privately owned with rights reserved for farming and grazing livestock (Mahannah and others, 1993). The Depot primarily stores chemical and conventional munitions, but other activities included metal and ore storage, munition maintenance, disposing explosive washout water to lagoons, disposing missile fuels and pesticides at pits, and burning or burying sewage sludge, munitions, and scrap (Dawson and others, 1982). The Army has postponed closing the Umatilla Depot Landfill until 1997 to allow proper disposal of Depot environmental cleanup site materials (Liggett, 1994).

The Depot is scheduled to close under the Base Realignment and Closure (BRAC) program with plans for on-site incineration of chemical agents (Mahannah and others, 1993, Ritchie and others, 1992). The land may sell to private interests or shift to another government agency. Future use could include military training, light industry, residences, and agriculture (Ritchie and others, 1992, Mahannah and others, 1993).

Military Waste: A Groundwater Contamination Source

Soil and groundwater contamination exists at Depot sites (see Appendix 3H). Other investigators found contaminants in surface soil, subsurface soil, septic tanks, alluvial groundwater, and groundwater from basalt (Ritchie and others, 1992). Contaminants detected include some metals, explosives, cyanide, and nitrate-nitrite (Dawson and others, 1982, Ritchie and others, 1992).

Some Depot soil contaminants could become mobilized. For example, Dawson, and others (1982) noted that with insufficient water, TNT explosives remained attenuated in Depot soils. However, Dawson and others (1982) warned that the TNT could flush to groundwater with increased water applications. Dawson, and others (1982) noted rapid travel time to groundwater with seven inches of precipitation from November and December 1973 influencing alluvial groundwater elevations 14 months later.

Previous investigations have attributed Depot nitrate-nitrogen contamination to Depot and non-Depot sources. Depot groundwater with nitrate-nitrogen concentrations exceeding the drinking water standard of 10 mg/L was detected in five areas (Ritchie and others, 1992):

- the south boundary near the Administration Area
- the explosive washout lagoon vicinity
- the active landfill vicinity in the northeast Depot area
- well 005 in the central Depot area, and
- the ammunition demolition area (northwest portion) in the northwest Depot area.

Nitrate-nitrogen in the washout lagoon vicinity was attributed to breakdown of explosives which the Depot had discharged to the lagoons. Nitrate-nitrogen in the active landfill vicinity was attributed to nearby food processing wastewater land application and possibly the landfill which had accepted sewage for disposal. Agricultural activities outside the Depot were identified as nitrate-nitrogen sources at the south boundary and the ammunition demolition area. Nitrate-nitrogen in Well 005 was attributed to unknown sources (Ritchie, and others, 1992).

Explosives, metals and other Depot contamination identified by previous investigations is summarized by site in Appendix 3H.

Managing Military Waste

The U.S. Army, EPA and DEQ have proposed a groundwater cleanup plan to address explosives and elevated nitrate-nitrogen in the explosive washout lagoons (Bowen and others, 1992). The proposed cleanup includes extracting groundwater at the site, treating the water with granular activated carbon, and reinfiltrating the water through a washout lagoon at a cost of 5.8 million dollars (U.S. Army and others, 1994).

DEQ is preparing a draft environmental permit for an incineration facility to destroy the chemical weapons stockpiled at the Depot. The permit is expected to be issued by the end of 1995. Construction will take three years, followed by extensive testing. Actual operation is expected to last three years, after which the facility will be dismantled (Oliver, 1995).

The Umatilla Depot Landfill closure design includes a clean soil and geomembrane cap to keep water out of the landfill, and groundwater sampling at previously constructed monitoring wells (Liggett, 1994).

Military Site History

The Depot's chronological history, reviews of selected sites and types of contamination detected by other investigators can be found in Appendix 3H.

1940s

The U.S. Army acquired 16,000 acres for the Depot by purchase from private land owners and through a transfer from the U.S. Bureau of Land Management. The Army established the Umatilla Depot to store conventional munitions in 1001 ammunition storage igloos. The Army added ammunition demolition and renovation to the Depot's activity in the mid-1940s (Ritchie and others, 1992).

From 1941 to 1943, the U.S. War Department acquired 150 square miles for a precision bombing range. The site was originally named the Arlington Bombing Range, and later renamed the Boardman Air Force Range. The U.S. Army Air Corps used the Bombing Range from 1942 to 1948. War games were conducted within a 36-square-mile area during World War II, leaving the area littered with various military ordnance (DEQ Environmental Cleanup File 1030).

1950s-1960s

A U.S. Army plant began removing explosives from munitions, bombs and projectiles through water or steam cleaning. The residual wastewater was discharged to two lagoons. The Army purchased more acreage as a safety buffer and began storing chemical agents and munitions in 1962 (Ritchie and others, 1992).

The U.S. Air Force and U.S. Navy used the Bombing Range from 1948 to 1960. This use, along with previous Army Air Corp use, left unexploded bombs and a variety of ammunition at target sites. The Air Force transferred the entire Bombing Range to other government organizations, with ownership eventually going to the U.S. Department of the Navy in 1960. The state of Oregon acquired the range in 1963 and leased it out to Boeing Corporation for 77 years. Boeing renamed the leased area the Boardman Space Age Industrial Park (Hafley, 1992, DEQ Environmental Cleanup File 1030).

Since 1968, the U.S. Army has operated an unlined gravel pit as the Umatilla Depot Landfill (DEQ file: Solid Waste Disposal Facility Permit Number 320). Eight inactive disposal sites are located within the south central area of the U.S. Army Umatilla Depot Activity (Ritchie and others, 1992).

1970s-1980s

The Depot was included in a 1978 assessment to evaluate the environmental quality of past use, treatment and disposal of toxic and hazardous materials. The assessment found parts of the Depot to be contaminated with explosives. In 1985, the Army applied for an environmental permit to construct and operate an incineration facility to demilitarize obsolete chemical agents at the Depot (Ritchie and others, 1992).

An Initial Remedial Investigation in 1988 was conducted to determine the extent of contamination at the following sites: the explosive washout lagoons, ammunition demolition activity, active and inactive landfills, the deactivation furnace and septic tanks (Ritchie and others, 1992). The investigation found explosives, nitrate/nitrite, cyanide and certain metals in septic tanks, surface soil, subsurface soil, and both alluvial and basalt groundwater. Sources included Depot activities and fertilized farming outside the Depot (Roy F. Weston, Inc., 1989).

Boeing leased some acreage to Portland General Electric (PGE) coal fired plant that began operating in 1980 (DEQ Environmental Cleanup File 1030, Carter, 1987). Boeing also returned 2,700 acres to the state, which was leased to the Port of Morrow in 1983. A 1989 U.S. Army Corps of Engineers inspection of the Boardman Air Force Range found unsafe debris, hazardous and toxic waste contamination and unexploded ordinance. (DEQ Environmental Cleanup Site File 1030).

1990s

In a federal preliminary assessment for EPA, DEQ concluded that the Boardman Air Force Range posed a minimal threat to the surrounding population and environment (Hafley, 1992).

The Umatilla Depot Landfill was about half full by 1992 (Golder Associates, Inc., 1992). Because of landfill regulation changes, the U.S. Army had intended to close the Umatilla Depot Landfill by 1993 (DEQ file: Solid Waste Facility Permit Number 320). The U.S. Army submitted a draft closure and post-closure plan in 1992 (Golder Associates, Inc., 1992). However, the Army postponed closing the landfill until 1997 to allow proper disposal of Depot environmental cleanup site materials (Liggett, 1994).

Investigation and cleanup of contaminated Depot sites continue, particularly at the explosives washout lagoon and for the incineration of stored chemicals.

Military Waste Nitrogen Loading

Significant nitrogen loading apparently occurred at the Depot's explosive washout lagoons (0.09 acres total), and some nitrogen loading may have occurred within the Depot's 1750 acre ammunition demolition area and 10-acre active landfill area. Project information was not sufficient to calculate nitrogen loading at the Depot sites.

Groundwater contamination by the U.S. Army Umatilla Depot Activity includes metals, nitrate, explosives and other organic chemicals. Some of the nitrate-nitrogen observed has been attributed to non-Depot sources by other investigators (Ritchie and others, 1992).

Nitrogen loading at the unlined Explosive Washout Lagoons occurred from the mid 1950s to the mid 1960s via discharge of approximately 85 million gallons of explosive washout water to the lagoons. Other investigators have concluded loading at the washout lagoons has contaminated groundwater (Dawson and others, 1982, Ritchie and others, 1992, Bowen and others, 1993)

Nitrogen loading at the Ammunition Demolition Area may have occurred since 1945 via demolition and disposal of explosives and/or pesticides in the area. Other investigators have concluded activity at the Ammunition Demolition Area has not and will not contaminate groundwater (Mahannah and others, 1993).

Dried sludge from the U.S. Army Umatilla Depot Activity sewage treatment facility has been disposed within the 10-acre active landfill at the Depot since the early 1980s. Other investigators attributed nitrate-nitrogen in vicinity groundwater to an offsite source and possibly the landfill (Ritchie and others, 1992; Golder and Associates, Inc., 1992). Project information was insufficient to determine the nitrogen loading at the active landfill or any other solid waste disposal sites.

Debris in disposal trenches was discovered and removed during a 1989 U.S. Army Corps of Engineers inspection of the former Boardman Air Force Range, and removed in 1990. No contamination was reported (Hafley, 1992, DEQ Environmental Cleanup Site File 1030).

Solid Waste Disposal

Three active landfills are located within the Lower Umatilla Basin: Finley Butte, Umatilla Butte, and Umatilla Depot. Inactive landfill sites are present within the Umatilla Depot, at the former Boardman Air Force Range, and possibly at other sites unidentified by this investigation. Sites identified are shown on Plate 3.2.

Potential for Groundwater Contamination from Landfills

Of the three active landfills, only Finley Butte Landfill has a constructed liner to minimize deep percolation of leachate to groundwater. Some of the active and inactive landfills did and may still receive waste containing nitrogen. Landfills at Finley Butte and Umatilla Butte can accept waste loads with up to 25 gallons of free liquid, including sewage sludge and septic tank pumpings. The U.S. Army disposed of dried sludge at the Depot's Active landfill since the early 1980s to late 1993 (Ritchie and others, 1992, Golder and Associates, 1992, Dana, 1993, DEQ files: Solid Waste Facility Permit Numbers, 143, 320, 394).

The potential for groundwater contamination from the Umatilla Butte Landfill has been discussed, investigated and re-evaluated since at least 1985. In 1986, a DEQ review considered groundwater contamination from the landfill a low risk, given the arid climate, no recorded alluvial groundwater in nearby wells; low vertical permeability of individual basalt flows, and geologic structures compartmentalizing local groundwater. However, an attached 1985 WRD memo presented an unanswered cautionary question: did the Service Anticline folding create unobserved fractures through which contaminants can migrate? In 1992, DEQ staff reviewed existing reports and concluded that leachate from the landfill could potentially migrate to basalt groundwater (DEQ file: Solid Waste Disposal Facility Permit Number 143).

Solid Waste History

The active and inactive sites within the Depot and the former Boardman Air Force Range are discussed under Military Sites. A chronological history for the Umatilla Butte Landfill is presented in Appendix 3I.

1950s-1980s

The types of waste disposed of at the Umatilla Butte Landfill is presented in Appendix 3I.

From 1956 through 1972, open dumping occurred at Umatilla Butte near the current Umatilla Butte Landfill including a gravel quarry. Authorized dumping occurred from 1956 to 1961. Unauthorized dumping occurred from 1962 through 1972.

DBA Hermiston Sanitary Service operated the Umatilla Butte landfill during the early 1970s, apparently spreading a thin layer of waste with little compaction or covering (Advanced Sciences, Inc., 1992). Sanitary Disposal, Inc. compacted the trash, covered it with sand excavated nearby (weekly before 1979, daily after 1979), and controlled dust with water from 1972 to approximately 1983 (Advanced Sciences, Inc., 1992). From 1985 to at least 1992, Desert Wind, Inc. disposed of compacted trash in lifts covered daily with 6 inches of soil and intermediately with 12 inches of soil. The landfill design did not include engineered run-on or run-off control, leachate collection or treatment, liners, caps or groundwater monitoring (Advances Sciences, Inc., 1992).

The Umatilla Butte Landfill was inspected and audited from 1972 through 1992. The Bureau of Land Management reporting no major problems in eight compliance checks from 1972 to 1990. DEQ staff conducted five inspections and noted some permit compliance violations (Advanced Sciences, Inc., 1992, DEQ file: Solid Waste Disposal Facility Permit Number 143).

1990s

The Finley Buttes Landfill opened in 1990 about 10 miles south and east of Boardman (Plate 3.2). The facility was constructed and operates under a DEQ Solid Waste Disposal Facility Permit issued to the Finley Buttes Landfill Company of Vancouver, Washington in 1990 (DEQ file: Solid Waste Disposal Facility Permit Number 394). Finley Buttes Landfill disposes waste within 8 to 20-acre cells designed to prevent subsurface contamination (DEQ file: Solid Waste Disposal Facility Permit Number 394). A leak detection system revealed a leak in the upper liner of the evaporation pond which was reported in June 1992. The leak was confirmed and repaired the same year (DEQ file: Solid Waste Disposal Facility Permit Number 394).

The Finley Buttes Landfill Company began sampling groundwater from six monitoring wells in 1990. Nitrate-nitrogen concentrations have remained well below 1 mg/L with elevated manganese and total dissolved solids concentrations detected occasionally (Finley Buttes Landfill, 1992b). DEQ's laboratory staff have had similar results in groundwater sampled from the landfill's monitoring wells in 1992 (DEQ file: Solid Waste Disposal Facility Permit Number 394).

Advanced Sciences, Incorporated staff audited Umatilla Butte Landfill in 1991 for BLM. The auditors found a suitable existing site, adequate local soils for a landfill site, and no evidence of leachate generation at the landfill. However, the auditors also found numerous problems. The corrective actions they identified included a need to characterize groundwater, install monitoring wells, and implement a groundwater monitoring program (Advanced Sciences, Inc., 1992).

DEQ required the Umatilla Butte landfill to characterize the local groundwater and propose neighboring wells for groundwater quality monitoring in the facility's solid waste 1986 disposal permit renewal (DEQ file: Solid Waste Disposal Facility Permit Number 143). Landfill consultants recommended a regular groundwater monitoring program at the landfill using three existing offsite wells (Hickerson and Associates, 1987). In response, the landfill operation began monitoring groundwater at two well sites using only one of the wells recommended by the consultants (Advanced Sciences, Inc., 1992).

In 1992, DEQ staff used existing reports to review the physiographic, geologic and hydrogeologic conditions of the Umatilla Butte Landfill site. DEQ staff concluded that a potential existed for Umatilla Butte Landfill leachate to migrate to basalt groundwater below. The staff recommended the landfill operator characterize the landfill site and assess any potential groundwater quality impacts from past landfill activity (DEQ file: Solid Waste Disposal Facility Permit Number 143).

Potential Nitrogen Loading of Solid Waste

Information about nitrogen loading from solid waste disposal sites is limited. The nitrate-nitrogen concentrations in groundwater sampled at Finley Buttes Landfill are reported to be well below 1.0 mg/L (Finley Buttes Landfill, 1992b). DEQ has concluded that Umatilla Butte Landfill leachate could potentially migrate to basalt groundwater, as noted earlier.

At the Depot, consultants attributed elevated nitrate-nitrogen and other contaminants at the active landfill to an off-site source and possibly the landfill. (Ritchie and others, 1992). Depot consultants did not consider the Depot responsible for soil and/or groundwater contamination detected at or near some of the Depot's inactive landfill sites (Ritchie and others, 1992). This investigation attributes elevated nitrate-nitrogen in the active landfill vicinity to a Depot source and in the inactive landfill vicinity to an off-site source (Chapter 4).

Debris in disposal trenches was discovered and removed during a 1989 U.S. Army Corps of Engineers inspection of the former Boardman Air Force Range, but no contamination was reported (Hafley, 1992, DEQ Environmental Cleanup Site File 1030).

Electricity Generation

Electrical production is expanding in the Lower Umatilla Basin. Electricity generation facilities could potentially contaminate groundwater in two ways: constituent leaching from the incinerated coal ash at the PGE facility and salt from land applied co-generation cooling water.

Electricity Generation History

Before 1990s

Electric generation activity in the Lower Umatilla Basin began with the McNary hydroelectric dam north of Hermiston, which was constructed between 1947 and 1956. The 14-generator facility has a 100-year life expectancy (Stephenson, 1994) and presents no known groundwater contamination threat.

Portland General Electric (PGE) began operating a 530 mega-watt coal fired generating plant at the Carty site about 12 miles southwest of Boardman in 1980 (Carter 1979, 1987). Potential groundwater contamination sources at the PGE facility include fly ash and cooling water. The ash contains heavy metals, some low level radioactivity, and elevated pH (Carter, 1979). The ash is collected for commercial sale, or transported to a 240-acre disposal area southeast of the plant (Carter, 1979). PGE uses the adjacent Carty Reservoir south of the plant as a cooling and industrial waste pond for heat and selected chemicals resulting from plant operations (Carter, 1979).

PGE expected Carty Reservoir to leak between 1,000 to 4,000 acre-feet per year (Carter, 1979). Actual leakage is estimated as 4,000 acre-feet per year (Carter, 1987). PGE reports that reservoir leakage has created perched groundwater adjacent to the reservoir, and dominates the bicarbonate, potassium, and sodium concentrations and lowers the nitrate-nitrogen concentration in other groundwater (Carter 1987, 1988).

PGE has conducted groundwater monitoring and analyses through the 1980s to present. Groundwater monitoring wells are located within the ash disposal area, north and northwest of Carty Reservoir, and along Sixmile Canyon.

PGE's annual groundwater sampling analyses indicates agricultural activity rather than the ash disposal operation elevates the chloride, magnesium, and nitrate-nitrogen concentrations in groundwater at wells near the agricultural area west of Sixmile Canyon (Carter, 1987, 1988, 1989, 1990). At some of these wells, agriculture reportedly elevates the phosphorous concentration in groundwater occasionally (Carter, 1987, 1989, 1990, 1991). Elevated potassium concentrations in groundwater at one well site was also attributed to nearby agricultural activities (Carter, 1991). Lower nitrate-nitrogen concentrations in groundwater from a well within a marsh area northeast of the agricultural area was attributed to vegetation uptake and anaerobic nitrate-nitrogen reduction (Carter, 1987).

1990s and Future

Proposed natural gas electric co-generation facilities may be constructed in the Lower Umatilla Basin. Each proposed facility will provide steam to nearby potato processors for their potato processing activities. Salt enriched process wastewater from the co-generation facilities may be land applied (Barlow and Tipton, 1993, CH2M Hill, 1992, IDA-West Energy Company, 1993).

Locations proposed for the co-generation facilities include the Port of Morrow Industrial Zone (Barlow and Tipton, 1993), near Lamb-Weston Incorporated's potato processing plant (CH2M Hill, 1992) and adjacent to the J.R. Simplot Company potato processing plant (IDA-West Energy Company, 1993).

Potential Nitrogen Loading of Electrical Generation

Available information indicates possible loading from existing or proposed facilities is limited to salt and constituents other than nitrogen. PGE has reported elevated nitrate-nitrogen in groundwater sampled in the vicinity of the coal fired plant. PGE attributes the contamination to nearby agriculture (Carter, 1987, 1988, 1989, 1990). This investigation attributes the nitrate-nitrogen contamination to an off-site source.

Union Pacific Railroad

The history of the Union Pacific Railroad Co. primarily involves oil or diesel except for domestic sewage and grain washed out of railcars. DEQ files and databases record 48 accidents and spills between 1978 and 1992 (Appendix 3J). Most of these incidents involved 10 to 1,000 gallons of diesel. Only one spill involved nitrogen. This project expects no deep percolation of nitrogen from these accidents and spills.

Union Pacific Railroad History

Before 1970s

From 1951 to 1960, the Union Pacific Railroad Company consolidated three railroad terminals at Rieth, Oregon, Umatilla, Oregon, and Attalia, Washington into the Hinkle terminal, south of Hermiston. The consolidation accompanied a need to relocate railroad tracks away from the McNary Dam and a need to service diesel rather than black oil steam locomotives (DEQ Water Quality File 90860).

The facility installed septic tanks and drainfields for sewage disposal and allowed storm water runoff to discharge directly to the Umatilla River. A three-section concrete basin separated and collected grain wastewater from grain car cleaning washout water. The grain waste was hauled to a disposal pit while effluent water discharged to an open lagoon before discharging to the Umatilla River. Shop area oil, grease and cleaning detergent wastes were collected at an oil-water separator and removed for burial. Later, they were used with boiler fuel. Three settling basins/pools trapped remaining effluent waste before the effluent discharged to the Umatilla River. The lower pools were skimmed or burned every 90 days. Burning apparently ended in 1971 (DEQ Water Quality File 90860).

1970s-1990s

The Union Pacific Railroad Company used a waste oil lagoon from 1971 through 1976 (DEQ Environmental Cleanup Site File 516). The lagoon was unlined in very sandy soil and approximately one-third of an acre. The company disposed of about 400,000 gallons total of waste oil sludge into the lagoon. Some of the oil may have been burned at the lagoon. Subsurface seepage was strongly suspected. In 1976, environmental cleanup occurred at the site (DEQ Environmental Cleanup Site File 516).

Union Pacific completed a new oil-water separation facility in 1973. It experienced wastewater treatment and management problems during the 1970s. Improvements included use of a multi-media filter, and land applying recovered oil sludge at a 16-acre site (DEQ Water Quality Files 90860 and 90861).

Potential Nitrogen Loading from Union Pacific Railroad

The facility uses septic tanks and drainfields for domestic sewage (DEQ Water Quality File 90860). Deep percolation of nitrate-nitrogen at the Hinkle Railroad Inn drainfield may annually reach 551 pounds per acres over a 2.4 acre site (Appendix 3F). Project information was not sufficient to identify other septic systems and drainfields servicing the Hinkle facility. Grain washed out of railcars is hauled to a pit. Project information was not sufficient to estimate nitrogen loading from this activity. It is considered small.

Pendleton Grain Growers, Incorporated - Stanfield

Chemicals and nitrogen released in a 1988 fire at Pendleton Grain Growers, Inc. (PGG) nearly two miles south of Hermiston, prompted an environmental cleanup (DEQ Environmental Cleanup Site File 639).

PGG History

The PGG fertilizer and agricultural chemical facility constructed in 1968 included a chemical warehouse, fertilizer mixing equipment, a hopper tower for loading fertilizers into application equipment, and a railroad spur (DEQ Environmental Cleanup Site File 639).

Fire destroyed the warehouse, the hopper towers, and an office on August 29, 1988 (DEQ Environmental Cleanup Site File 639). The fire involved an estimated 10,000 pounds of agricultural pesticide chemicals and 600,000 pounds of various fertilizers. Firefighting water carried contaminants to an evaporative pond and left standing water around the chemical buildings until the next day. Approximately 70,000 gallons were pumped from the pond to the tanks and bladder bags after DEQ staff observed pond leakage (DEQ Environmental Cleanup Site File 639).

Later, soil samples were collected at the facility from ground surface to 40 feet depth, and groundwater was sampled from two PGG wells about 100 feet from the site. Seventeen chemicals were detected in surface and near surface soil. Dinoseb and 2,4-D were detected between 30 and 40 feet below surface beneath the evaporative pond. No groundwater contamination related to the site was detected (DEQ Environmental Cleanup Site File 639).

Remedial action at the PGG cleanup site is completed (DEQ Environmental Cleanup Site File 639). The cleanup involved land application of the non-hazardous fire runoff water, excavation of contaminated soil which was placed in the evaporative pond, and caps constructed over the pond and excavated areas (DEQ Environmental Cleanup Site File 639).

PGG Potential Nitrogen Loading

Nitrate-nitrogen at concentrations greater than 10 mg/L was detected in groundwater from one PGG well, but the source was attributed to a neighboring animal feedlot (Gilles, 1993). Sufficient information to estimate nitrogen loading at this facility was not obtained.

Groundwater Recharge Projects

Groundwater use in some Lower Umatilla Basin areas has exceeded annual recharge, causing local groundwater level declines. The Oregon Water Resources Department (WRD) responded to the declines by declaring several areas Critical Groundwater Areas and restricting groundwater use. Local residents seek to improve the groundwater supply by artificially recharging local aquifers. One groundwater recharge project exists. Other projects are proposed.

Concern for Groundwater Contamination from Recharge Projects

The potential of groundwater contamination from groundwater recharge projects rests with the contamination concentrations found in the source of water used to artificially recharge aquifers.

History

1970s-1990s

The County Line Water Improvement District began operating an alluvial groundwater recharge project authorized by WRD in 1977 (Miller, 1985, OWRD Water Right File: Application 48966, Permit 41512). Using canal leakage to recharge groundwater, the project diverts Umatilla River water from the 18-mile High Line Canal 500 feet east of Lost Lake. The diverted water flows to a open canal near County Line Road, ending at a 7-acre catch lake (Miller, 1985, Henry, 1978). Reportedly, an estimated 11,000 acre-feet of recharge water per year percolates from the canal to the alluvial groundwater, which reportedly flows from the recharge area at a rate of 500-1000 feet per day (Miller, 1985).

Since 1991, the recharge project's potential for contaminating local groundwater has concerned DEQ, whose authority to protect groundwater quality is limited to a modification clause in the 1988 Water Right (Patton, 1992, Bidleman, 1992).

Future

The City of Hermiston seeks to recharge city wells supplied by underlying basalt aquifers with local alluvial groundwater via an injection well (City of Hermiston, 1986). Contaminants detected in the proposed recharge water have delayed this project (Loeb, 1992, Bidleman, 1993). WRD's Water Right permit prohibits recharge water from containing organic chemicals or volatile organic compounds (OWRD Water Right File: Application G-11891, Permit G-10935). The City has continued its efforts to implement the recharge demonstration project.

Groundwater withdrawal has exceeded the Butter Creek area's natural recharge since the late 1950s. WRD first declared Butter Creek a Critical Groundwater Area in 1976, but it did not take effect until 1988 (Norton and Bartholomew, 1984, Miller, 1994). Echo Junction area groundwater users must decrease their 1993-1997 groundwater withdrawal by 53 to 100 percent. They propose injecting Columbia River water through wells into basalt aquifers beneath the local alluvial sediments during wet months and withdraw the same water through the same wells in the dry months (CH2M HILL, 1993). Concerns about protecting the injection water quality and injecting into multiple basalt water bearing zones has delayed this project (Dulay, 1993, Grondin, 1993, Sellars, 1993).

Potential Nitrogen Loading from Groundwater Recharge

A project review found little nitrogen loading associated with existing or proposed groundwater recharge projects. The County Line Groundwater Recharge Project diverts Umatilla River water from High Line Canal for groundwater recharge via seepage. High Line Canal water collected by DEQ staff in June 1992 at the recharge project diversion site had a nitrate-nitrogen concentration of 0.03 mg/L (Appendix 4F).

The City of Hermiston Groundwater Recharge Demonstration Project proposes to inject shallow alluvial aquifer water into deeper Columbia River Basalt aquifers via a recharge well. Some nitrate-nitrogen loading from this project is anticipated given the recharge water's 2.6 mg/L of nitrate-nitrogen versus the receiving groundwater's 0.28 mg/L of nitrate-nitrogen. This has drawn less concern than the organic chemicals in the recharge water (City of Hermiston, 1986).

The proposed Echo Junction Aquifer Storage and Recovery Project intends to inject Columbia River water into Columbia River Basalt aquifers via recharge wells. Columbia River water samples collected by DEQ in 1992 had nitrate-nitrogen concentrations from not detected to 0.04 mg/L (Appendix 4F).

Project investigators found no information to support or refute rumors of unofficial groundwater recharge activity in the basin.

Miscellaneous Potential Sources

Reported Accidents/Spills

From 1981 through 1992, 83 accidents, spills and leaks in the Lower Umatilla Basin were reported to DEQ. Many accidents and spills involved 50 to 1,000 gallons of diesel fuel. Several other accidents included sewage overflows onto land surface. One accident involved 1,000 gallons of fertilizer along Powerline Road. A list of the accidents, spills and leaks can be found in Appendix 3K, and man of their locations are shown on Plate 3.7. Loading related to these accidents and spills primarily involved constituents other than nitrogen.

Hazardous Waste/Substance Handlers

Hazardous waste and substance sites located in the Lower Umatilla Basin and on file in the DEQ Hazardous Waste database are listed in Appendix 3L. These facilities generate, store, collect, dispose and/or treat useless, unwanted, or discarded pesticides and/or manufacturing residue that is toxic, corrosive, ignitable, or reactive. Less than 50 handlers are on file, although others may exist.

Lower Umatilla Basin facilities recorded in the State Fire Marshall Toxic Release Inventory database with potentially hazardous and toxic substances are listed in Appendix 3L. Less than five facilities are on file. Listed facilities handle more than 55 gallons of liquid hazardous and toxic substances, and/or 500 pounds of dry or solid hazardous and toxic substances, and/or 200 cubic feet of hazardous and toxic compressed or liquified gas. Some Lower Umatilla Basin facilities may be missing from the list.

No nitrogen or other loading should be occurring at Lower Umatilla Basin hazardous waste handling sites.

Underground Storage Tanks

Many underground storage tanks are present in the basin. Some have reportedly leaked. Appendix 3M lists the underground storage tanks located in the Lower Umatilla Basin, on file in DEQ's underground storage tank database, and the tanks having a reported petroleum product release. Some tanks may be missing from the lists. No nitrogen loading associated with underground storage tanks in the Lower Umatilla Basin is suspected.

Natural Nitrogen Sources

Natural nitrogen sources include lightning, rain, water-dissolving igneous rocks, organic decomposition, and nitrogen fixation by bacteria (Davis and DeWeist, 1966, Hem, 1985, Waring, 1949).

Loading information is not sufficient to determine the actual amount of nitrogen coming from natural sources. However, a USGS report and low background concentrations in upgradient Lower Umatilla Basin groundwater samples suggest the contribution from natural sources is small. The U.S. Geological Survey reports a median nitrate+nitrite-nitrogen concentration of 0.15 mg/L for 620 Oregon groundwater samples collected from various aquifers, and 0.46 mg/L for 142 samples collected from Oregon basin fill and alluvial aquifers (Miller and Gonthier, 1984). Project sampling has found groundwater nitrate-nitrogen concentrations well below 1 mg/L at some basin locations.

Summary

Diversity, change and growth best describes land use in the Lower Umatilla Basin. Former, existing and proposed land uses may contaminate basin groundwater with nitrate-nitrogen, salts, agricultural pesticides, explosives or petroleum products.

Given the basin soils, most land uses have the potential to contaminate groundwater. The potential for a land use to contaminate groundwater with nitrate-nitrogen or other constituents relates to loading. Groundwater contamination can occur whenever water (or another liquid) and nitrate-nitrogen (or another contaminant) is released and exceeds or bypasses:

- removal by crops or other vegetation
- removal by evaporation
- soil capacity to prevent deep percolation

Good management practices can reduce or prevent nitrate-nitrogen or other contaminant loss to groundwater.

Irrigated Agriculture

Irrigated agriculture covers almost half of the study area and is considered to be the greatest loading source in the basin, based on limited information. Deep percolation of nitrogen (or other constituents) to groundwater can occur when water or fertilizer exceed soil capacity and a crop's ability to remove nitrogen. Because of the high permeability of the soil in the area, irrigated agriculture, even when well-managed, remains a groundwater quality concern in the Lower Umatilla Basin.

Irrigated wheat and row crops (potatoes, field corn, watermelon, winter wheat, alfalfa hay, and pasture) replaced dryland wheat farming in the basin. This change led to increased total nitrogen fertilizer and pesticide use.

Irrigated agriculture has expanded to nearly 180,000 acres by the early 1990s due to available water, technologic improvements, and market demands. Of this total acreage, about half produced irrigated wheat and potatoes. Center pivots--which were also used for fertilizer applications--irrigated nearly 90 percent of the total irrigated area (IRZ Consulting, 1993). Irrigation technology continues to evolve with drip irrigation being introduced at large poplar tree farms.

Some of the highest nitrate-nitrogen concentrations in basin groundwater have been linked to irrigated agriculture. However, since this activity is among the least regulated, the least is known about how much nitrogen is applied to crops and escapes the root zone.

This investigation calculated a range of nitrogen applied to irrigated agriculture, beginning with a very conservative estimate for 1975. The minimum estimate assumes nitrogen applied to irrigated basin crops has annually exceeded 7 million pounds total since 1975. This estimate multiplies 1975 acreage with a nitrogen application rate of 50 pounds per acre. This estimate is conservative when compared to a project analysis of Pumphrey and others (1991). That analysis indicates more than 20.5 million pounds were applied to nearly 132,500 acres in 1990.

Current crop nitrogen application rates range from 0 to 410 pounds per acre per year depending upon the crop grown. Based on a nitrogen budget analysis, 20 to 265 pounds of residual nitrogen could remain after the growing season. Basin soil studies indicate some nitrogen has the potential to escape beyond the root zone on irrigated crop fields.

Ritter (1989) and Vitosh (1991) indicate nitrate-nitrogen loss to deep percolation at agricultural fields in the U.S. can range from 1 to more than 50 percent depending upon the amount of nitrogen applied, the time of application, soil texture, and the amount and timing of water applied. Applying a five percent deep percolation nitrate-nitrogen loss to the conservative estimate of 7 million pounds of nitrogen application per year means more than 350,000 pounds of nitrogen from irrigated agriculture have annually reached groundwater since 1975. The 1990 deep percolation loss may have exceeded one million pounds, assuming 20.5 million pounds were applied with a five percent loss to deep percolation.

Food Processing

Elevated nitrate-nitrogen concentrations have been linked to some food processing facilities. Very little vegetable food processing occurred in the Lower Umatilla Basin before 1970. The cannery, slaughterhouse and potato packing houses that did exist probably contributed very little nitrogen to basin groundwater.

Large-scale potato processing for fast food and other uses began in the basin during the 1970s, and expanded to dominate the local food processing industry in the 1980s. The industry produces large volumes of nutrient and/or salt rich wastewater which is land applied. Historically, wastewater storage occurred in unlined ponds, and the land application occurred at limited acreages, during all seasons at some sites, and at amounts exceeding crop nutrient needs.

Since the 1980s, food processors have produced more than one million pounds of nitrogen waste per year. In response to state permit requirements, the industry has expanded their land application areas, built or expanded lined wastewater storage, and limited land application to crop water and nutrient need.

Livestock

Livestock production began in the basin by 1900 and expanded to include sheep, turkeys, chickens, hogs, dairy and beef cattle. Livestock manure was the primary fertilizer for local crop production until the local dairy industry declined after World War II. Confined livestock facilities with thousands of animals have operated in the basin. Some remain active or have resumed operation. Waste management at these facilities is a groundwater quality concern, with one facility already identified as a groundwater contamination source before this technical investigation began.

Available but incomplete information indicates confined animal feeding operations are a major nitrogen source covering a limited area in the basin. Livestock activity involving nitrogen includes:

- livestock yards,
- waste lagoons or ponds,
- manure stockpile sites, and
- land application sites.

During the 1980s, basin livestock may have produced 3.4 million pounds of total nitrogen per year. The nitrogen amount land applied or stockpiled possibly dropped to more than 780,000 pounds per year after storage. Due to insufficient information, nitrogen leaching to deep percolation from land application, stockpiles, unlined livestock yards and waste ponds in the basin was not determined. Nitrogen estimates for the 1990s were not conducted due to insufficient information.

Domestic Sewage

Potential nitrogen sources from sewage include local municipal wastewater treatment facilities, sewage sludge imported from Portland and Washington County, large on-site systems at the U.S. Army Umatilla Depot Activity, unsewered mobile home parks, freeway rest areas, and hotels or other businesses, and possibly more than 4,300 individual septic systems.

Some of the local municipal wastewater facilities land apply their treated wastewater and/or sewage sludge within agronomic rates for nutrients and soil limits for metals. Sewage sludge from Portland and Washington County is land applied to irrigated and non-irrigated land within agronomic rates for nutrients, soil limits for metals, and limits for other constituents.

Land application of treated municipal wastewater and sewage has expanded. The land application area has expanded from less than 400 acres during the 1980s to more than 2,700 acres by 1993. The application rate ranged from 0 to 215 pounds per acre from the 1980s through 1992. The average annual nitrogen loading rate increased from more than 2,200 to more than 4,500 pounds per acre in 1990 and 1992 respectively.

The City of Irrigon uses rapid infiltration beds that discharge sewage wastewater directly to the subsurface over a two-acre area. Estimated subsurface nitrogen loading at the beds is 2,200 pounds per acre in 1990, increasing to 4,500 pounds per acre in 1992.

Most of the large on-site systems discharge wastewater directly to the subsurface via infiltration beds, bottomless sand filters, drainfields, and a few disposal wells. Mobile home parks, highway rest areas, hotels/motels, business and other facilities outside sewer service areas rely on large on-site sewage systems. Subsurface nitrogen loading from these facilities may exceed 4,700 pounds per year over an area exceeding ten acres.

Individual septic systems serve approximately 4,375 homes, mobile homes, and other units in the Lower Umatilla Basin. Wastewater from these units discharge directly to the subsurface and can affect an area where units are highly concentrated. Nitrogen loading from each unit was estimated as 26 pounds per year for individual units, 0 to 6,200 pounds annually per square mile section, and a total of 113,000 pounds per year for the basin.

Military Sites

A variety of military activities involving metals, ammunition, bombs and chemical agents have occurred over 180 square miles in the Lower Umatilla Basin since 1941. These activities have involved the U.S. War Department, Army, Army Air Corp, Air Force, and Navy. The Oregon Department of Veteran's Affairs eventually acquired 91 square miles in 1963, which it later leased to Boeing and the Port of Morrow. Current active military areas include the U.S. Army Umatilla Depot Activity and the U.S. Navy Boardman Bombing Range.

Soil and groundwater contamination exists at Depot sites. Other investigators found contaminants in surface soil, subsurface soil, septic tanks, alluvial groundwater, and groundwater from basalt (Ritchie and others, 1992). Contaminants detected include some metals, explosives, cyanide, and nitrate-nitrite (Dawson and others, 1982, Ritchie and others, 1992).

Previous investigations have attributed Depot nitrate-nitrogen to Depot and non-Depot sources. Depot groundwater with nitrate-nitrogen concentrations exceeding the drinking water standard of 10 mg/L was detected in five areas:

- the south boundary near the Administration Area
- the explosive washout lagoon vicinity
- the active landfill vicinity in the northeast Depot area
- well 005 in the central Depot area, and
- the northwest portion of the ammunition demolition area in the northwest Depot area.

Nitrate-nitrogen in the washout lagoon vicinity was attributed to the breakdown of explosives which the Depot had discharged to the lagoons. Nitrate-nitrogen in the active landfill vicinity was attributed to nearby food processing wastewater land application and possibly the landfill where sewage disposal occurred. Agricultural activities outside the Depot were the sources identified for nitrate-nitrogen at the south boundary and the ammunition demolition area. Nitrate-nitrogen at Well 005 was attributed to an undetermined source (Ritchie, and others, 1992).

Significant nitrogen loading has occurred at the Depot's explosive washout lagoons, although information was not sufficient to calculate nitrogen loading at this or other Depot sites.

Solid Waste

Of the Lower Umatilla Basin's three active landfills--Finley Butte, Umatilla Butte and Umatilla Depot--only Finley Butte uses liners to prevent deep percolation of leachate to groundwater. At least two have disposed of sewage in dried or liquid form.

Information about nitrogen loading from solid waste disposal sites is limited. The Finley Buttes Landfill's nitrate-nitrogen concentrations in groundwater samples are reported to be well below 1 mg/L. In 1992, DEQ concluded that Umatilla Butte Landfill leachate could potentially migrate to groundwater.

Depot consultants attributed elevated nitrate-nitrogen and other contaminants at inactive landfills to background conditions or an off-site source. Elevated concentrations at the active landfill were attributed to an off-site source and possibly the landfill. This investigation attributes elevated nitrate-nitrogen in the active landfill vicinity to a Depot source and in the inactive landfill vicinity to an off-site source. No contamination was reported at the Boardman Air Force Range.

Electricity Generating Facilities

A project review found little or no nitrogen loading associated with existing or proposed electricity generation facilities. This includes the McNary hydroelectric dam, the Portland General Electric (PGE) coal fired plant and the natural gas electric co-generation facilities proposed for the basin.

Electricity generation facilities could potentially contaminate groundwater in two ways: constituent leaching from the incinerated coal ash at the PGE facility and salt from land applied co-generation cooling water. PGE has reported elevated nitrate-nitrogen concentrations in groundwater sampled at the ash disposal and other sites. PGE attributes the contamination to nearby agriculture. This investigation attributes the nitrate-nitrogen contamination to an off-site source.

Union Pacific Railroad

The history of the Union Pacific Railroad Co. primarily involves oil or diesel except for domestic sewage and grain washed out of railcars. This project expects no deep percolation of nitrogen from these accidents and spills.

Pendleton Grain Growers, Inc.

Environmental cleanup activity at the Pendleton Grain Growers site 3-acre site included a 1988 fire involving 10,000 pounds of agricultural pesticides and 600,000 pounds of various fertilizers. Soil cleanup at the site is completed. Observed groundwater contamination was attributed to a neighboring cattle feedlot.

Groundwater Recharge Projects

Existing or proposed groundwater recharge projects appear to add little nitrogen loading.

Miscellaneous Potential Sources

Reported Accidents and Spills

Numerous local accidents and spills at disperse sites in the Lower Umatilla Basin have been reported since the late 1970s. Only a few of the accidents and spills could have introduced nitrate-nitrogen to groundwater--three or more accidental sewage overflows onto land and 1,000 gallons of fertilizer spilled along Powerline Road near Hermiston.

Hazardous Waste/Substance Handlers

No nitrogen or other loading should be occurring in the Lower Umatilla Basin related to hazardous waste/substance handling or generation.

Underground Storage Tanks

No nitrogen loading associated with underground storage tanks in the Lower Umatilla Basin is suspected. Some tanks have reportedly released petroleum products.

Natural Sources

Lightning and rain contribute nitrogen at the land surface. Soil and rocks release nitrogen in the subsurface. These sources probably contribute nitrogen throughout the basin. Although actual loading is unknown, project sampling and analysis of a USGS report suggest the loading is small.

Chapter 4

Groundwater Chemistry

Hydrogeology, Groundwater Chemistry and Land Uses
in the
Lower Umatilla Basin Groundwater Management Area

Northern Morrow and Umatilla Counties
Oregon

Gerald H. Grondin
Oregon Department of Environmental Quality

Dennis O. Nelson
Oregon Health Division

1995

Chapter 4: Groundwater Chemistry

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CHAPTER 4: GROUNDWATER CHEMISTRY

Abstract

The Lower Umatilla Basin Groundwater Management Area technical investigation conducted a variety of activities to primarily understand the distribution and source of nitrate in local groundwater.

Sampling activities included reconnaissance, bimonthly, synoptic, and nitrogen isotopic sampling. Laboratory activities included analyzing samples for nitrate, other nutrients, major ions, metals, other inorganic constituents, volatile organic compounds, pesticides, and nitrogen isotopes.

Data analysis activities included general statistics, chemical constituent distribution maps, multiple graphical analyses, groundwater chemistry computer modeling for selected areas, and stable nitrogen isotope interpretations. Data analyses indicate multiple influences affect the groundwater chemistry in the basin. However, not all influences contribute nitrate. These other influences include cyclic evaporation and dissolution in the vadose (unsaturated) zone, canal leakage causing dilution, and a minor influence from water-rock interactions. Analyses also indicate a hydraulic connection exists between alluvial groundwater and basalt water-bearing zones.

Project sampling detected nitrate concentrations as high as 76 mg/L. Local facilities have reported groundwater nitrate concentrations greater than 100 mg/L. Groundwater samples from nearly 31 percent of the project sampling sites in the basin had a maximum nitrate concentrations greater than the 10 mg/L drinking water standard.

Nitrate concentrations greater than 10 mg/L in the Lower Umatilla Basin groundwater is not evenly distributed. Higher nitrate concentrations occur within these areas:

- Threemile and Sixmile Canyons,
- Boardman
- Port of Morrow
- north, west, and south of the U.S. Army Umatilla Depot Activity,
- two sites within the Depot,
- the Butter Creek-Umatilla River confluence, and
- the terrace south of Hermiston.

The highest concentrations detected by project sampling occur between the Port of Morrow and Irrigon.

Identified nitrate sources include food processing wastewater activity at established food processing land application sites, irrigated crop agriculture, animal waste, septic systems, and the U.S. Army Umatilla Depot Activity.

Evidence indicates the time required for nitrate to travel from land surface to groundwater ranges from less than one month to 18 months depending upon local conditions and water available for transport. This travel time is faster than suggested by other investigators.

Evidence also indicates local groundwater transport of nitrate is slow. For example, an apparent nitrate plume emanating from the U.S. Army Depot explosive washout lagoons has moved less than 4 miles in three to four decades. Hydrogeologic and other evidence indicate slow movement may occur at other locations also.

Support for Groundwater Quality Conclusions

Groundwater often contains many dissolved chemical constituents. Understanding and distinguishing various natural and/or human influences on the groundwater chemistry is possible with careful analyses of the groundwater chemistry and the hydrogeologic environment.

This understanding is useful. For example, understanding natural chemical changes in local groundwater aids the understanding of groundwater occurrence and flow in an area. It assists in the identification of human influences. Additionally, understanding any unique chemical characteristics of potential contamination sources can improve the identification of groundwater contamination sources.

Appendix 4A presents a background discussion about primary influences on groundwater chemistry. Appendix 4B presents a background discussion about nitrogen isotopes and how they relate to nitrate sources.

This report describes the groundwater chemistry observed in the Lower Umatilla Basin with an emphasis on the occurrence of nitrate. The discussion includes:

- data collection,
- general statistics,
- analyses used,
- spatial and temporal groundwater chemistry variations observed in the basin,
- natural processes influencing groundwater chemistry, and
- human activities contributing to nitrate contaminated groundwater.

Materials and Methods Used for the Groundwater Chemistry Investigation

Introduction

The groundwater chemistry phase of the Lower Umatilla Basin Groundwater Management Area technical investigation included multiple groundwater sampling, laboratory analyses, and data analyses. The groundwater sampling included reconnaissance, bimonthly, synoptic, and nitrogen-isotope sampling. The groundwater samples were chemically analyzed at Oregon Department of Environmental Quality (DEQ), Oregon Department of Agriculture, Oregon State University Department of Agricultural Chemistry, and Boston University Stable Isotope Laboratories. Data analyses conducted included some groundwater chemistry computer modeling, evaluation of stable nitrogen isotopes, and comparisons of constituent versus time, location, other constituents, and groundwater elevations.

Groundwater Sampling

The following presents how and why reconnaissance, bimonthly, synoptic, and nitrogen-isotope sampling were conducted. Wells used are presented in Appendix 4C and shown on Plate 4.1.

Reconnaissance Sampling

Lower Umatilla Basin reconnaissance groundwater sampling was conducted from July 1990 through October 1991. The sampling effort served to provide a preliminary understanding about the nature, extent and concentration range of local groundwater contamination in the basin. That understanding directed decisions about the data analyses and additional groundwater sampling needed to characterize the groundwater quality and contamination sources in the basin.

DEQ staff collected 206 total reconnaissance samples from 2 springs, one field drain, and 179 wells. The samples were collected and transported as directed by the field sampling protocol in DEQ's Laboratory mode of operations manual (Oregon DEQ, 1986) with subsequent attachments and a September 4, 1990 project sampling plan (see Appendix 4D). Initial reconnaissance sampling efforts collected samples with the greatest potential for groundwater contamination. Later reconnaissance sampling efforts improved the geographic distribution of samples, and collected samples representing little or no land use impacts.

Well construction was not considered for sample site selection during the initial reconnaissance sampling. As a result, samples were collected from 25 wells with no water well report (well log) and 9 wells that apparently mix water from the alluvial aquifer with water from one or more basalt water-bearing zones. Later reconnaissance sampling limited collecting groundwater from wells that have a water well report and appear to obtain water from a single source.

Bimonthly Sampling

Lower Umatilla Basin bimonthly groundwater sampling at 35 to 40 wells selected to represent the basin began in October 1991. The ongoing sampling effort serves to provide information about seasonal and long term nitrate and other constituent concentration trends at different locations and along groundwater flow paths. This data is needed to identify recharge and contamination sources at different locations, understand the fate of contaminants and other constituents along groundwater flow paths over time, and determine whether the groundwater quality is improving, degrading or remains unchanged at different locations.

Wells selected for the bimonthly sampling passed two screenings. The first screening selected wells that: Oregon Water Resources Department (OWRD) and/or DEQ staff had previously located and observed; received groundwater from alluvium only or from a single basalt water-bearing zone only; and appeared accessible for sampling throughout the year. The second screening selected wells that satisfied one or more of the following criteria:

- would provide data along a groundwater flow path; or
- would provide data in an isolated area; or
- had groundwater with moderate to high nitrate concentrations; or
- had groundwater with previously detected pesticides or volatile organic chemicals.

The list of the wells used for bimonthly sampling is presented in Appendix 4C.

Bimonthly groundwater sampling in the Lower Umatilla Basin occurs in January, March, May, July, September, and November. DEQ laboratory staff conducted the sampling field work from 1991 through 1994. In 1995, DEQ laboratory staff and a Umatilla County Soil and Water Conservation District staff person began alternately conducting the field work. Sample collection and transport has followed and will continue to follow the field sampling protocol found in the 1986 DEQ Laboratory mode of operations manual (Oregon Department of Environmental Quality, 1986) with subsequent attachments, the 1993 DEQ Laboratory Field Sampling Reference Guide (Oregon Department of Environmental Quality, 1993), and a November 1, 1991 project sampling plan with subsequent amendments (see Appendix 4E).

Synoptic Sampling

Synoptic sampling at 207 wells, 26 surface water locations, and a field drain in the Lower Umatilla Basin occurred during late June and early July 1992. Alluvial groundwater was collected from 179 wells, and groundwater from basalt water-bearing zones was collected from 28 wells. Sampling provided this information:

- concurrent data necessary for conducting basin-wide data analyses;
- characterizing the basin-wide distribution of nitrate and other constituents in alluvial groundwater;
- identifying different alluvial aquifer recharge and contamination sources at different locations in the basin; and
- understanding the fate of contaminants and other constituents along various alluvial groundwater flow paths.

An Oregon Strategic Water Management Group Groundwater Protection Grant ($30,000) made the synoptic sampling possible. Synoptic sampling was needed because reconnaissance and bimonthly sampling data were not sufficient for basin-wide data analyses. Reconnaissance samples were collected basin-wide over a 15 month period. Data differences could be time related. Bimonthly samples are collected concurrently and along some groundwater flow paths, but the number of samples collected are not sufficient for basin-wide data analyses.

Collecting the synoptic samples was a cooperative effort. Oregon Department of Environmental Quality, Oregon Water Resources Department, Oregon Department of Agriculture, and Oregon Health Division staff collected samples from 134 wells, 26 surface water locations, and a field drain. Port of Morrow, J.R. Simplot Company, A.E. Staley Manufacturing Company, Hermiston Foods, Lamb-Weston, Incorporated, Portland General Electric, City of Irrigon, and U.S. Army Umatilla Depot Activity staff or their consultants collected samples from 73 wells total at their facilities. The sampling sites are listed in Appendix 4C. Samples were collected and transported in a manner consistent with the field sampling protocol found in the 1986 DEQ Laboratory mode of operations manual (DEQ, 1986) with subsequent attachments.

Sampling for Nitrogen-Isotopic Analysis

Sampling for nitrogen-isotopic analysis occurred in the Lower Umatilla Basin during the fall of 1993, spring of 1994, and fall of 1994 at approximately 20 wells, 3 lysimeters, and a food processing wastewater surge pond. The sampling effort provides data to verify or improve the identification of processes and nitrate sources influencing Lower Umatilla Basin groundwater. A U.S. Environmental Protection Agency 319 Grant to Dr. Dennis Nelson, Oregon Health Division, and Margot Truini, a Portland State University graduate student, funds this effort.

Truini and Nelson conducted the nitrogen isotope sampling. Wells selected for groundwater sampling are located in the Butter Creek drainage, the U.S. Army Umatilla Depot Activity Explosive Washout Lagoons vicinity, areas associated with food processing wastewater land application, areas associated with past animal feedlots, and areas associated with irrigated crop agriculture using commercial fertilizers. Lysimeters selected for sampling are located within food processing wastewater land application areas. Most wells were sampled in the fall of 1993, spring of 1994, and fall of 1994 to capture any variation with time, using standard techniques. Sampling occurred after three well bore volumes were purged and the temperature and electrical conductivity of the purge water had stabilized. The samples were shipped in ice to the Boston University Stable Isotope Laboratory for isotopic chemical analysis.

Laboratory Chemical Analyses Conducted

The laboratories used and laboratory chemical analyses conducted for the reconnaissance, bimonthly, synoptic, and nitrogen isotope samples in the Lower Umatilla Basin differed. The differences resulted from the availability of laboratories to conduct the chemical analyses and a need to conserve project resources.

Laboratory analysis procedures included conducting duplicate analyses to assess laboratory results. Those analyses assure the reliability and precision of the laboratory results. This in turn assures investigators that laboratory analytical uncertainty is far less than differences observed between samples.

Reconnaissance Sampling

Reconnaissance samples were chemically analyzed by DEQ, Oregon Department of Agriculture, and OSU Department of Agricultural Chemistry laboratories. The DEQ laboratory staff conducted chemical analyses for nutrients (including nitrate), total ions and metals, chemical oxygen demand, total organic carbon, volatile organic compounds, and physical parameters. The ODA and the OSU Department of Agricultural Chemistry laboratory staff analyzed all samples for pesticides. A September 4, 1990 project sampling plan (see Appendix 4D) describes the chemical analyses conducted and the laboratory methods used.

Bimonthly Sampling

Bimonthly groundwater sampling chemical analyses occurs primarily at DEQ and Oregon Department of Agriculture laboratories. DEQ laboratory staff conduct chemical analyses for nitrate, other inorganic constituents, and volatile organic compounds. The total list of constituents analyzed varies according to a sampling plan schedule. The ODA laboratory staff conduct chemical analyses for pesticides for a limited number of samples according to a sampling plan schedule. The OSU Department of Agricultural Chemistry laboratory staff has contributed chemical analyses for pesticides. A November 1, 1991 project sampling plan with subsequent amendments (see Appendix 4E) describes the chemical analyses being conducted, the schedule for the analyses, and the laboratory methods used.

Synoptic Sampling

DEQ laboratory staff conducted the synoptic sampling chemical analyses. The analyses included nutrients (including nitrate), major ions, and metals.

Nitrogen Isotope Analysis

The Boston University Stable Isotope Laboratory conducted the nitrogen isotope chemical analysis.

Data Analyses Conducted

Understanding the distribution and source of nitrate contaminated groundwater is the primary purpose of the Lower Umatilla Basin groundwater technical investigation. The complexity of natural processes, land uses, groundwater flow, and groundwater chemistry in the basin made using various data analyses necessary to achieve that understanding. Data analyses conducted and their purpose are summarized in the following subsections.

General Statistics

Basic statistical analyses of the reconnaissance sampling data was conducted to gain an initial understanding of the groundwater contamination in the Lower Umatilla Basin. The statistical analyses included nitrate, selected constituents, pesticides, and volatile organic compounds. The statistics were useful for defining the nature of the groundwater contamination problem in the Lower Umatilla Basin. They were not useful for characterizing the fate of the groundwater contamination or identifying the contamination sources.

Chemical Constituent Maps

Concentration contour maps and maximum constituent concentration maps were produced and analyzed (Plates 4.2 through 4.13). The maps show the concentration distribution of selected chemical constituents across the basin. That concentration distribution was compared to the distribution of current and historic land uses in the basin to identify groundwater contamination sources and other influences on the groundwater chemistry.

Nine maximum concentration maps were produced: nitrate+nitrite-nitrogen, total dissolved solids (TDS), sodium, arsenic, chloride, phosphate, bromide, boron, and vanadium. For each map, the maximum concentration detected in groundwater sampled from July 1990 through March 1993 at each sampling site was identified. The number of samples collected at each site during that period varied from one to more than ten. Concentration ranges were color-coded, and each groundwater source (alluvial, basalt, and uncertain) was assigned a symbol. The appropriate symbol and color was printed at each sampling location to make reviewing the concentration distribution easier. Data from other sources were added in areas where project data were not available.

The nine constituents used for the maximum concentration maps were selected for different purposes. Nitrate is the focus of this investigation. TDS became a concern during the land use review and constituent loading assessment phases of this investigation (see Chapter 3). Arsenic and sodium were mapped because they were detected in Lower Umatilla Basin groundwater samples at concentrations that could pose health concerns. Phosphate, chloride, bromide, and boron were mapped to help identify different sources of nitrate in local groundwater. Vanadium was mapped, because the unusual concentrations detected in Lower Umatilla Basin groundwater may be linked to local groundwater contamination.

The maximum concentration maps offer benefits and limitations for data analyses. The benefits relate to the fact that not all Lower Umatilla Basin project wells were sampled during a single sampling event, nor did maximum constituent concentrations at different sites occur at the same time. Using maximum concentrations detected increased the number of project wells represented on the map, highlighted contaminated groundwater areas, and helped preliminary assessment of groundwater contamination sources. Using data from multiple sampling events limited data analyses also. It prevented some well to well data comparisons.

Concentration contour maps showing the distribution of nitrate+nitrite-nitrogen and total dissolved solids in alluvial groundwater during June-July 1992 were produced using synoptic sampling data. Concurrent Simplot Feedlot data were also used for the nitrate+nitrite-nitrogen map. Nitrate was mapped, because it is the focus of this investigation. TDS was mapped for two reasons. TDS became a possible constituent of concern during this investigation, and TDS concentration distribution variations appear related to different nitrate sources and other groundwater chemistry influences in the basin.

Linear interpolation between alluvial groundwater sampling sites was used to draw the contours. Shallow unconfined alluvial groundwater and basalt groundwater sampling sites were not used for the contouring. However, these sampling sites and the associated nitrate+nitrite-nitrogen and TDS concentrations were printed on the map for comparison. Color between contours was added to make the concentration distribution patterns more readable.

The contour maps best show the pattern of high versus low concentration for nitrate and TDS. However, caution must be used when reading the maps. Some contour shapes are artifacts of the contouring method. For example, the shape and size of some higher concentration areas may be irregular and either enlarged or reduced due to sparse data in the area. Without careful review, the irregular shapes could cause some misinterpretations about contamination sources and the direction of contaminant movement. Similarly, the size of high concentration areas may be misinterpreted as larger or smaller than really exist. Despite these limitations, the contour maps are very useful for understanding area-wide groundwater chemistry and for identifying contamination sources.

Graphical Analyses of Chemical Data

Graphs used to analyze Lower Umatilla Basin groundwater and surface water chemistry data included a variety of x-y graphs, Piper trilinear graphs and Schoeller Diagrams. The x-y graphs show the relationship between a component, such as constituent concentrations and groundwater elevations, plotted along a vertical axis and another component such as time, location, or another constituent, plotted along a horizontal axis. Piper trilinear graphs and Schoeller Diagrams, show the relationship between multiple constituents. Project data analysis reviewed the graphs for relationships and variability to identify processes and nitrate sources that influence the basin's groundwater.

Computer Modeling Groundwater Chemistry Variations

This investigation used NETPATH (Plummer and others, 1991) and PHREEQE (Parkhurst and others, 1980) groundwater chemistry computer models for data analyses. The project selectively used computer models to understand and differentiate natural versus human influences upon Lower Umatilla Basin groundwater.

PHREEQE is a "forward" model that calculates how groundwater chemistry will change in a reaction with minerals identified by the model user. Mixing is an option also. This investigation used PHREEQE to assess the likelihood that constituent concentrations in some groundwater samples are a result of natural water-rock reactions.

This investigation used NETPATH to assess and refine interpretations of natural and human influences on groundwater chemistry along selected groundwater flow paths. NETPATH calculates the net geochemical mass-balance reactions (with or without mixing) that may be responsible for changing an initial water chemistry to a final water chemistry along a groundwater flow path segment. The model user must specify the appropriate initial water(s), final water, and mineral phases potentially reacting with the water based upon independent and site specific data. The equation the program attempts to solve is:

$$\{[\text{Initial water 1}] + [\text{Initial water 2 (if mixing)}] + [\text{Minerals dissolved}]\}$$
$$= \{[\text{Final water}] + [\text{Minerals precipitated}]\}$$

Often, NETPATH generates many possible solutions. The solutions represent groundwater chemical evolution possibilities rather than prove certain reactions have occurred. The solutions become useful when they provide chemical reaction pathways that appear consistent with observed groundwater chemistry changes between supposedly related sampling sites.

Nitrogen-Isotopic Analyses

The nitrogen isotopic composition of Lower Umatilla Basin groundwater was analyzed to identify sources of nitrogen at selected groundwater sampling locations. This was conducted as a supplement to other data analyses that identify nitrogen sources. Appendix 4B provides an explanation about nitrogen isotopes and how they can be used to identify sources of nitrogen in groundwater.

General Groundwater Chemistry Data Observations and Interpretations

Introduction

State agency staff conducted a variety of groundwater sampling and data analyses for this groundwater technical investigation. The materials and methods section presented the types of sampling and analyses conducted. Appendix 4F provides July 1990 through March 1993 project groundwater sampling data for selected inorganic constituents. Appendix 4G provides July 1990 through December 1994 data for pesticides and volatile organic compounds.

This section presents general groundwater chemistry data observations and interpretations. Local observations and interpretations are presented in area specific sections that follow. The area specific sections are included to help the reader find all local information more easily.

General Statistics and Occurrence

State agency staff collected and chemically analyzed more than 825 groundwater samples from more than 250 Lower Umatilla Basin wells from July 1990 through March 1993. Staff collected the samples during reconnaissance, bimonthly, and a synoptic groundwater sampling. The bimonthly groundwater sampling continues. Samples came from wells receiving groundwater from alluvial sediments, undifferentiated basalt water-bearing zone(s), both alluvial sediments and undifferentiated basalt water-bearing zone(s), and unidentified sources (no water well report found for these wells).

Nitrate+Nitrite-Nitrogen

The groundwater technical investigation focused primarily upon nitrate. Table 4.1 shows nitrate+nitrite-nitrogen statistics related to groundwater sampling in the basin from July 1990 through March 1993. It represents the maximum concentration detected in groundwater sampled from each project well. Figure 4.1 shows the maximum concentration distribution for all the project wells sampled. The number of samples collected at each site varied from one to more than ten.

Nearly 30 percent of the project groundwater samples and nearly 31 percent of the project groundwater sampling sites had nitrate+nitrite-nitrogen concentrations greater than the current 10 mg/L drinking water standard. The percent of samples and sites with concentrations exceeding 10 mg/L is greatest for groundwater from alluvial sediments. The greatest concentrations detected in groundwater sampled from alluvial sediments and basalt water-bearing zones were 76 mg/L and 64 mg/L, respectively. Conversely, approximately 26 percent of the groundwater sampling sites had nitrate+nitrite-nitrogen concentrations less than 2 mg/L.

Table 4.1 Statistics of maximum nitrate+nitrite-nitrogen concentration detected in groundwater sampled from each project well.

	Number of Wells With NO_3+NO_2-N Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)	Project Wells with Sample(s) > 10 mg/L	
						Number	Percent
All Wells With NO_3+NO_2-N Analyses	252	76.00	<0.02	9.66	5.80	78	30.95
Groundwater from Alluvium	186	76.00	<0.02	10.49	6.45	64	34.41
Groundwater from Basalt	32	64.00	<0.02	7.48	1.04	6	18.75
Groundwater from Basalt & Alluvium	9	20.00	0.02	6.72	3.60	3	33.33
Undetermined Source	25	31.00	<0.02	7.34	4.50	5	20.00

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The Maximum Contaminant Level for Nitrate in Drinking Water is 10 mg/L.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

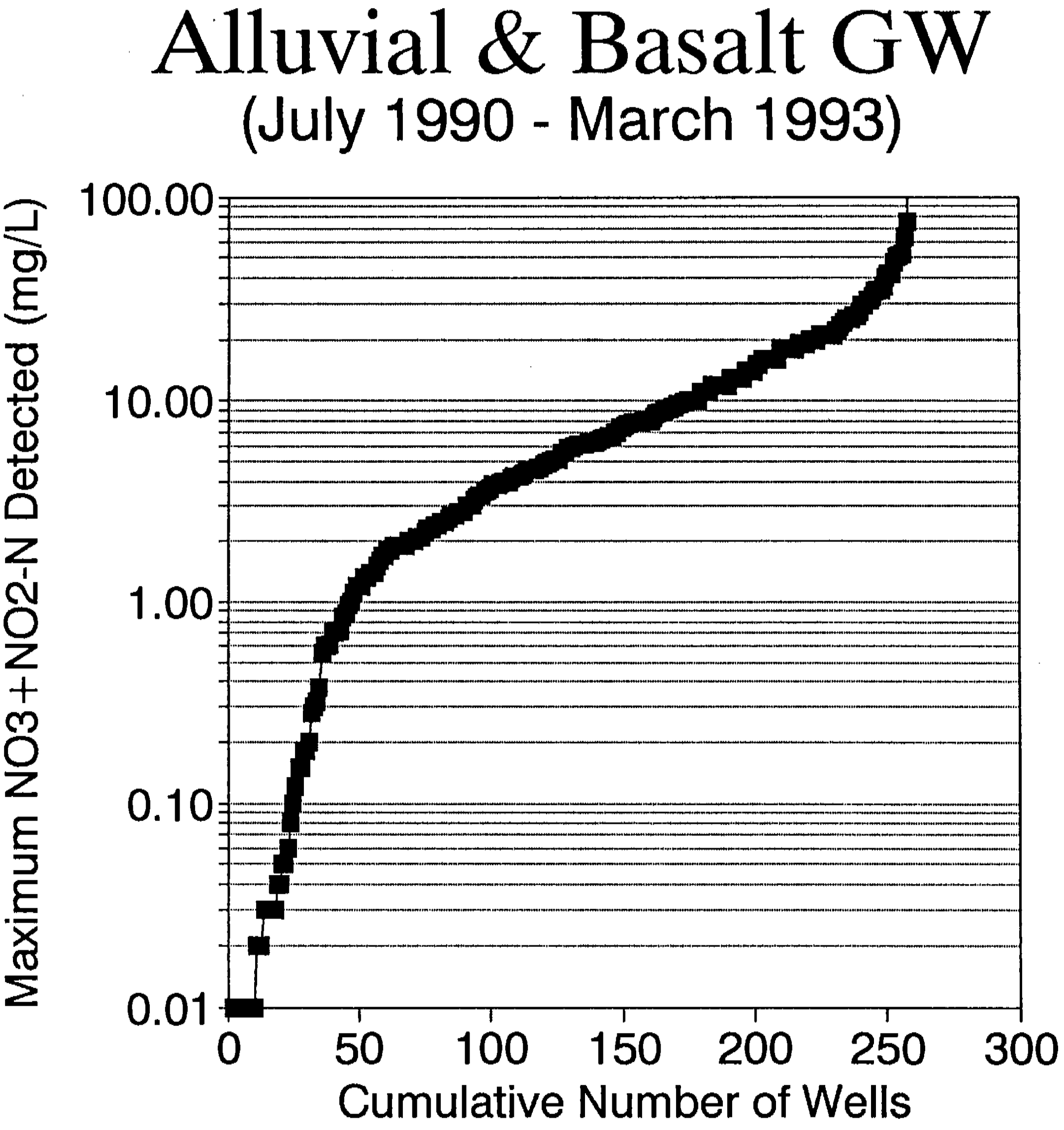


Figure 4.1 Cumulative frequency of maximum nitrate+nitrite-nitrogen concentrations detected in groundwater sampled from each project sampling site.

Note: The graph shows the number of project groundwater sampling site with a maximum nitrate+nitrite-nitrogen concentration less than a given concentration.

Areas of high and low nitrate+nitrite-nitrogen concentrations are not uniformly distributed across the basin. Plate 4.2 shows the interpolated concentration distribution for the June-July 1992 synoptic sampling. Plate 4.3 shows the maximum concentration detected at each project sampling site by color coded concentration ranges.

Areas where nitrate+nitrite-nitrogen concentrations in project groundwater samples exceed 10 mg/L include:

- the Three and Six Mile Canyon area;
- the Boardman area;
- the area between the Navy Bombing Range, U.S. Army Umatilla Depot Activity, Irrigon, and the wildlife refuge;
- the area between Irrigon and Umatilla;
- the northeast corner of the Army Depot;
- the central area of the Army Depot; the area between the Army Depot and Lost Lake;
- the general Butter Creek and Umatilla River confluence area;
- an area between Interstate 82 and the Umatilla River; and
- an area between Stanfield Loop Road and Diagonal Road near the Cold Springs Reservoir.

The highest concentration area is located between Boardman and Irrigon where center pivot crop irrigation currently occurs. Nitrogen isotopic analysis identifies commercial fertilizer as the nitrate source.

The sources responsible for the higher concentrations across the basin appear to vary by location. Past and/or current general sources include:

- agriculture using various irrigation methods including center pivots;
- food processing wastewater land application;
- livestock operations;
- U.S. Army Umatilla Depot Activity;
- sewage waste at municipal infiltration beds, large on-site systems, and areas with concentrated individual septic systems.

Local sources are presented in the area specific sections.

Low concentration areas include:

- locations in the Three and Six Mile Canyon area;
- the Irrigon area;
- the western and southwestern portion of the Army Depot;
- the Hermiston trough area;
- an area enclosed by Stanfield Loop Road;
- an area between Highway 395 and Butter Creek Road south of Highland Avenue;
- a small area near the Butter Creek and Umatilla River confluence;
- portions of Echo Meadows area; and
- some locations near and south of Lost Lake.

Background conditions and dilution appears responsible for some of the lower concentrations. This is discussed more in area specific sections.

Groundwater nitrate transport in portions of the basin appears slow. For example, an elevated nitrate+nitrite-nitrogen concentration area in the middle of the U.S. Army Umatilla Depot Activity appears to be a plume emanating from the Explosive Washout Lagoon area (Plate 4.2). The apparent plume extending through UMA 216 may be real, or it may a contouring artifact. Regardless, analysis of the nitrate concentration distribution, the local hydrogeology, and the site history indicates contaminant transport in the local alluvial groundwater may take decades. Depot explosive washout activity ended during the mid-1960s. If the apparent plume extending through UMA 216 is real, nitrate from the washout lagoons has moved less than four miles over three to four decades. If the plume through UMA 216 is not real, nitrate from the washout lagoons has moved less than 0.5 miles over the same time period. This apparently long travel time has important implications about the time needed for groundwater quality improvements to occur within the Depot and similar areas.

Total Dissolved Solids

Total Dissolved Solids (TDS) became a concern during the land use review and constituent loading assessment phases of this investigation. Table 4.2 shows TDS statistics related to project groundwater sampling from July 1990 through March 1993. It represents the maximum concentration detected in groundwater sampled from each project well.

More than 20 percent of the project groundwater samples and more than 25 percent of the project groundwater sampling sites had TDS concentrations greater than the current 500 mg/L secondary (aesthetic) drinking water standard. The percent of sampling sites with maximum concentrations exceeding 500 mg/L is greatest for groundwater from alluvial sediments. The greatest concentration detected in groundwater sampled from alluvial sediments and basalt water-bearing zones was 1200 mg/L and 1600 mg/L, respectively.

Areas of high and low TDS concentrations are not uniformly distributed across the Lower Umatilla Basin. Plate 4.4 shows the interpolated concentration distribution for the June-July 1992 synoptic sampling. Plate 4.5 shows the maximum concentration detected at each project sampling site by color coded concentration ranges.

High and low TDS concentration areas are similar to the distribution of high and low nitrate+nitrite-nitrogen concentration areas with some exceptions. The exceptions appear related to the nitrate sources. Areas with the highest TDS concentrations are located along Six Mile Canyon and between Boardman and Irrigon. A high TDS concentration area in the middle of the U.S. Army Umatilla Depot Activity is much less extensive than the high nitrate+nitrite-nitrogen concentration area. An area between Interstate 82 and the Umatilla River with nitrate+nitrite-nitrogen concentrations in groundwater exceeding 10 mg/L has TDS concentrations in groundwater less than 500 mg/L. Local influences upon the TDS concentration in groundwater are discussed in the area specific sections.

Table 4.2 Statistics of maximum total dissolved solids concentrations detected in groundwater sampled from each project well.

	Number of Wells With TDS Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)	Project Wells with Sample(s) > 500 mg/L	
						Number	Percent
All Wells With TDS Analyses	247	1600	140	425	370	63	25.51
Groundwater from Alluvium	183	1200	140	432	380	52	28.42
Groundwater from Basalt	32	1600	190	444	350	6	18.75
Groundwater from Basalt & Alluvium	9	540	260	361	330	2	22.22
Undetermined Source	23	740	230	372	320	3	13.04

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The Maximum Contaminant Level (secondary) for TDS in Drinking Water is 500 mg/L.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Arsenic

Arsenic in groundwater can pose a health risk. Table 4.3 shows the statistics for total arsenic related to project groundwater sampling from July 1990 through March 1993. The table represents the maximum concentration detected in groundwater sampled from each project well. Plate 4.6 shows the maximum concentration detected at each project sampling site by color coded concentration ranges.

Four dispersed alluvial groundwater sampling sites had total arsenic concentrations exceeding the current 0.05 mg/L drinking water standard. Their locations are: the northwest corner of the U.S. Army Umatilla Depot Activity; the east side of the Depot; east of the Depot's northeast corner; and west of Stanfield.

Arsenic was not detected in groundwater samples collected from some areas. Those areas include portions of Six Mile Canyon, most of Township 3 North from Range 25 through 29 East, portions of the northeast corner of the U.S. Army Depot, portions between Umatilla River Road and the U.S. Army Depot, an area south of Feedville Road and east of Highway 395, and a southeastern portion of Stanfield Loop Road.

Table 4.3 Statistics of maximum total arsenic concentrations detected in groundwater sampled from each project well.

	Number of Wells With Arsenic Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentrations (mg/L)	Project wells with sample(s) > 0.05 mg/L	
						Number	Percent
All Wells With Arsenic Analyses	253	0.120	<0.005	0.007	0.006	4	1.58
Groundwater from Alluvium	187	0.120	<0.005	0.008	0.007	4	2.14
Groundwater from Basalt	32	0.013	<0.005	0.003	< 0.005	0	0.00
Groundwater from Basalt & Alluvium	9	0.012	<0.005	0.004	< 0.005	0	0.00
Undetermined Source	25	0.013	<0.005	0.005	0.006	0	0.00

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The Maximum Contaminant Level for Arsenic in Drinking Water is 0.05 mg/L.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Sodium

Most natural water contains low levels of sodium. Sodium sources include human activity and natural processes. Water chemistry is frequently characterized by the relationship between sodium and other common ions such as magnesium, potassium, calcium, chloride, sulfate, carbonate and bicarbonate.

Elevated sodium concentrations in groundwater can pose a health risk to persons on a physician prescribed sodium restricted diet. These individuals should notify their doctor if the water they consume contains sodium exceeding 20 mg/L.

Table 4.4 presents total sodium statistics related to project groundwater sampling from July 1990 through March 1993, and Plate 4.7 shows the distribution of maximum concentration detected at each project sampling site by color coded concentration ranges. The table represents the maximum concentration detected in groundwater sampled from each project well. Nearly 85 percent of all project sampling sites had total sodium concentrations in groundwater greater than the 20 mg/L currently recommended for persons with a physician prescribed sodium restricted diet. The highest concentrations detected in groundwater from alluvial sediments versus basalt water-bearing zones was 300 mg/L and 140 mg/L, respectively. However, groundwater from basalt water-bearing zones had the highest average maximum concentration. The occurrence of sodium related to sources and other chemical constituents is discussed in the area specific sections.

Table 4.4 Statistics of maximum total sodium concentrations detected in groundwater sampled from each project well.

	Number of Wells With Sodium Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)	Project wells with sample(s) > 20 mg/L	
						Number	Percent
All Wells With Sodium Analyses	253	300.0	8.9	44.5	37.0	214	84.58
Groundwater from Alluvium	187	300.0	8.9	41.3	32.0	154	82.35
Groundwater from Basalt	32	140.0	15.0	62.8	60.5	28	87.50
Groundwater from Basalt & Alluvium	9	99.0	20.0	54.1	50.0	8	88.89
Undetermined Source	25	100.0	17.0	42.4	38.0	24	96.00

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The Maximum Sodium Concentration in Drinking Water Recommended for Persons with a Physician Prescribed Sodium Restricted Diet is 20.0 mg/L.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Chloride

Natural water commonly contains chloride. Chloride sources include human activity and natural processes. Water chemistry is frequently characterized by the relationship between chloride and other common ions such as magnesium, potassium, calcium, sodium, sulfate, carbonate and bicarbonate.

Table 4.5 shows the chloride statistics related to project groundwater sampling from July 1990 through March 1993. The table represents the maximum concentration detected in groundwater sampled from each project well. Only one sampling site had a groundwater chloride concentration exceeding the current 250 mg/L secondary (aesthetic) drinking water standard. That site obtains groundwater from basalt.

Plate 4.8 shows the distribution of maximum chloride concentration detected at each project sampling site by color coded concentration ranges. The occurrence of chloride related to sources and other chemical constituents is discussed in the area specific sections.

Table 4.5 Statistics of maximum chloride concentrations detected in groundwater sampled from each project well.

	Number of Wells With Chloride Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)	Project Wells with Samples > 250 mg/L	
						Number	Percent
All Wells With Chloride Analyses	253	490	3.3	32.4	19.0	1	0.40
Groundwater from Alluvium	187	190	3.3	30.6	19.0	0	0.00
Groundwater from Basalt	32	490	4.2	53.6	21.0	1	3.13
Groundwater from Basalt & Alluvium	9	73	11.0	25.0	16.0	0	0.00
Undetermined Source	25	53	6.7	20.7	17.0	0	0.00

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The Maximum Contaminant Level (secondary) for Chloride in Drinking Water is 250 mg/L.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Phosphate, Boron, and Bromide

The occurrence and relative proportions of phosphate, boron, and bromide to other chemical constituents in groundwater can occasionally help identify nitrate sources. Tables 4.6, 4.7, and 4.8 show total phosphate, dissolved boron, and bromide statistics related to project groundwater sampling from July 1990 through March 1993. They represent the maximum concentration detected in groundwater sampled from each project well. Groundwater from alluvial sediments had the maximum concentration detected for each constituent.

Plates 4.9, 4.10, and 4.11 show the distribution of maximum total phosphate, dissolved boron, and bromide concentrations detected at each project sampling site by color coded concentration ranges. The occurrence of these constituents relative to nitrate, other chemical constituents, and nitrate sources is discussed in area specific sections.

Table 4.6 Statistics of maximum total phosphate concentrations detected in groundwater sampled from each project well.

	Number of Wells With Total-PO_4 Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)
All Wells With Total PO_4 Analyses	252	50.80	<0.01	0.48	0.07
Groundwater from Alluvium	186	50.80	0.01	0.63	0.08
Groundwater from Basalt	32	0.14	<0.01	0.04	0.02
Groundwater from Basalt & Alluvium	9	0.05	<0.01	0.02	0.02
Undetermined Source	25	0.32	0.01	0.09	0.06

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.

Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Table 4.7 Statistics of maximum dissolved boron concentrations detected in groundwater sampled from each project well.

	Number of Wells With Boron Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)
All Wells With Boron Analyses	175	0.18	<0.03	0.03	0.04
Groundwater from Alluvium	114	0.18	<0.03	0.04	0.04
Groundwater from Basalt	27	0.08	<0.03	0.02	0.03
Groundwater from Basalt & Alluvium	9	0.07	<0.03	0.03	0.03
Undetermined Source	25	0.08	<0.03	0.02	0.03

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.

Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Table 4.8 Statistics of maximum bromide concentrations detected in groundwater sampled from each project well.

	Number of Wells With Bromide Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)
All Wells With Bromide Analyses	205	4.30	<0.05	0.26	0.13
Groundwater from Alluvium	176	4.30	<0.05	0.26	0.13
Groundwater from Basalt	27	1.90	<0.05	0.25	0.18
Groundwater from Basalt & Alluvium	1	0.07	0.07	0.07	0.07
Undetermined Source	1	0.08	0.08	0.08	0.08

Note: For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.

Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Vanadium

Vanadium concentrations in Lower Umatilla Basin groundwater are an unusual curiosity that other researchers may want to investigate. Typically, vanadium concentrations in groundwater rarely exceed 0.01 mg/L (Hem, 1985). However, average maximum vanadium concentrations in Lower Umatilla Basin basalt water-bearing zones and alluvial sediment groundwater samples are 0.02 mg/L and 0.04 mg/L. The maximum concentration detected was 2.00 mg/L in an alluvial sediment groundwater sample.

Table 4.9 shows the total vanadium statistics related to project groundwater sampling from July 1990 through March 1993. The table represents the maximum concentration detected in groundwater sampled from each project well. Plate 4.12 shows the distribution of the maximum total vanadium concentration detected at each project sampling site by color coded concentration ranges.

Table 4.9 Statistics of maximum total vanadium concentrations detected in groundwater sampled from each project well.

	Number of Wells With Vanadium Analyses	Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Median Concentration (mg/L)
All Wells With Vanadium Analyses	250	2.00	<0.03	0.03	< 0.03
Groundwater from Alluvium	185	2.00	<0.03	0.04	< 0.03
Groundwater from Basalt	32	0.07	<0.03	0.02	< 0.03
Groundwater from Basalt & Alluvium	9	0.04	<0.03	0.01	< 0.03
Undetermined Source	24	0.09	<0.03	0.02	< 0.03

For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through March 1993.
Note: The average concentration calculations used 0 mg/L for concentrations below the laboratory detection limit.

Volatile Organic Compounds and Pesticides

Volatile organic compounds (VOCs) or pesticides in groundwater come from human activity. Table 4.10 shows the six constituents detected in Lower Umatilla Basin groundwater, the number of sampling sites associated with the detections, the maximum concentrations detected, and the maximum contaminant level for drinking water. Appendix 4G presents all the VOCs and pesticides detected from July 1990 through September 1994. Plate 4.13 shows the distribution of the different constituents detected.

Most of the Lower Umatilla Basin groundwater samples containing VOCs and/or pesticides came from alluvial sediments. Only ethylene dibromide (EDB) was detected at concentrations exceeding current drinking water standards. The occurrence of these constituents is discussed in the area specific sections.

Table 4.10 Volatile organic compounds and pesticides concentrations detected in groundwater sampled from each project well.

Constituent	Number of Groundwater Sampling Sites with Detections	Maximum Concentration Detected	Maximum Contaminant Level for Drinking Water
Ethylene Dibromide (EDB)	1	0.0026 mg/L	0.00005 mg/L
1,1,2,2 Tetrachloroethylene	1	0.0011 mg/L	0.0050 mg/L
Chloroform	4	0.0028 mg/L	0.1000 mg/L
Toluene	1	0.0013 mg/L	1.0000 mg/L
Atrazine	6	0.0023 mg/L	0.0030 mg/L
Dacthal Acid	4	0.0200 mg/L	---
For Groundwater Samples Collected from Lower Umatilla Basin Groundwater Management Area Project Wells: July 1990 through September 1994			

General Graphic Analyses

State agency staff conducted graphical analyses of Lower Umatilla Basin sampling data to identify the chemical and physical processes influencing observed groundwater chemistry variations. Alluvial groundwater data and basalt water-bearing zone groundwater data were analyzed separately, because they represent different hydrogeologic units. This section presents basin-wide observations. Area specific sections present local observations.

Nitrate Versus Other Chemical Constituents

A positive correlation exists between nitrate+nitrite-nitrogen and some chemical constituents in Lower Umatilla Basin groundwater. For example, the proportion of chloride and sulfate relative to other anions often increases with increasing nitrate+nitrite-nitrogen concentrations. Total dissolved solids and electrical conductivity best correlate with nitrate+nitrite-nitrogen concentrations. Basin-wide, a weaker correlation exists between nitrate+nitrite-nitrogen and other chemical constituents, such as calcium.

Significant correlations suggest a common influence. Processes or activities contributing nitrate contribute other constituents as well. The amount of correlation between nitrate+nitrite-nitrogen and other chemical constituents varies from constituent to constituent.

Figure 4.2 shows nitrate+nitrite-nitrogen concentrations versus total dissolved solids (TDS) and sulfate for all Lower Umatilla Basin groundwater samples. Both constituents correlate well with nitrate+nitrite-nitrogen for concentrations greater than 1 mg/L. The correlation exists despite significantly different groundwater chemistry histories represented by the data. The tighter and more linear grouping for TDS indicates TDS generally correlates better to nitrate+nitrite-nitrogen in the basin's groundwater than sulfate. The relationship between NO_3 and other constituents is even poorer and probably reflects variable sources contributing to groundwater along flow paths which are discussed later.

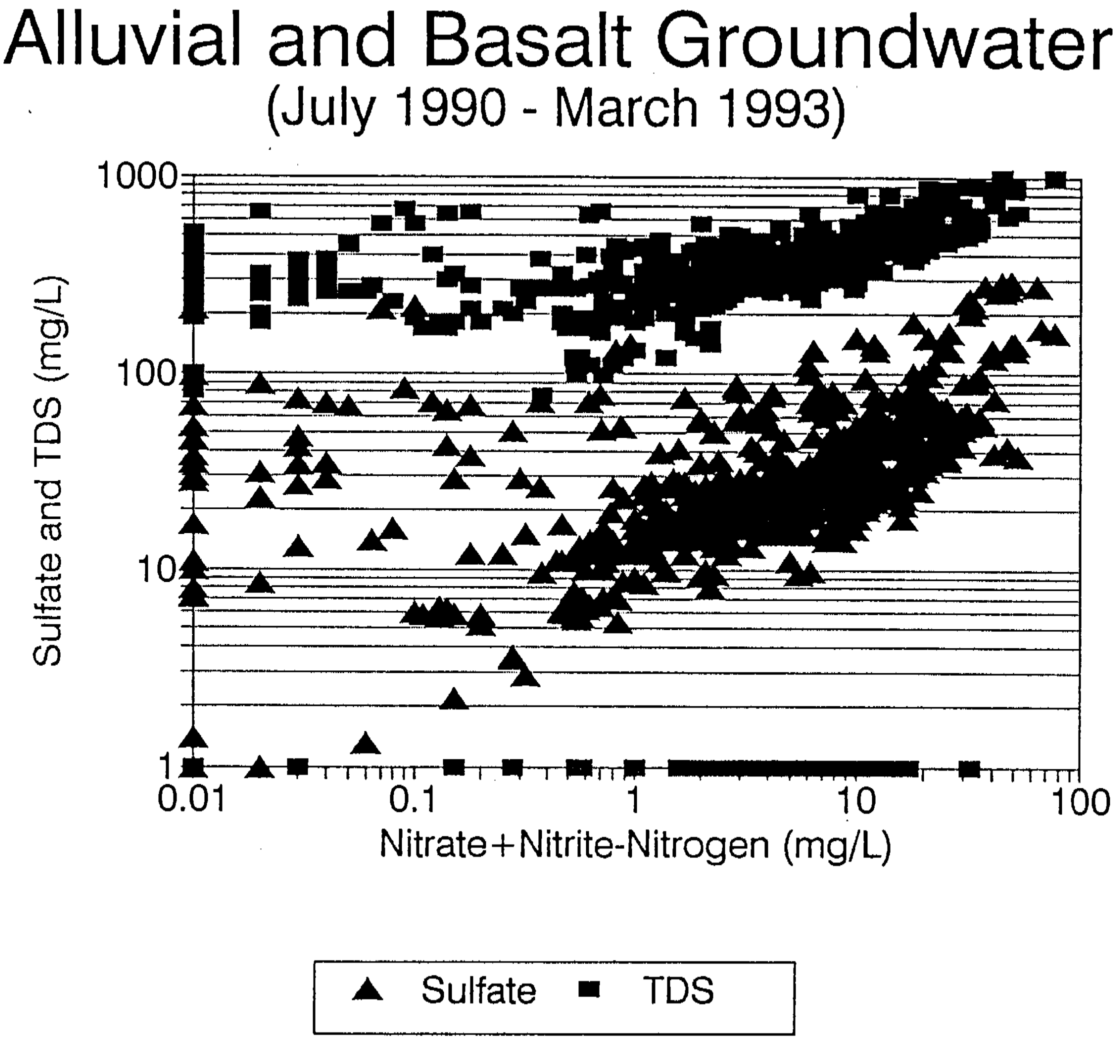


Figure 4.2 Nitrate+nitrite-nitrogen concentrations versus total dissolved solids and sulfate concentrations for all project groundwater samples collected from July 1990 through March 1993.

The graphical change from scatter below 1/mg/L nitrate+nitrite-nitrogen to correlation above 1 mg/L in Figure 4.2 suggests the dominating chemical influence upon local groundwater possibly changes from natural processes to human activity. This project interprets the 1 mg/L nitrate+nitrite-nitrogen concentrations as the maximum background concentration for groundwater in the basin. At lower nitrate concentrations, no clear correlation exists between nitrate, TDS, and sulfate, because the three constituents apparently have no common natural source. The correlation at higher nitrate concentrations indicates common external sources related to human activities.

This project analyzed the relationship between total dissolved solids (TDS) and nitrate+nitrite-nitrogen concentrations for Lower Umatilla Basin groundwater samples apparently impacted by a single land use activity. Activities represented included septic systems, land application of food processing wastewater, confined animal feeding operations, and irrigated crop agriculture. The TDS and nitrate+nitrite-nitrogen concentrations correlated well for each land use. Each correlation indicates the associated land use activity contributes nitrate and TDS to groundwater.

The good correlation for each land use activity represented means multiple sources in the Lower Umatilla Basin contribute nitrate and TDS to groundwater. However, the amount of nitrate and TDS contributed by each land use activity varies. For example, groundwater sampled in areas associated with septic systems generally have nitrate+nitrite-nitrogen concentrations less than 15 mg/L and TDS concentrations less than 500 mg/L. These analyses are discussed more in the potential nitrate sources section.

Other Constituent Versus Constituent Relationships

Project graphical analyses included plotting groundwater data for chloride, potassium, sodium, sulfate, bromide, calcium, magnesium, nitrate+nitrite-nitrogen, and total dissolved solids (TDS) in various combinations. The analyses yielded information about the influence of evaporation, mixing, and nitrate sources.

Graphical analyses of chloride versus potassium, sodium, sulfate, and nitrate+nitrite-nitrogen plotted as molar concentrations yielded several findings:

- Evaporation appears to influence groundwater at many sampling sites in the basin by changing the molar quantities of constituents present. However, the data graphed are often displaced from the evaporation line toward chemical compositions representing potential nitrate sources.

- The Umatilla River may be receiving nitrate and total dissolved solids from either groundwater or runoff.

- Groundwater in some basalt water-bearing zones appear hydraulically connected to alluvial groundwater. These analyses and findings are discussed more in the evaporation and mixing section.

This project conducted graphical analysis to distinguish sources contributing nitrate to groundwater. Graphs analyzed included:

- potassium versus bromide, chloride, and bromide,
- magnesium versus calcium and sulfate,
- chloride versus chloride-bromide ratios, and
- nitrate versus total dissolved solids.

Data used for the analyses were limited to groundwater samples obtained from areas presumably influenced by a single land use activity. The influence of food processing wastewater and septic systems appeared as distinct groupings on graphs showing chloride, potassium, and bromide. The influence of individual food processing wastewater sources were chemically distinguished on magnesium versus sulfate and calcium graphs. Chemical differences observed may relate to the source water used, human activity unique to the facility operation, or geochemical processes unique to the land application area. These analyses and findings are discussed more in the potential nitrate sources section.

Schoeller Diagram and Piper Trilinear Diagram Observations

Graphical analyses of constituent relationships included using Schoeller semi-logarithmic and Piper trilinear diagrams. Schoeller diagrams show concentration ranges in the vertical direction and constituents of interest along the horizontal axis. A line connects the constituent concentrations for each sample represented. Piper trilinear diagrams show the relative proportion of major ions for each sample represented.

Only project bimonthly and synoptic sampling data were graphed. Bimonthly sampling data were graphed by sampling site to observe time-related relationships. Synoptic sampling data were graphed by common geographic area and aquifer type to observe well to well relationships. General observations are presented here. Area specific observations are presented in the area specific sections.

Analysis of the Piper trilinear and Schoeller semi-logarithmic diagrams yielded the following general observations:

- Most groundwater samples plotted as mixed-cation/bicarbonate dominated and calcium/bicarbonate dominated water on the Piper trilinear diagrams. Few groundwater samples plotted as mixed-cation/chloride, calcium/mixed-anion, magnesium/mixed-anion, sodium+potassium/bicarbonate, or no ion dominant type water on the Piper trilinear diagrams.

- Surface water sampled plotted as mixed-cation/bicarbonate dominated and calcium/bicarbonate dominated water on the Piper trilinear diagrams.

- All food processing and animal wastewater sampled from wastewater ponds plotted as sodium+potassium/bicarbonate dominated water on the Piper trilinear diagrams.

- Chloride and sulfate proportions on trilinear graphs often varied similarly to nitrate+nitrite-nitrogen concentration variations over time and by location. Occasionally, calcium proportions varied similarly or inversely to nitrate+nitrite-nitrogen concentrations. The proportion variations frequently plotted as mixing lines on Piper trilinear diagrams.

- Many major ion concentrations in Lower Umatilla Basin groundwater sampled often related similarly to nitrate+nitrite-nitrogen concentration variations over time and by location. This relationship frequently appeared on the Schoeller diagrams as similar line patterns shifting up, down, or superimposing when nitrate+nitrite-nitrogen concentration increased, decreased, or remained unchanged, respectively.

- Detectable phosphate concentrations in Lower Umatilla Basin groundwater sampled often related inversely to nitrate+nitrite-nitrogen concentration variations over time and by location.

Groundwater samples related to specific nitrate sources did not graph uniquely on these diagrams. However, the diagrams helped link some groundwater samples indirectly to nitrate sources as follows. When the source of nitrate detected in some samples was uncertain, the diagrams helped chemically relate those samples to a nearby group of samples where the nitrate source was better identified.

Constituent Concentration Versus Time Observations

Project graphical analyses included reviewing and comparing constituent concentrations versus time graphs. Data used for the analyses came from project bimonthly groundwater sampling and local facility groundwater monitoring reports. Project bimonthly sampling constituent versus time graphs included nitrate+nitrite-nitrogen, total dissolved solids, chloride, sulfate, bicarbonate, sodium, calcium, phosphate and boron. Local facility groundwater sampling constituent versus time graphs primarily included nitrate and total dissolved solids. The graphical analyses noted when peak concentrations occurred and compared constituent concentration graphs related to the same sampling site. Basin-wide observations are presented here. Area specific observations are presented in the area specific sections.

Nitrate concentrations fluctuate in Lower Umatilla Basin groundwater with some exceptions. Nitrate concentration peaks generally occurred in November, January, or March for project bimonthly groundwater samples (Figure 4.3). Nitrate concentration peaks for groundwater samples collected and reported by local facilities generally occurred primarily in September, October, November, December, March, April, or June depending on the site (Figure 4.4). Concentration peaks occurred less frequently during the mid-summer months for all samples analyzed. Concentration peaks for other constituents graphed occurred during fall, winter, and spring months also.

Concentration peaks occurring primarily during fall, winter, and spring may relate to one or more influences. The concentration peaks timing may relate to the time needed for nitrogen, other constituents, and water applied at land surface to travel to groundwater. It may also relate to when nitrogen, other constituents, and water can most easily leach to groundwater. For example, evaporation and uptake by crops and other vegetation may inhibit water, nitrogen, and other constituents from escaping to groundwater during mid-summer months. Conversely, sufficient moisture and little or no vegetative growth during fall, winter, and spring months may allow available nitrogen and other constituents to leach.

Relatively steady nitrate+nitrite-nitrogen concentrations over time were observed for groundwater sampled from some wells. Steady concentrations ranged from less than 0.1 mg/L to 20 mg/L. Steady nitrate+nitrite-nitrogen concentrations below 1 mg/L appear related to background conditions or constant dilution. Steady nitrate+nitrite-nitrogen concentrations above 1 mg/L appear related to a constant source like septic systems, or nitrate accumulating in areas with limited groundwater movement.

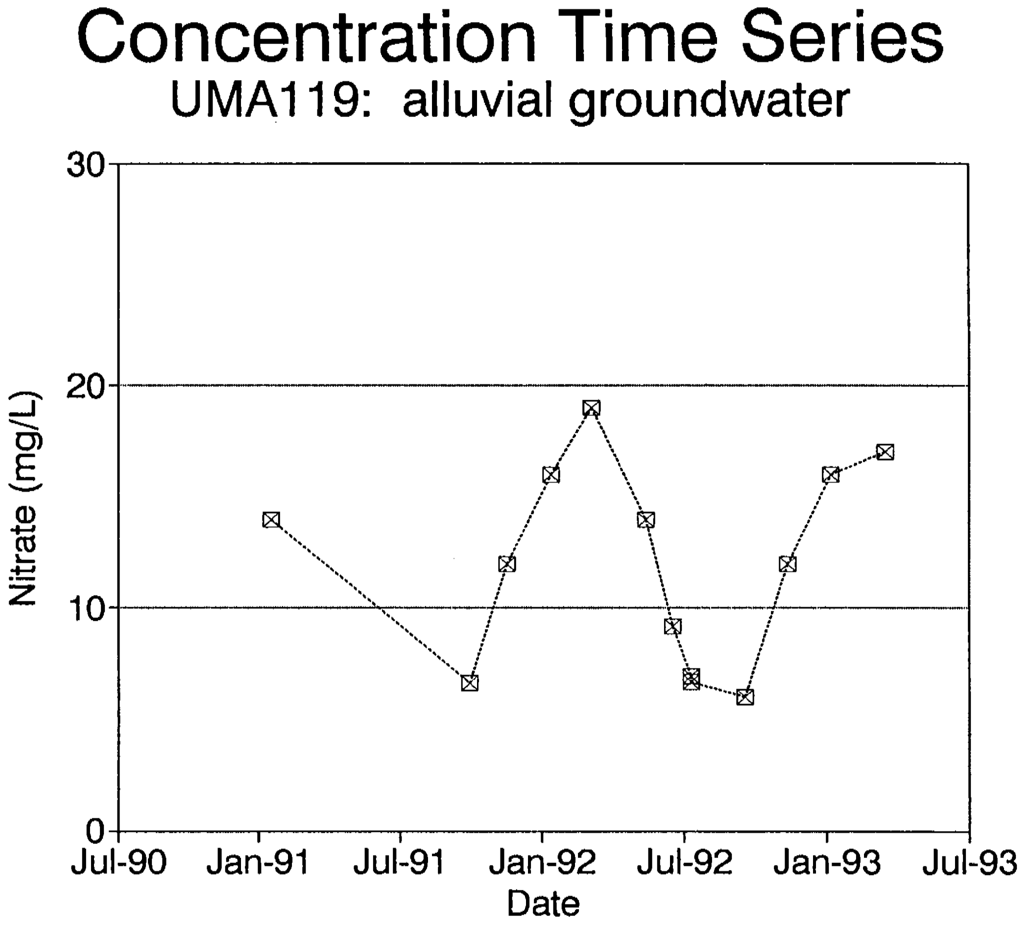


Figure 4.3 Nitrate+nitrite-nitrogen versus time in alluvial groundwater at UMA 119 located southwest of Hermiston.

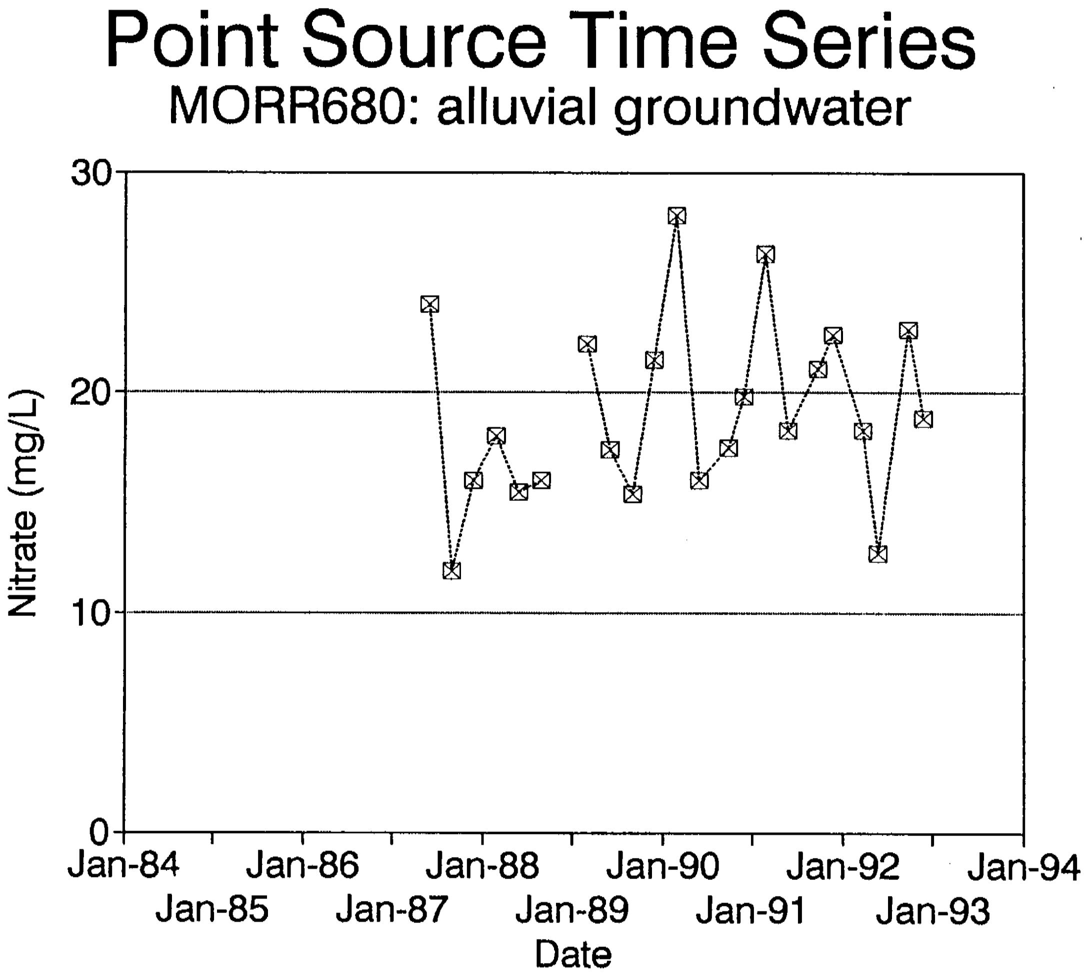


Figure 4.4 Nitrate+nitrite-nitrogen versus time in alluvial groundwater at Port of Morrow monitoring well MW-5 (MORR 0680) located northeast of Boardman.

Constituent concentration versus time graphs were compared to each other to observe similarities and differences that may distinguish sources or processes influencing the local groundwater chemistry. Only graphs that relate to the same sampling site were compared. Land use activities surrounding the sampling sites include septic systems, irrigated crop agriculture, food processing wastewater land application, and confined animal feeding operations.

The constituent concentration versus time graph comparisons did not distinguish different sources and processes. The set of constituents showing similar, opposite, or no concentration fluctuation correlations varied from sampling site to sampling site. Weak to strong correlation between nitrate+nitrite-nitrogen, TDS, chloride, sulfate, bicarbonate, sodium, and calcium graphs were observed. Many nitrate+nitrite-nitrogen graphs correlated best with total dissolved solids (TDS) graphs. Boron and phosphate showed no consistent relationship to the other constituents. Efforts to distinguish general sources or processes responsible for concentration fluctuations showing similar versus opposite or no correlation to other constituent concentration fluctuations did not succeed.

Constituent Concentration and Groundwater Elevation Versus Time Graphs Compared

Project graphical analyses included comparing constituent concentration versus time graphs to groundwater elevation versus time graphs related to the same sampling location. The analyses used long term nitrate, total dissolved solids, sodium and groundwater elevation data reported by Lower Umatilla Basin facilities. The facilities measured groundwater elevations concurrently with collecting groundwater samples, whereas project groundwater sampling did not. General observations related to these comparisons are presented here. Area specific observations are presented in the area specific sections.

Correlation between the constituent concentration and groundwater elevation graphs varied. This project explored possible explanations for the different correlations.

Constituent concentrations and groundwater elevations correlated over time for many graphs compared. Figure 4.5 is an example. The majority of these correlations related to sampling sites where groundwater came primarily from coarse-grained or flood plain alluvial sediments and constructed well depths ranging primarily between 19 and 110 feet. Several exceptions included sampling sites where groundwater came from fine-grained alluvial sediments or basalt water-bearing zones and one coarse-grained sediment site with a 200 feet deep well. The very similar correlations suggest constituent loading at these sites relates somehow to local groundwater recharge, and the travel time to groundwater is relatively short under conditions existing during the time periods compared.

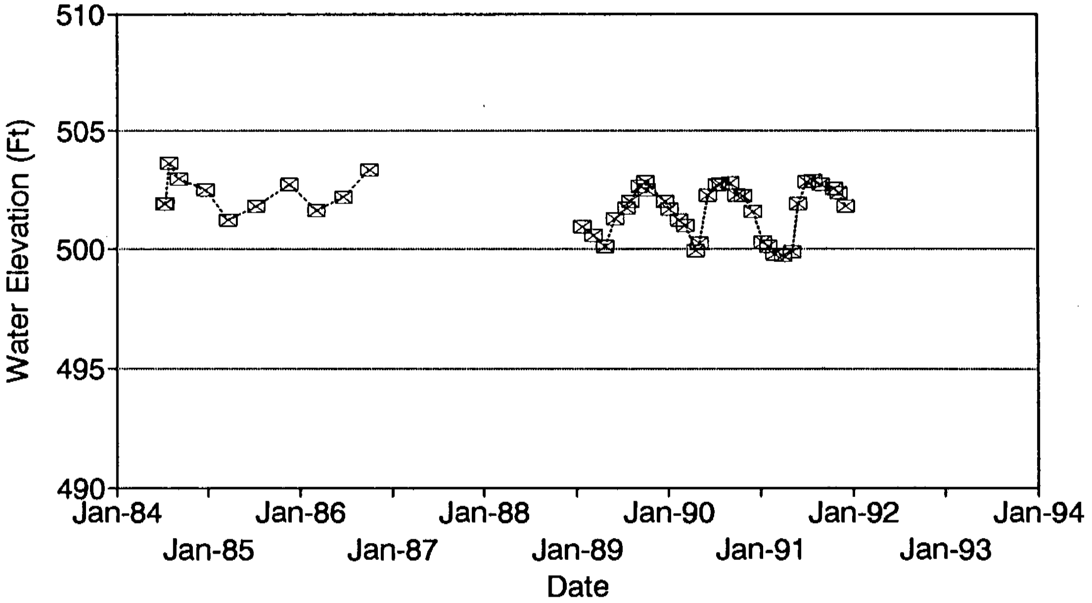
Some constituent concentrations and groundwater elevations appeared to correlate inversely over time. Constituent concentrations were observed to decline when groundwater elevations rose, and rise when elevations declined.

The relationship between groundwater elevation and well construction was explored as an explanation for the apparently inverse constituent concentration and groundwater elevation correlations. A vertically fluctuating groundwater table close to where groundwater enters a well can influence the correlation when the constituent concentrations in groundwater are stratified. For example, groundwater near the water table having higher constituent concentrations than deeper groundwater below can yield an inverse correlation as follows:

- Constituent concentration in the groundwater samples collected increases when the water table drops near or intercepts the groundwater entrance to the well and shallow groundwater with the higher concentrations enters the well.

- Conversely, groundwater sample constituent concentrations decrease when the water table rises and deeper groundwater with lower concentrations enters the well.

The groundwater table in the Lower Umatilla basin does intercept or move within 10 feet of where groundwater enters many facility wells. However, inverse correlations did not dominate the graphical comparisons related to these sites. Instead, the graphical comparisons yielded a nearly equal number of similar, and inverse, and no correlations between constituent concentrations and groundwater elevation. These different correlations suggest the influence of groundwater elevations relative to well construction fails to apply in the Lower Umatilla Basin.



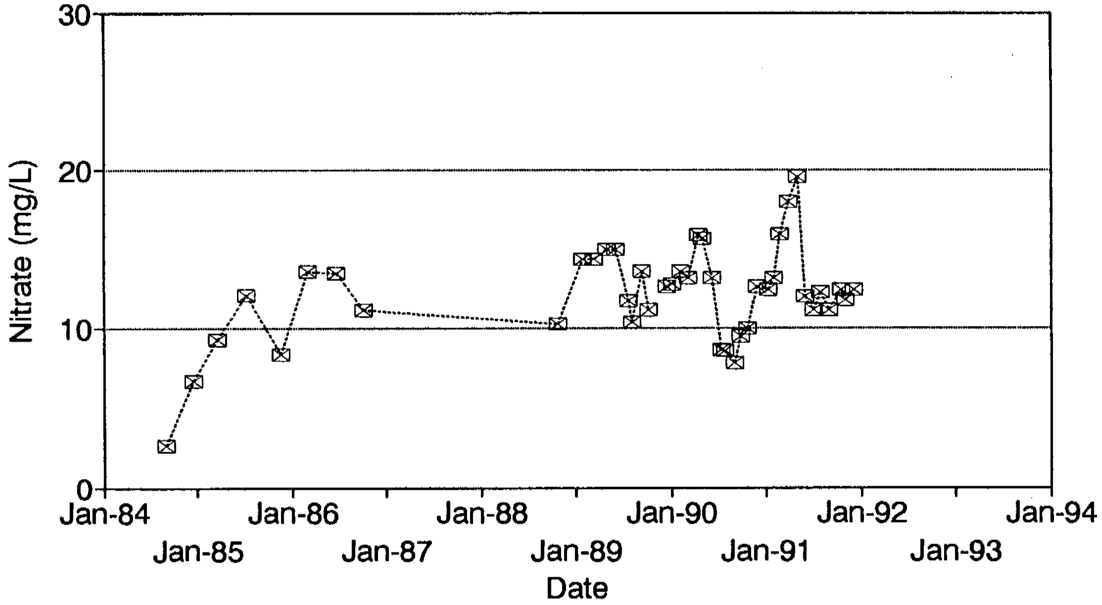


Figure 4.5 An example of correlating nitrate concentration and groundwater elevation fluctuations at UMA 261 (LUB 042, Simplot MW-115).

This project also explored time lags as an explanation for the apparently inverse and no correlation observed between groundwater elevation and constituent concentration. A true time lag implies groundwater elevations and constituent concentrations share common influences. However, the influences affect groundwater elevations more quickly than constituent concentrations. This situation appears to exist in the Lower Umatilla Basin at some locations.

A time lag became suspected after several groundwater elevation and constituent concentration graphs having uniquely similar fluctuations occurring at different times were observed. The graphs correlated when shifted to superimpose the uniquely similar fluctuations. Other apparently inverse or no correlation graph sets also correlated when a time lag shift was considered. A time lag correlation was not established for some graph sets due to insufficient data over time.

Graph sets with observed time lags primarily related to sampling sites where groundwater came from fine-grained sediments and constructed well depths exceeding 100 feet. Exceptions included several sites where groundwater comes from coarse-grained or flood plain sediments and sites with wells constructed less than 30 feet deep. Observed time lags for nitrate ranged from 0 to 18 months.

Analysis indicates the nitrate time lags may change significantly when sufficient water is available. For example, the observed time lag related to one flood plain site with a well 19 feet deep temporarily changed from 10 months to less than 1 month due to a flood event.

The time lag related correlations between groundwater elevations and constituent concentrations have very important implications for the Lower Umatilla Basin. The correlations indicate nitrate may move to groundwater more quickly than previously estimated by other investigators.

Constituent Concentration Versus Groundwater Flow Path Location

Project graphical analyses included reviewing and comparing constituent concentrations versus location and time along groundwater flow paths. This graphical analysis was limited to the Butter Creek and U.S. Army Umatilla Depot Activity areas where the hydrogeology and land use activities are more complex. The analyses observed the following:

- Multiple influences affect the groundwater chemistry along each groundwater flow path. This includes influences unrelated to nitrate;

- More than one source contributes nitrate to groundwater along each groundwater flow path;

- Nitrate concentrations correlate better to calcium and chloride than sodium and sulfate along each groundwater flow path; and

- Constituent concentrations in groundwater along the Butter Creek flow path do not progressively increase downgradient, which would be expected from chemical influences limited to progressive water rock reactions or non-point source loading. Instead, a stationary groundwater chemistry anomaly exists along the groundwater flow path.

Specific observations and discussions related to the groundwater flow path graphical analyses are presented in the area specific sections.

Evidence of Evaporation and Mixing Affecting Alluvial Groundwater Chemistry

Analyses of a series of constituent versus constituent graphs indicate evaporation and mixing processes influence the alluvial groundwater chemistry in the Lower Umatilla Basin. Graphs analyzed represent alluvial groundwater presumably sampled in areas influenced by a single nitrate source, samples from four potential nitrate sources, and samples from three irrigation water sources. The groundwater samples came from wells within or near areas with septic systems, animal feedlots, irrigated crop agriculture, and land application of food processing wastewater. Samples representing potential nitrate sources came from wastewater lagoons at a sewage treatment plant (STP), two food processors [(SP) and (LW)], and a dairy (HD). Samples representing irrigation water came from the Columbia River (CR), the Umatilla River (UR), and well UMA 082 cased into the uppermost basalt (BW).

The graphs show constituent concentrations as molar quantities, which represent the number of atoms or molecules present rather than mass. Using molar quantities was necessary for the analyses, because changes during evaporation and certain other reactions are based on molecules rather than mass. Simple evaporation appears as a 1-to-1 slope on graphs using molar quantities. Other processes will appear on the graphs as a departure from the theoretical evaporation line.

Figure 4.6 shows chloride versus potassium. Most samples from the wastewater lagoons and irrigation water sources show evidence of evaporation. They appear to graph along an approximate evaporation trend that begins with a dilute source such as the Columbia or Umatilla Rivers. Water from the basalt well and the sewage treatment plant graph within the trend of alluvial groundwater data where potassium remains low and relatively constant while chloride continues to increase. The higher chloride concentrations in the alluvial groundwater probably relates to evaporation. The relatively constant and low potassium concentrations in the alluvial groundwater may relate to cation exchange (Drever, 1982). Available clay mineral surfaces tend to adsorb potassium as water percolates from land surface to groundwater through the vadose (unsaturated) zone.

The observation that groundwater sampled from the basalt well graphed within the same trend as the alluvial groundwater samples is important. Basalt mineral chemistry can not explain the conformance. No mineral can serve as the chloride source. Additionally, potassium concentrations in minerals comprising basalt are very low. Instead, the conformance indicates alluvial groundwater and groundwater in the basalt water-bearing zones experienced the same processes such as evaporation. This shared experience indicate the alluvial groundwater and the basalt groundwater are connected. This observation is consistent with conclusions reached in the hydrogeologic section that the uppermost basalts are hydraulically connected to the alluvial aquifer. Analyses presented in the next section further supports a hydraulic connection.

Figure 4.7 shows chloride versus nitrate+nitrite-nitrogen. The alluvial groundwater samples show evidence of evaporation. However, they graph at nitrate concentrations greater than expected for simple evaporation from a dilute source. They graph in a manner consistent with a model of water mixing with nitrate enriched waters. The Umatilla River sample has a nitrate concentration higher than expected from evaporating a dilute source. The higher nitrate concentration may reflect nitrate loading from groundwater or surface water runoff. All but one of the potential nitrate source samples graph well below the evaporation line. Nitrogen occurring primarily as ammonia and Total Kjeldahl Nitrogen in these sources appears responsible. Nitrogen in these sources converting to nitrate during or subsequent to land application would result in nitrate concentrations similar to the other potential nitrate source sample.

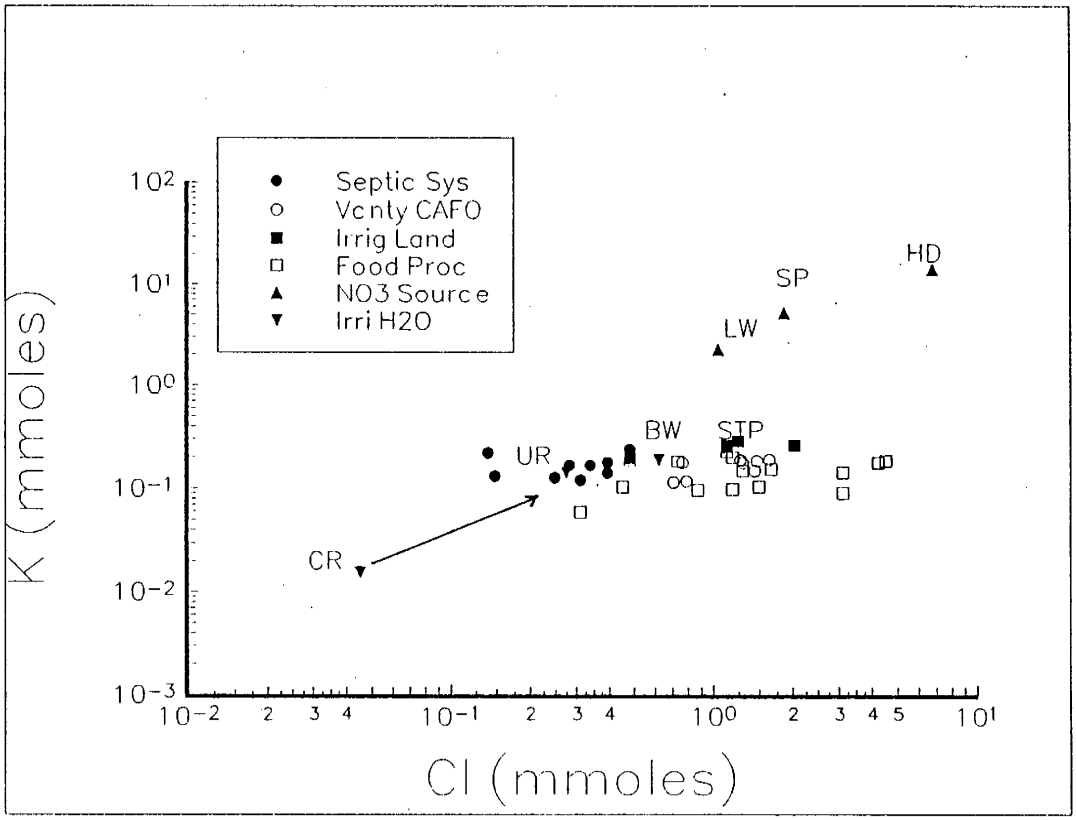


Figure 4.6 Chloride versus potassium concentrations for selected alluvial groundwater samples, potential nitrate source samples, and irrigation water sources.

Note: The evaporation trend for irrigation water sources and potential nitrate sources, and the nearly constant potassium concentration.

Note: CR=Columbia River, UR= Umatilla River, BW=basalt well, STP=sewage treatment plant, LW=Lamb Weston, Inc. wastewater lagoon, SP=J.R. Simplot Co. wastewater lagoon, and HD=Hillview dairy wastewater lagoon.

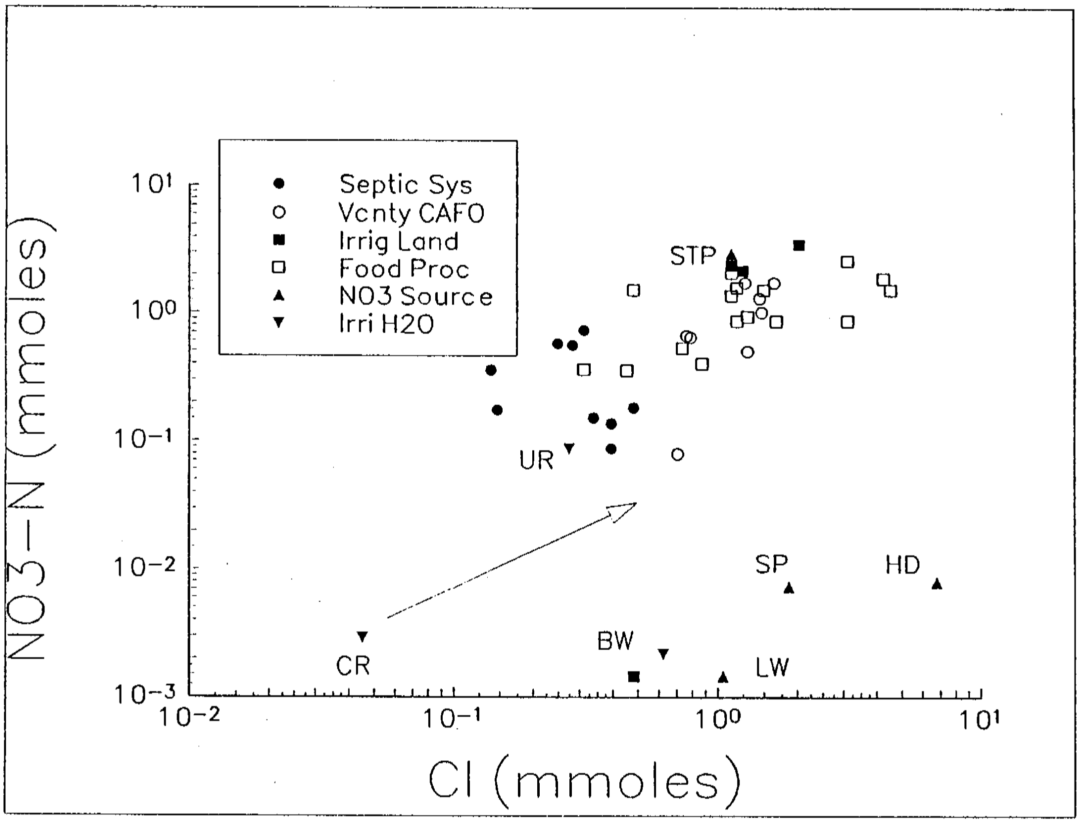


Figure 4.7 Chloride versus nitrate+nitrite-nitrogen concentrations for selected alluvial groundwater samples, potential nitrate source samples, and irrigation water sources sample.

Note: The alluvial groundwater samples graph parallel to the evaporation trend at concentrations greater than predicted by simple evaporation and the low nitrate concentrations for potential nitrate sources due to nitrogen present as ammonia and TKN rather than nitrate.

Note: The symbol label abbreviations are the same as in Figure 4.6.

The groundwater sample from the basalt well graphs at a much lower nitrate+nitrite-nitrogen concentration in Figure 4.7 than the alluvial groundwater samples. Two possibilities may explain the lower concentration despite chloride and potassium evidence indicating water with higher total dissolved solids has reached basalt water-bearing zones. Perhaps nitrate was not present in the high TDS water initially, or if nitrate was present, denitrification occurred. Denitrification can occur if chemically reducing conditions exist within basalt water-bearing zones.

Figure 4.8 shows chloride versus sodium. Samples representing the Columbia and Umatilla Rivers and groundwater from the basalt well appear related as they graph along the evaporation line. Samples representing potential nitrate sources do not graph along the evaporation line except for one food processing sample. Their diversion from the evaporation line suggests additional factors influenced the water chemistry. The water history probably plays a significant role. The alluvial groundwater samples graph along a trend to the right of the evaporation line and subparallel to the trend defined by the potential nitrate sources. Although the overall trend has similarities to the trend observed for potassium in Figure 4.6, differences exist.

Individual trends exist within the general alluvial groundwater trend in Figure 4.8. Alluvial groundwater samples collected in the vicinity of septic systems, animal feedlots, and other sources have individual trends with positive slopes toward the potential nitrate sources. Although cation exchange may be operating, there is indication that mixing between groundwater and nitrate source waters may impact the water quality also.

Similar arguments can be made using Figure 4.9 which shows chloride versus sulfate. Again, the alluvial groundwater samples on the graph are displaced from the evaporation line towards the field defined by the potential nitrate sources. Both the Umatilla River and the basalt well are displaced as well.

In summary, graphical analyses indicate evaporation and ambient groundwater mixing with water infiltrating from various nitrate sources influences the alluvial groundwater chemistry. Contributions from various individual nitrate sources can not be distinguished using the analyses presented in this section. Methods that can distinguish nitrate sources are presented in the potential nitrate source section.

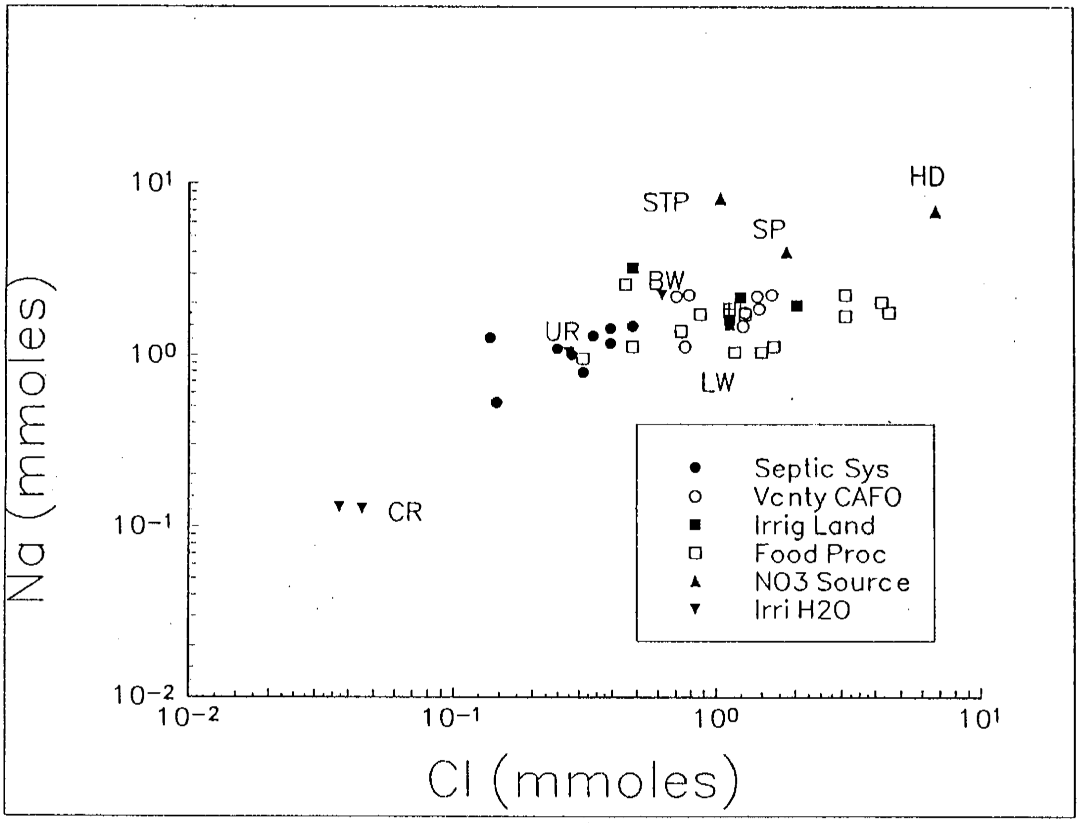


Figure 4.8 Chloride versus sodium for selected alluvial groundwater samples, potential nitrate source samples, and irrigation water sources.

Note: The subtrends have positive slopes within the general trend.
Note: The symbol label abbreviations are the same as in Figure 4.6.

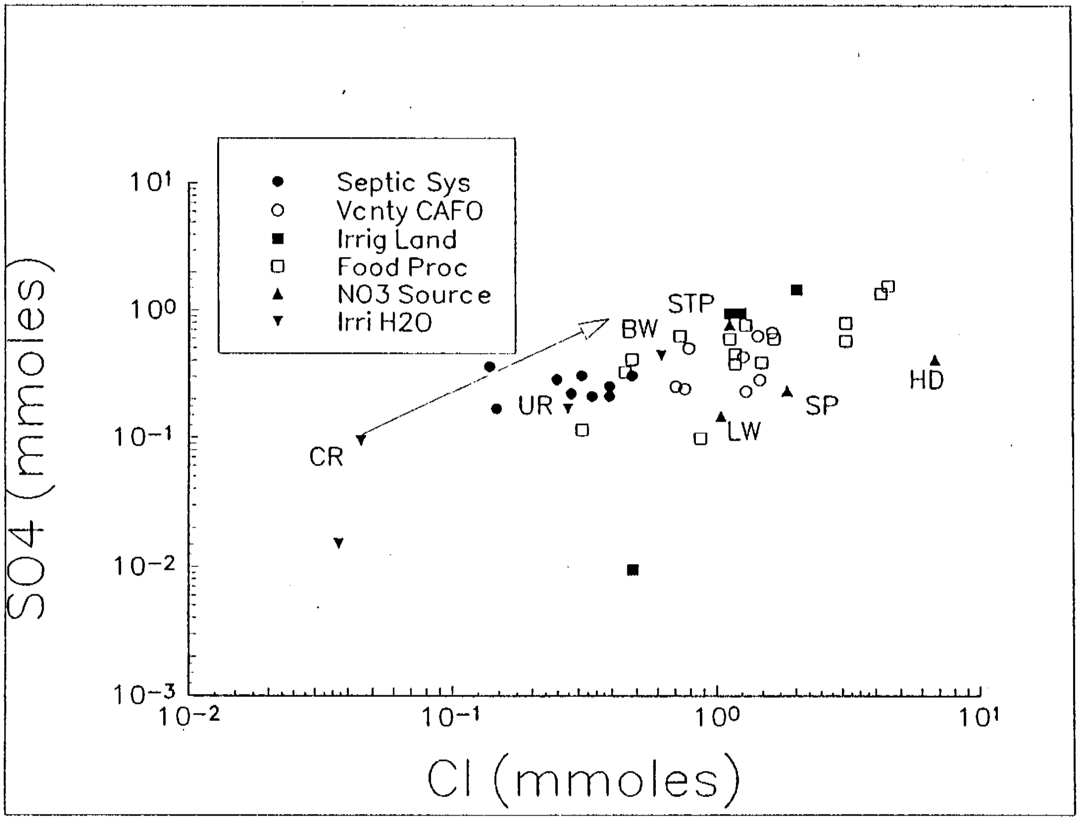


Figure 4.9 Chloride versus sulfate for selected alluvial groundwater samples, potential nitrate source samples, and irrigation water sources.

Note: The alluvial groundwater samples are displaced away from the evaporation trend toward potential nitrate sources.

Note: The symbol label abbreviations are the same as in Figure 4.6

Evidence of External Influences Affecting Basalt Groundwater Chemistry

This section presents a series of graphs and analyses representing groundwater samples collected from Lower Umatilla Basin basalt water-bearing zones. Constituents are graphed as milligrams per liter (mg/L). Analyses of the graphs support the observation that some groundwater from basalt wells follow trends similar to alluvial groundwater. This indicates a hydraulic connection exists between alluvial groundwater and some basalt water-bearing zones.

Figure 4.10 shows total dissolved solids (TDS) versus calcium. A positive correlation exists between the constituents. The highest calcium concentration shown is approximately 150 mg/L. Review of the graph raises questions about the source of calcium in the groundwater sampled. Basalt minerals can contribute calcium to groundwater. However, an analysis using groundwater chemistry computer modeling indicates achieving the higher calcium concentrations from natural water-rock reactions is unlikely. That analysis is presented in the general groundwater chemistry computer modeling section. The modeling result suggests calcium comes from an external source.

Review of other constituent versus constituent graphs also indicate an external source affects the groundwater chemistry in some basalt water-bearing zones. They include chloride versus total dissolved solids and nitrate+nitrite-nitrogen versus total dissolved solids.

Figure 4.11 shows chloride versus total dissolved solids. The chloride concentrations reach values exceeding 220 mg/L. The chloride probably did not come from the basalt, because no primary basalt mineral contains appreciable chloride. It probably did not come from halite, a highly soluble chloride mineral, because halite occurring with the saturated basalt water-bearing zone is unlikely.

Figure 4.12 shows nitrate+nitrite-nitrogen versus total dissolved solids. A positive correlation between TDS and nitrate+nitrite-nitrogen exists for some basalt groundwater samples. Nitrate does not occur naturally in basalt which again suggests an external source. Additionally, many of the samples plot within the same area of the graph as alluvial groundwater samples, which are shown as open squares in Figure 4.12. This correlation suggests alluvial and some basalt groundwater are related.

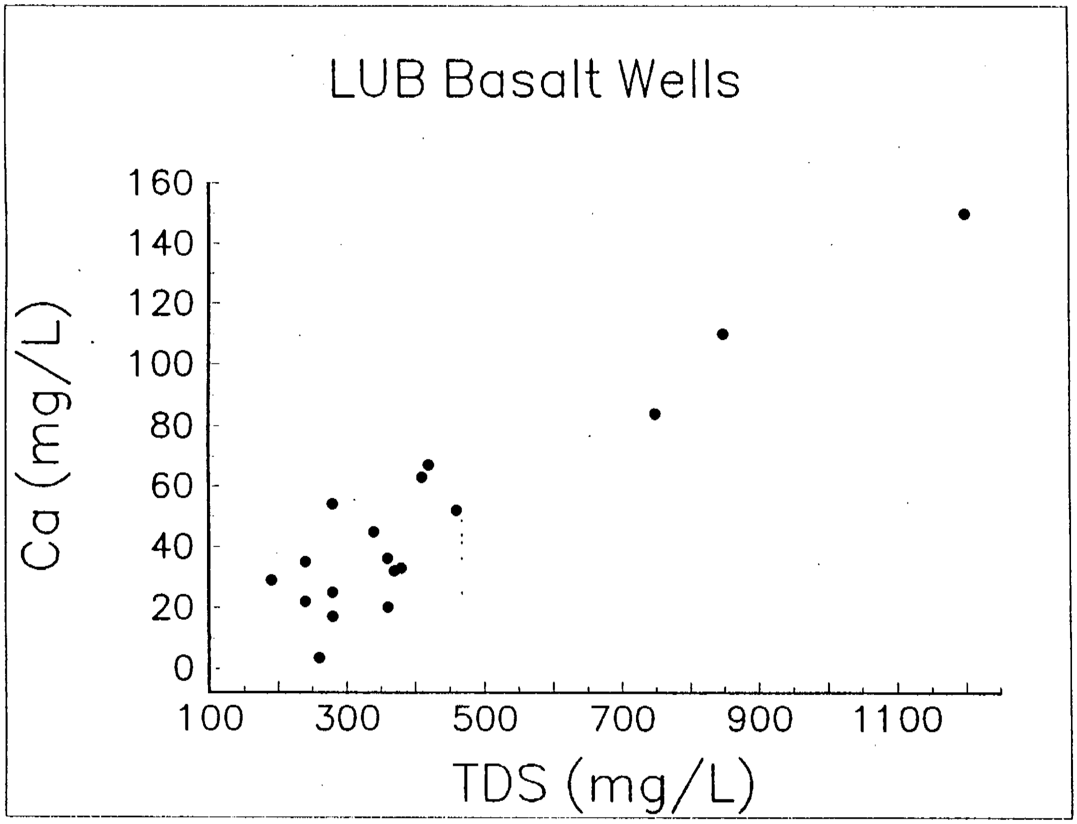


Figure 4.10 Total dissolved solids versus calcium for groundwater sampled from basalt water-bearing zones in the Lower Umatilla Basin.

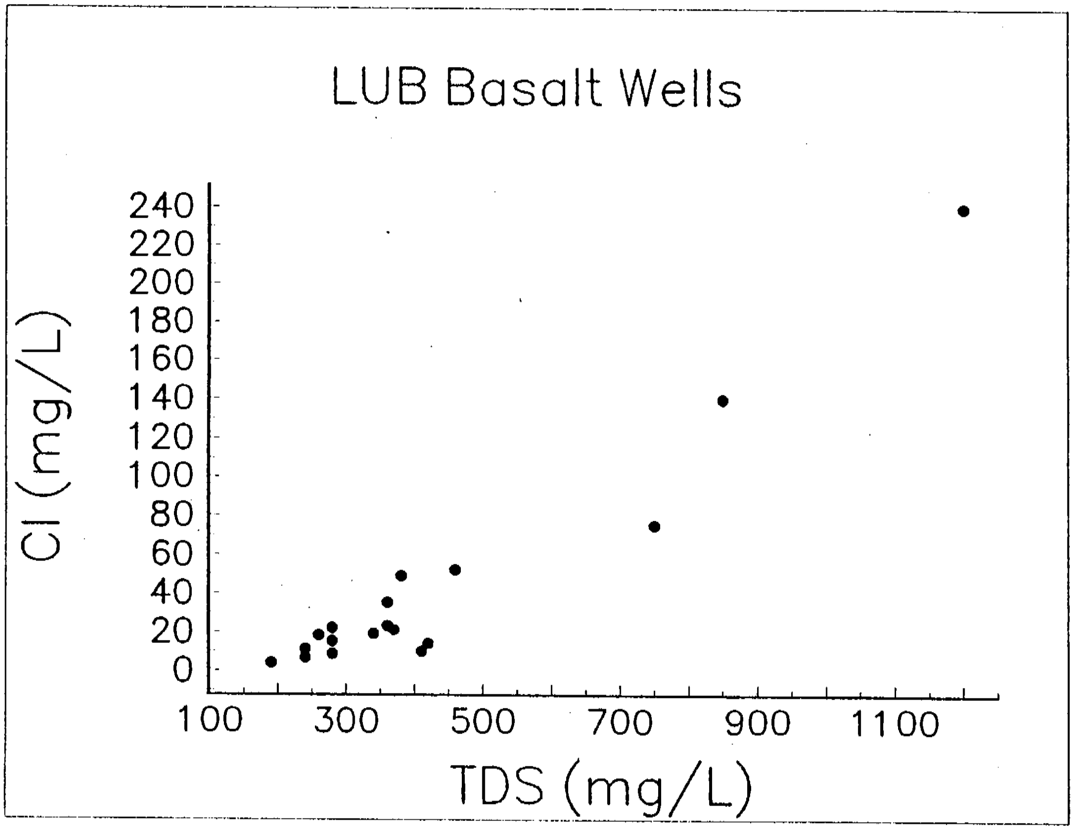


Figure 4.11 Total dissolved solids versus chloride for groundwater sampled from basalt water-bearing zones in the Lower Umatilla Basin.

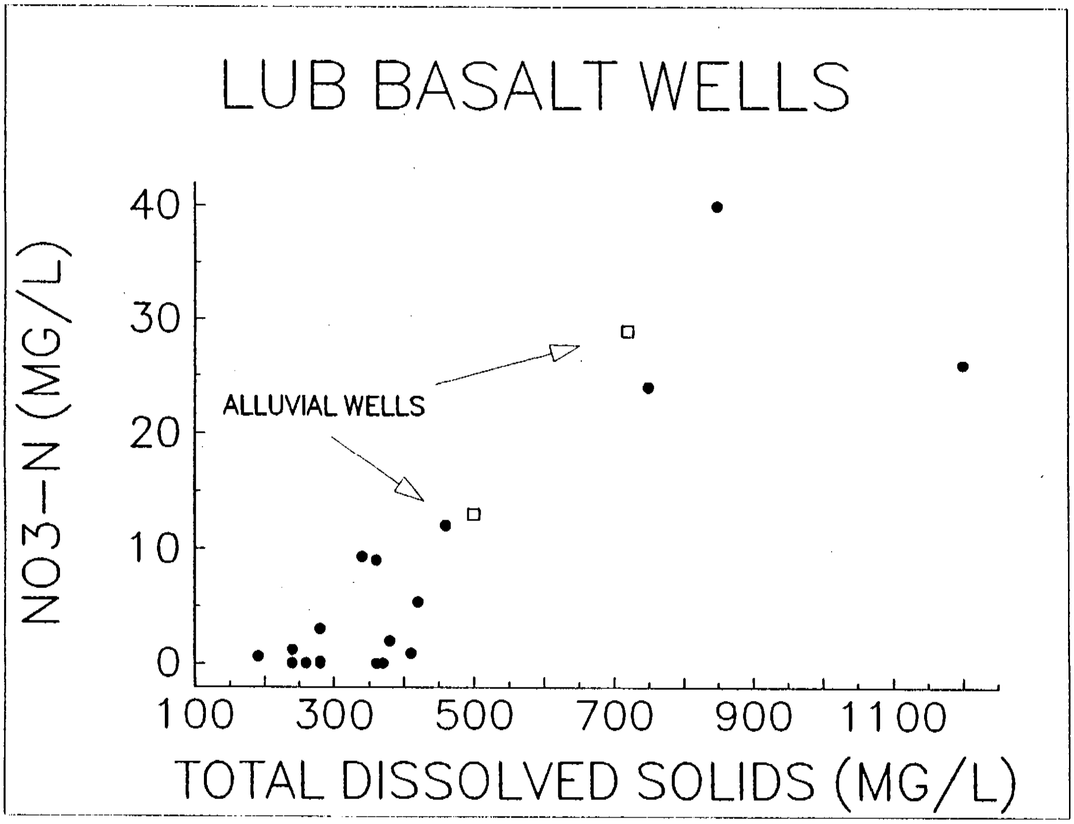


Figure 4.12 Total dissolved solids versus nitrate+nitrite-nitrogen for groundwater sampled from basalt water-bearing zones in the Lower Umatilla Basin.

Note: The dashed line encloses the nitrate+nitrite-nitrogen field for alluvial groundwater samples.

In summary, groundwater in some basalt water-bearing zones originally comes from shallow alluvial groundwater affected by surface activities. Information presented in the hydrogeology chapter support alluvial groundwater directly entering some basalt water-bearing zones. Saturated alluvial sediments directly contact basalt water-bearing zones in some areas. Additionally, some wells are constructed improperly. The wells provide a direct conduit from the alluvial aquifer to one or more basalt water-bearing zones below.

Evidence of Potential Nitrate Sources Influencing Groundwater Chemistry

Some constituent versus constituent graphs analyzed may potentially characterize the influence of some nitrate sources upon Lower Umatilla Basin groundwater. Each graph analyzed shows several groupings of groundwater samples each of which was presumably influenced by a single nitrate source. Assuming a single source may not be correct given the diverse land use history in the areas. Additionally, not all potential sources are represented. Omitting these other sources should not be interpreted as vindicating their role as a nitrate contributor to the basin's groundwater.

The groundwater samples graphed came from wells within or near areas with septic systems, animal feedlots, food processing wastewater land application areas, and irrigated crop agriculture. Samples representing potential septic system influences came from Hermiston and Irrigon rural residential home areas. Samples representing potential animal feedlot influences came from wells downgradient from C and B Livestock near Hermiston and from historic hog and poultry operations. Samples representing potential food processing wastewater influences came from wells within or near Lamb Weston, Simplot and Hermiston Foods land application sites. Samples representing potential irrigated crop agriculture came from Western Empire farm wells southwest of Irrigon. The analyses primarily used June-July 1992 synoptic sampling data. Groundwater samples influenced by sewage sludge land application only, nursery operations only, and other potential nitrate sources only were not obtained.

The rationale for this analysis is nitrate does not travel alone. Instead, nitrate must travel in water percolating from the surface downward to groundwater. That water will contain other constituents that reflect its source and the chemical modifications that occurred during its history. Therefore, nitrate delivered by water percolating downward from different land uses may have identifiably different chemical signatures. This hypothesis proved true in some cases.

Figure 4.13 shows total dissolved solids versus nitrate+nitrite-nitrogen for all categories. A positive correlation exists between these constituents. Analyses of the graph indicates no single source is solely responsible for the elevated nitrate in the basin. Instead, the data indicates all the sources represented contribute nitrate and TDS to groundwater in the basin.

Groundwater samples related to septic systems graph differently from samples related to the other potential nitrate sources in terms of TDS and nitrate+nitrite-nitrogen (Figure 4.13). Groundwater sampled near irrigated crop agriculture, animal feedlots, and food processing wastewater land application areas graph over a wide concentration range. The range associated with on-site septic systems is much more limited. The concentrations are generally less than 500 mg/L for TDS and less than 15 mg/L for nitrate+nitrite-nitrogen. This is consistent with the observations of Komor and Anderson (1993) for the Sand-Plains aquifers of Minnesota. A review of Lower Umatilla Basin groundwater data related to septic systems found the concentration ranges noted were retained over time except once, where the TDS concentration reached 560 mg/L and nitrate+nitrite-nitrogen reached 18 mg/L in the same sample. These generally lower values indicate septic systems can not explain the full TDS and nitrate concentration ranges observed in Lower Umatilla Basin groundwater.

Figures 4.14 and 4.15 show potassium versus bromide and chloride versus potassium. Graphical analysis yielded three findings:

- Groundwater influenced by septic systems has lower chloride concentrations than other sources in addition to having lower TDS and nitrate concentrations.

- The influence of food processing wastewater upon groundwater chemistry is significantly different from the influence of other sources in terms of bromide to potassium and chloride to potassium relations.

- Each potential source groups into separate fields on the graphs.

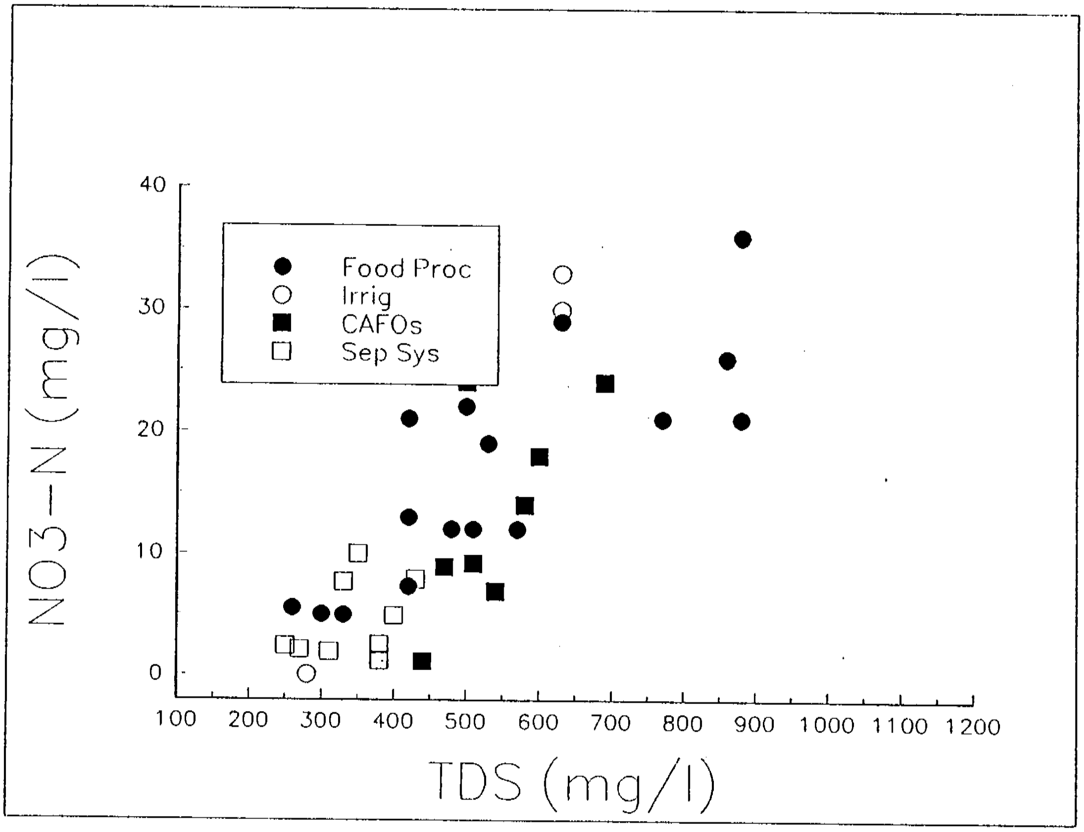


Figure 4.13 Total dissolved solids versus nitrate+nitrite-nitrogen for groundwater sampled in the vicinity of potential nitrate sources.

Note: The samples related to septic tank influences graph within a limited area.

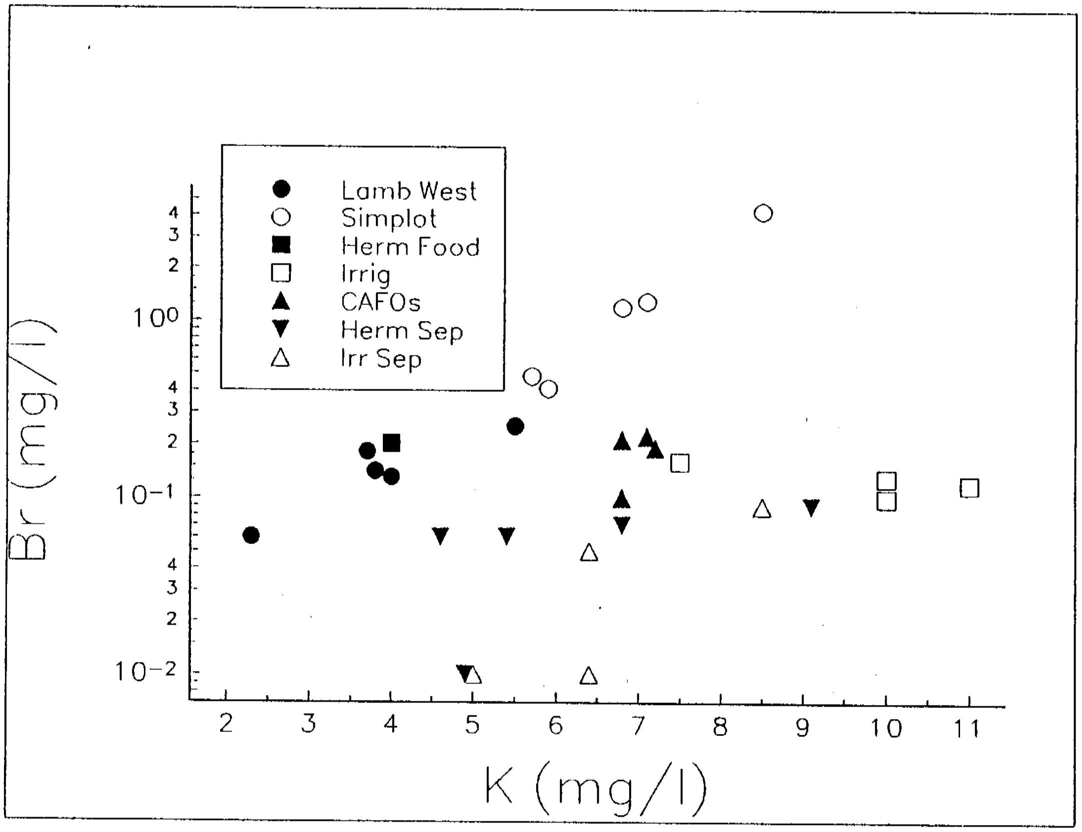


Figure 4.14 Potassium versus bromide for groundwater sampled in the vicinity of potential nitrate sources.

Note: The samples related to food processing wastewater influences graph within the same field regardless of sampling location. Samples related to septic systems also graph similarly despite different sampling locations.

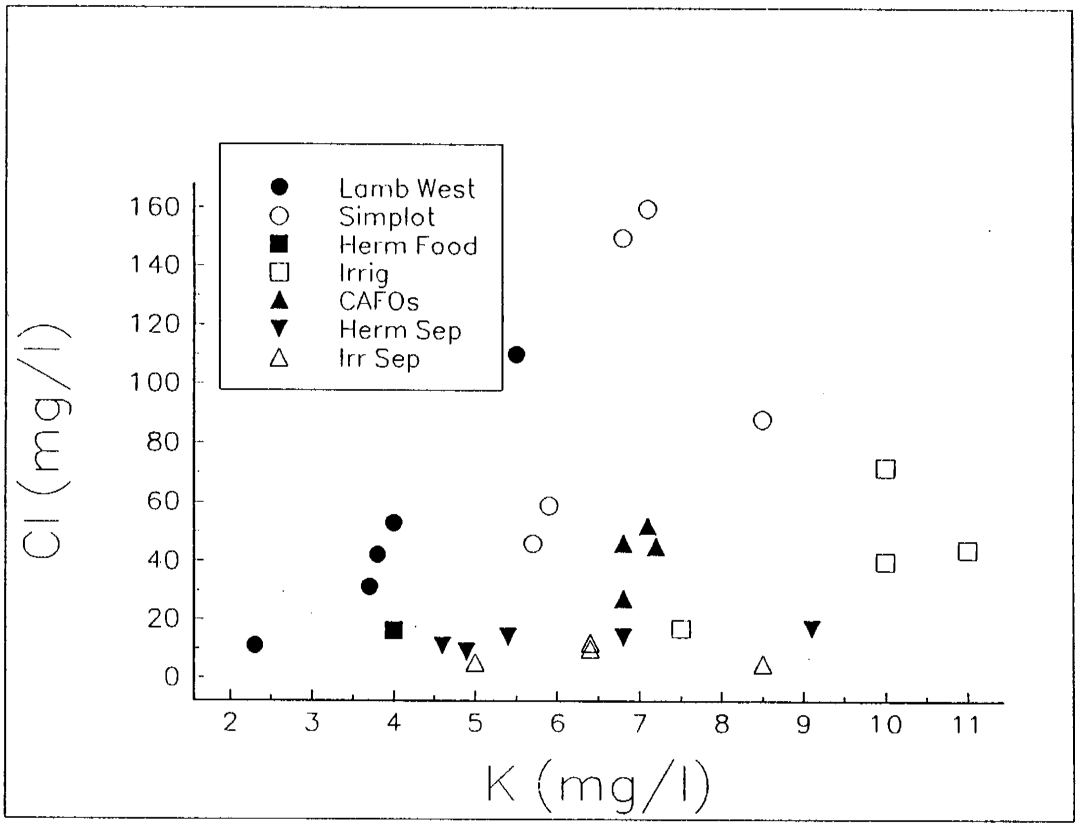


Figure 4.15 Potassium versus chloride for groundwater sampled in the vicinity of potential nitrate sources.

Note: The distinct fields for samples are related to food processing wastewater influences and are related to septic systems.

All septic system related samples graph along the same trend regardless of their sampling location. All food processing wastewater related samples graph along their unique trend regardless of the food processing source. All animal feedlot related samples graph within a small field despite sampling locations separated by several miles and being on separate flow paths. This observation suggests the chemical patterns displayed reflect chemical influences unique to each potential nitrate source category represented rather than influences common to geographic areas in the basin. As a result, these graphical comparisons can help identify land uses influencing groundwater sampled in the basin. Comparisons for the basin are presented in Appendix 4H.

In some cases, graphical analyses could distinguish individual sources within the same potential source category. Figures 4.16 and 4.17 are an example. They show magnesium versus sulfate and calcium versus magnesium, respectively. Note that groundwater sampled in the vicinity of Lamb Weston's land application area have higher magnesium with respect to both calcium and sulfate than samples related to Simplot or Hermiston Foods. Figure 4.14 previously shown is another example. Samples related to Simplot operations tend toward higher bromide concentrations than samples related to other food processing operations. These characteristics may reflect the chemical composition of the water that each facility uses for food processing as well as facility specific processes.

Data related to samples collected directly from potential nitrate sources were added to the graphs analyzed to see whether they would appear as end members to the trends observed (Figure 4.18). Septic systems and irrigated crop agriculture were not represented, because project sampling did not include obtaining water from these sources. In Figure 4.18, the trend defined by groundwater sampled in the vicinity of food processing wastewater land application sites is evident. That the Lamb Weston wastewater lagoon sample does not appear as an end member on the trend is equally evident. This observation does not diminish or invalidate the previous observations. Instead, the differences may reflect the influence of processes the water experiences in the vadose (unsaturated) zone prior to reaching groundwater.

In summary, the chemical composition of a given groundwater sample reflects several influences. Potential nitrate sources influence groundwater by imparting an overall identifiable chemical relationship pattern and vadose zone chemical processes also influence groundwater. Given the different influences, a lack of correlation between samples obtained directly from potential nitrate sources and groundwater influenced by those sources does not present a serious contradiction problem.

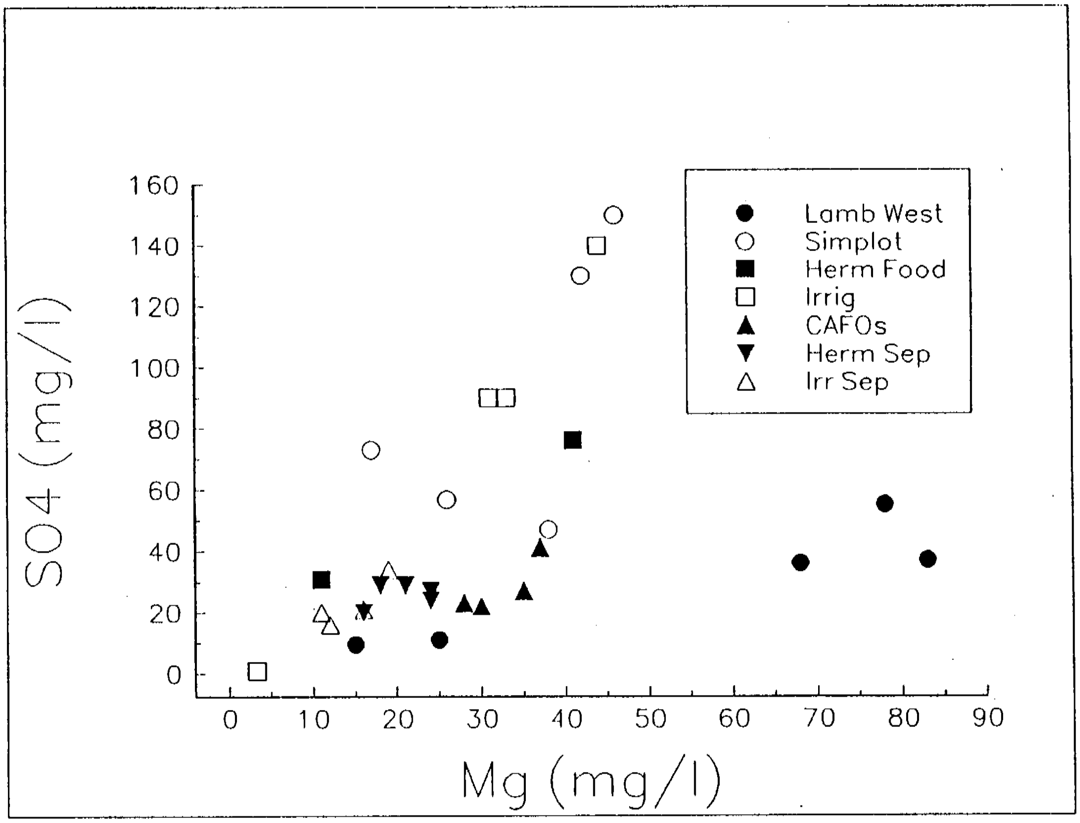


Figure 4.16 Magnesium versus sulfate for groundwater sampled in the vicinity of potential nitrate sources.

Note: Groundwater samples related to Lamb Weston wastewater influences graph separately from other food processing facilities, and the limited range of fields related to septic systems and animal feedlots.

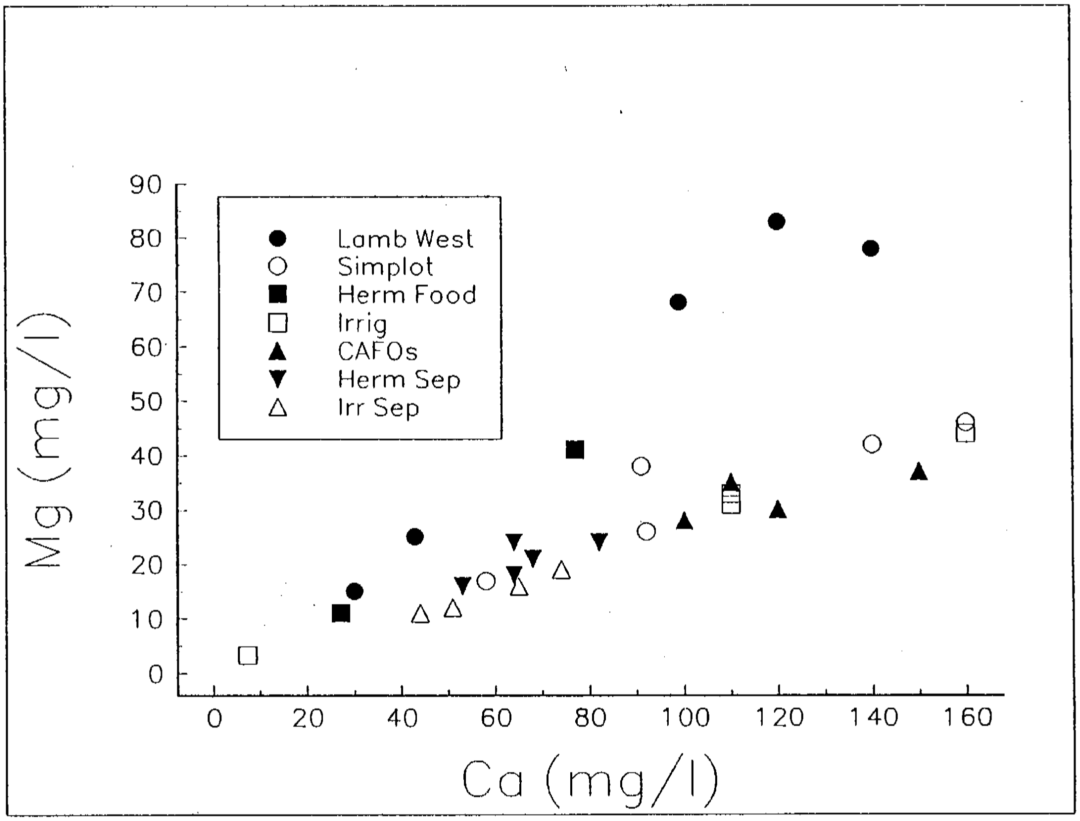


Figure 4.17 Calcium versus magnesium for groundwater sampled in the vicinity of potential nitrate sources.

Note: Groundwater samples apparently related to Lamb Weston wastewater influences are magnesium enriched relative to other food processing facilities.

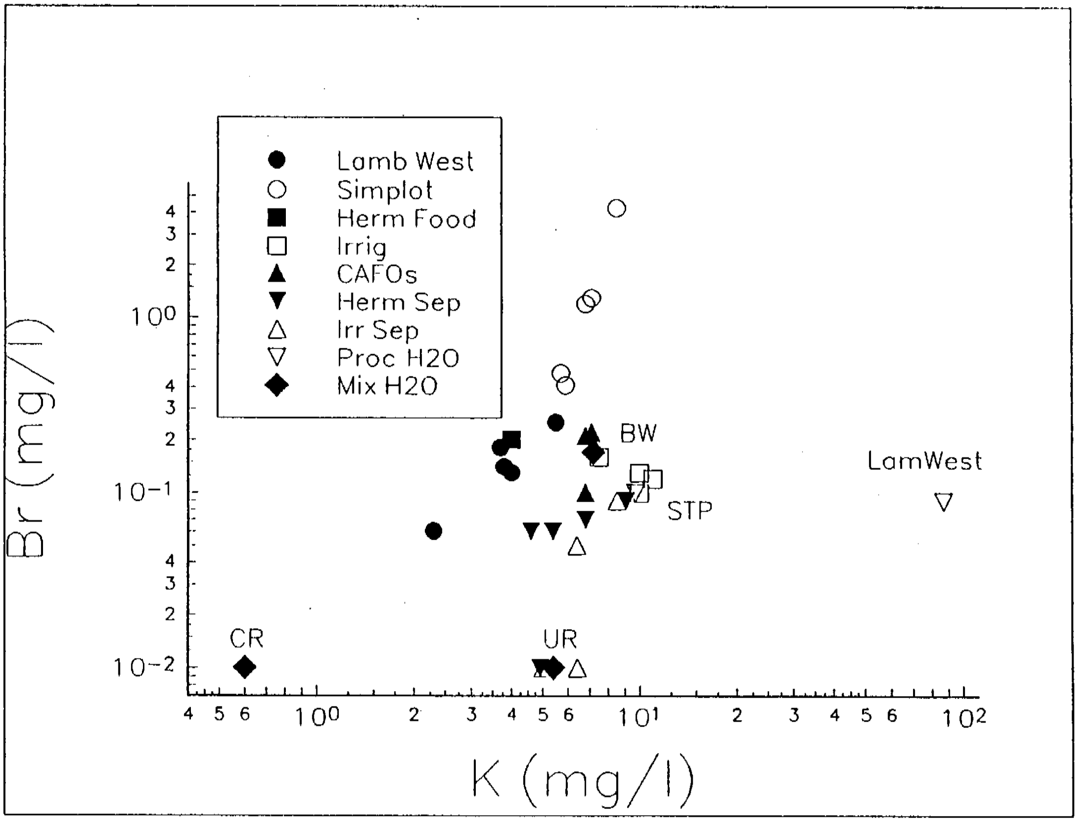


Figure 4.18 Potassium versus bromide for groundwater sampled in the vicinity of potential nitrate sources, irrigation water sources, and a food processing wastewater lagoon.

Note: Groundwater samples related to food processing wastewater appear unrelated to the food processing wastewater lagoon sample.

General Groundwater Chemistry Computer Modeling Results

This investigation used NETPATH (Plummer and others, 1991) and PHREEQE (Parkhurst and others, 1980) groundwater chemistry computer models for some data analyses. The models were selectively used to understand and differentiate natural versus human influences upon Lower Umatilla Basin groundwater. General results are presented in this section. Area specific results are presented in area specific sections.

General NETPATH Groundwater Chemistry Modeling Results

This investigation used NETPATH to assess and refine interpretations of natural and human influences on groundwater chemistry along selected groundwater flow paths. Groundwater concurrently sampled from a series of wells along the flow path provides the data needed to analyze and interpret how groundwater compositions evolved. This is true as long as different influences are not transitory.

Results from individual NETPATH analyses that apply to the entire Lower Umatilla Basin include:

- Mixing of deeper alluvial groundwater with infiltrating shallower water primarily explains the chemical composition observed in alluvial groundwater;
- Groundwater undergoes minor changes along a flow path as a result of water-rock mineral reactions typical of a groundwater basalt system;
- Cyclic evaporation-dissolution occurs locally in the vadose (unsaturated) zone; and
- Water from canal leakage does influence local groundwater chemistry;

General PHREEQE Groundwater Chemistry Modeling Results

The PHREEQE computer model was used to explore elevated calcium concentrations observed in Lower Umatilla Basin groundwater samples collected from some basalt water-bearing zones. The model calculates how groundwater chemistry changes as a result of prescribed reactions with minerals.

Two scenarios were explored. One had "unimpacted" basalt groundwater dissolve calcium bearing basalt minerals (plagioclase and clinopyroxene). The other had the same groundwater dissolve basaltic glass with a chemical composition described by Allan and Strope (1983). The results from both scenarios indicate obtaining the observed calcium concentrations from natural water-rock reactions is unlikely. For example, both scenarios indicate calcium in groundwater will reach saturation with calcite and dolomite at concentrations much lower than observed in groundwater samples collected. Reaching saturation should limit the calcium concentration in the groundwater when influenced by natural water-rock reactions only. The basalt glass scenario result indicates potassium and phosphate concentrations in groundwater should exceed 60 mg/l and 25 mg/L respectfully if water-basalt glass reactions were responsible for the calcium concentrations observed. These elevated potassium and phosphate concentrations were not observed in Lower Umatilla Basin basalt groundwater samples collected.

The results suggest an external calcium source influences some basalt groundwater through hydraulic connection with alluvial groundwater.

General Nitrogen Isotopic Analysis Results

Nitrogen-isotope sampling occurred in the Lower Umatilla Basin during the fall of 1993, spring of 1994, and fall 1994 at approximately 20 wells, 3 lysimeters, and a food processing wastewater surge pond. A summary of results is presented in this section. A complete discussion is presented in the Stable Nitrogen Isotope Analysis section.

Analysis of the nitrogen isotopic data found the following:

- The nitrogen isotopic compositions (delta ^{15}N) showed minor differences over time for most of the repeat samples collected;

- Current isotopic data indicates no area-wide denitrification occurs within the Lower Umatilla Basin. This finding does not preclude denitrification occurring locally in flood plain deposits adjacent to existing drainages if appropriate denitrification conditions exists.

- An organic waste influence is clearly evident from the delta ^{15}N values for groundwater sampled from well UMA 258. The well is located within an established food processing land application area north of the Umatilla River and east of the Butter Creek Highway.

- A commercial fertilizer influence is clearly evident from the delta ^{15}N values for groundwater sampled from three irrigation wells located north of Highway 730 between Boardman and Irrigon. The delta ^{15}N values remained constant over time despite nitrate+nitrite-nitrogen concentration fluctuations. That indicates the nitrogen source remains uniform and hydraulic flushing of nitrate is very slow. The delta ^{15}N values for the eastern wells are higher. That indicates an additional nitrate source influence is possible.

- The influence of animal waste appears evident from the delta ^{15}N values related to groundwater sampled from well UMA 133. This well is located along County Line Road approximately 2 miles south of Interstate 84. Historic and current animal waste sources are located nearby.

- Delta ^{15}N values related to groundwater sampled from wells near the U.S. Army Umatilla Depot Activity explosive washout lagoons indicates most of the nitrate in the groundwater came from explosive contaminants.

- Delta ^{15}N values related to other groundwater samples collected were not diagnostic of a single nitrogen source. Instead, the values indicate mixed nitrogen influences.

Area Specific Groundwater Chemistry Data Observations and Interpretations

Introduction

This section presents area specific groundwater chemistry data observations and interpretations. Some geographic areas have more observations and interpretations than other areas. This occurred because more information was available in some geographic areas. Also, more data analyses were needed for areas with more complex land uses, hydrogeology, and groundwater chemistry. Some data analyses were not repeated for each area, since results appear to apply basin wide.

Threemile Canyon and Sixmile Canyon Area

The Threemile Canyon and Sixmile Canyon area includes Ranges 23 and 24 East and Townships 3 and 4 North. Historic and current activity in the area includes the J.R. Simplot Company confined animal feeding operation, Taggares Farm irrigated agriculture, Portland General Electric (PGE) coal fired electric generating facility, Carty Reservoir, Boeing Company antenna field, the western half of the former Boardman Air Force Range, and some smaller activities. PGE and the Simplot Feedlot regularly collect groundwater samples and report the results to the Oregon Department of Environmental Quality. Project groundwater sampling in the area included reconnaissance and synoptic groundwater sampling. This section presents analysis of the project and private facility sampling data.

Map and Data Set Observations: Nitrate

Elevated nitrate concentrations have been detected in groundwater sampled from local alluvial sediments and basalt water bearing zones. Areas with elevated concentrations include the Simplot Feedlot lagoon vicinity, the southern portion of Sixmile Canyon, and a portion of the PGE ash disposal area. Plate 4.2 shows the June-July 1992 concentration distribution in alluvial groundwater based upon project synoptic sampling and concurrent sampling reported by the Simplot Feedlot. Concentrations detected in synoptic basalt groundwater samples are printed next to each sampling location. Plate 4.3 shows the distribution of maximum concentrations detected based upon project sampling only.

Threemile Canyon alluvial groundwater nitrate concentration data came from the J.R. Simplot confined feeding operation. The data represents groundwater sampled from three monitoring wells located adjacent to the facility's wastewater lagoons. This investigation found no water well reports for the wells. The wells were apparently constructed with a backhoe (Hammond, 1993). Reported nitrogen concentrations in the groundwater sampled varies geographically and over time. Reported nitrate-nitrogen concentrations range from 0.3 to 23.3 mg/L. Reported Total Kjeldahl Nitrogen (TKN) and ammonia-nitrogen concentrations range from 1.02 to 9.15 mg/L and non detect to 2.10 mg/L, respectively (DEQ Water Quality File 81591). Peak concentrations correspond to different well sites over time. This change over time may relate to the wastewater lagoon history. The TKN and ammonia values noted are unusually high for the basin. The values suggest nitrogen conversion to nitrate is incomplete. The TKN values also suggests animal waste or another organic source is the primary contributor of nitrate to groundwater locally.

Sixmile Canyon alluvial groundwater nitrate concentration data came from project synoptic sampling and PGE sampling at two PGE monitoring wells, UMA 274 (PGE 101) and UMA 275 (PGE 103). Both are located east of Taggares Farm where land application of animal waste did occur and where center pivot crop irrigation does occur. PGE apparently samples alluvial groundwater from additional wells, but data related to those wells were not found in PGE reports reviewed. PGE reported non-detect to 1.9 mg/L and 33 to 40 mg/L nitrate-nitrogen concentrations in groundwater collected from well UMA 274 and UMA 275, respectively (Carter 1987, 1988, 1989, 1990, 1991, 1992). Project synoptic sampling found non-detect and 32 mg/L nitrate+nitrite-nitrogen concentrations in groundwater collected from UMA 274 and UMA 275, respectively. Synoptic sampling data indicates nitrogen is present in groundwater at UMA 274 as TKN and ammonia rather than nitrate. The TKN and ammonia-nitrogen concentrations detected were both 18 mg/L. Those TKN and ammonia values are exceptionally high when compared to other project groundwater samples collected in the basin. The values suggest local reducing conditions may inhibit nitrogen conversion to nitrate. The nitrogen values and known land uses in the UMA 274 vicinity strongly suggest animal waste as the nitrogen source. Animal waste and/or commercial fertilizer could be the nitrogen source in the UMA 275 vicinity.

Sixmile Canyon shallow basalt water bearing zone nitrate concentration data came from project and/or PGE groundwater sampling at PGE basalt monitoring wells which are less than 100 feet deep. The wells are located in the Taggares Farm's southeast corner vicinity, Carty Reservoir vicinity, and the PGE ash disposal area. The Taggares Farm and Carty Reservoir vicinity wells obtain groundwater from the basal Elephant Mountain aquifer. The ash disposal area wells obtain groundwater from the upper Pomona aquifer. PGE reports nitrate-nitrogen concentrations ranging from 21 to 58 mg/L, non detect to 0.2 mg/L, and 0.3 to 70 mg/L in groundwater sampled from wells in the Taggares Farm vicinity, Carty Reservoir vicinity, and ash disposal area, respectively (Carter 1987, 1988, 1989, 1990, 1991, 1992). A review of the local hydrogeology and well construction indicates a likely connection exists between water in the alluvial sediments and the shallow basalt water bearing zones in the Taggares Farm vicinity and the ash disposal area. A connection would account for the higher nitrate concentrations observed. The connection appears to occur naturally and via well construction. An additional review of shallow basalt well site locations versus lower nitrate concentrations within the Carty Reservoir vicinity and the ash disposal area suggests the reservoir dilutes nearby groundwater.

Project shallow basalt groundwater sampling in Sixmile Canyon occurred at PGE 107 (UMA 271) and reportedly at PGE 104 (UMA 273) only. The wells are located in the Taggares Farm vicinity. The sampling found nitrate+nitrite-nitrogen concentrations at 26 and 0.10 mg/L, respectively. The 26 mg/L value compares well to PGE reported data related to the same well. The 0.10 mg/L compares poorly to the 33 to 58 mg/L values reported by PGE for groundwater sampled from well UMA 273. The other constituent values also compare poorly. Perhaps the synoptic sampling misidentified the PGE well sampled. The UMA 273 data compares best to PGE 018 rather than PGE 104.

Project shallow basalt groundwater sampling near Interstate 84 occurred at Castle (UMA 197) and the Wilson Golf Course (UMA 179). The wells are located approximately 3 and 6 miles east of Sixmile Canyon, and they are constructed 216 and 100 feet deep, respectively. Nitrate+nitrite-nitrogen concentrations in groundwater sampled from these wells measured as non detect to 1.3 mg/L.

Deeper basalt groundwater sampling occurred at wells more than 500 feet deep located within Taggares Farm (UMA 169), near Carty Reservoir (UMA 272), and within the Boeing antenna field (UMA 171). Project groundwater sampling measured nitrate+nitrite-nitrogen from these wells as non detect to 0.04 mg/L. PGE groundwater sampling at UMA 272 (PGE 001) measured nitrate-nitrogen from non detect to 0.7 mg/L (Carter 1987, 1988, 1989, 1990, 1991, 1992).

Map and Data Set Observations: Total Dissolved Solids

Elevated total dissolved solids (TDS) concentrations have been detected in groundwater sampled from local alluvial sediments and shallow basalt water bearing zones. The highest TDS concentrations detected in the basin came from this area. Plate 4.4 shows the June-July 1992 concentration distribution for alluvial groundwater based upon project synoptic sampling. Results for synoptic basalt groundwater samples are printed next to the sampling location. Plate 4.5 shows the distribution of maximum concentrations detected based upon project sampling only.

Local alluvial groundwater TDS data has been limited to samples collected from two PGE monitoring wells, UMA 274 and UMA 275, located east of Taggares Farm. PGE reports reviewed did not include data related to other PGE alluvial groundwater monitoring wells, and Simplot Feedlot groundwater monitoring data reviewed did not include TDS analyses. PGE reported TDS concentrations of 1,013 to 1,282 mg/L and 948 to 1,702 mg/L in samples collected from UMA 275 and UMA 274, respectively (Carter 1987, 1988, 1989, 1990, 1991, 1992). Project synoptic groundwater sampling detected TDS at 1200 mg/L and 1,100 mg/L in samples collected from UMA 274 and UMA 275.

TDS concentrations in local basalt groundwater varies. TDS measured less than 450 mg/L in groundwater collected from UMA 169, UMA 171, and UMA 272 (PGE 001) by this project and PGE (Carter 1987, 1988, 1989, 1990, 1991, 1992). These wells are more than 500 feet deep. TDS measured 400 to 420 mg/L in groundwater sampled by this project from shallow basalt water bearing zones near Interstate 84 east of Sixmile Canyon. Higher TDS concentrations have been measured in most Sixmile Canyon shallow basalt water bearing zone groundwater samples. PGE reported TDS at 805 to 1,654 mg/L, 252 to 277 mg/L, and 644 to 1154 mg/L in samples collected from wells in the vicinity of Taggares Farm southeast corner, Carty Reservoir vicinity, and the ash disposal area, respectively (Carter 1987, 1988, 1989, 1990, 1991, 1992). Project synoptic sampling at a Taggares Farm vicinity well, UMA 271, detected TDS at 1200 mg/L. A review of shallow basalt well site locations versus lower TDS concentrations within the Carty Reservoir vicinity and ash disposal area suggests the reservoir dilutes nearby groundwater.

Map and Data Set Observations: Other Constituents

Elevated arsenic calcium, chloride, sodium and sulfate concentrations have been detected in alluvial and basalt groundwater sampled in the area. Table 4.11 presents concentration ranges detected by project and PGE sampling. Plates 4.6, 4.7 and 4.8 show the maximum arsenic, chloride and sodium concentrations detected by project sampling only. Arsenic concentrations in alluvial groundwater sampled from UMA 275 (PGE 103) approach the drinking water standard of 0.05 mg/L. Sodium concentrations in local groundwater generally exceed 20 mg/L which is currently recommended for persons on a physician prescribed sodium restricted diet. Chloride concentrations exceeded the 250 mg/L secondary (aesthetic) drinking water standard in some Taggares vicinity and PGE ash disposal area shallow basalt water bearing zone samples. Some of the sulfate concentrations measured are among the highest detected in the Lower Umatilla Basin.

Groundwater sampling has detected bromide, boron, phosphate, and vanadium in local groundwater. Table 4.12 shows concentration ranges detected by project and PGE sampling. Plates 4.10, 4.11, 4.12, and 4.13 show the distribution of maximum concentrations detected by project sampling only. Bromide concentrations in groundwater samples from this area are generally among the higher concentrations detected in the basin. Boron concentrations reported by PGE (Carter 1987, 1988, 1989, 1990, 1991, 1992) are the highest concentrations detected in the basin.

Phosphate detected in Sixmile Canyon alluvial groundwater samples and in shallow basalt water bearing zone samples from the Taggares Farm vicinity and PGE ash disposal area are among the higher concentrations detected in the basin. Phosphate in alluvial groundwater samples from UMA 274 (PGE 101) are among the highest concentrations detected in the basin.

Vanadium concentrations in local groundwater samples are among the lower concentrations detected in the basin. They remain below 0.10 mg/L. However, the concentrations are higher than typically found in groundwater.

Table 4.11 Arsenic, calcium, chloride, sodium, and sulfate concentration ranges for groundwater sampled in the Threemile Canyon and Sixmile Canyon area.

Groundwater Sampling Categories	Constituents									
	Arsenic (mg/L)		Calcium (mg/L)		Chloride (mg/L)		Sodium (mg/L)		Sulfate (mg/L)	
	maximum	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	minimum
Alluvial: Sixmile Canyon UMA 274 and UMA 275	0.048	<0.002	132	31	195	108	342	127	945	125
Basalt Wells: More than 500 feet Deep (undifferentiated basalt)	0.014	<0.002	35	8	56	32	110	71	78	0.7
Shallow Basalt Wells: Taggares Farm SE Corner Vicinity (basal Elephant Mountain)	0.010	0.002	203	44	559	77.5	143	47	277	52
Shallow Basalt Well: Carty Reservoir Vicinity (basal Elephant Mountain)	0.014	0.007	37.8	30	20.6	15.4	76	25	19	13
Shallow Basalt Wells: PGE Ash Disposal Area (Pomona)	0.013	0.003	117	53	327.7	66.9	90	47	160	97
Shallow Basalt Wells: Near Interstate 84 UMA 179 and UMA 197	0.010	<0.005	65	11	36	7.6	120	37	98	20

Sources: Project Reconnaissance and Synoptic Data (July 1990 through July 1992)
Carter, 1987, 1988, 1989, 1990, 1991, 1992

Note: Alluvial groundwater data for the Simplot Feedlot wastewater lagoon vicinity is missing, because these constituents were apparently not analyzed.

Table 4.12 Bromide, boron, total phosphate, and vanadium concentration ranges for groundwater sampled in the Threemile Canyon and Sixmile Canyon area.

Groundwater Sampling Categories	Constituents							
	Bromide (mg/L)		Boron (mg/L)		Total Phosphate (mg/L)		Vanadium (mg/L)	
	maximum	minimum	maximum	minimum	maximum	minimum	maximum	minimum
Alluvial: Sixmile Canyon UMA 274 and UMA 275	1.30	1.00	0.4	<0.1	2.00	0.005	0.045	<0.005
Basalt Wells: More than 500 feet Deep (undifferentiated basalt)	0.28	0.28	0.2	0.05	0.034	0.01	0.022	<0.005
Shallow Basalt Wells: Taggares Farm SE Corner Vicinity (basal Elephant Mountain)	1.9	1.9	0.3	<0.1	0.145	0.012	0.055	0.018
Shallow Basalt Well: Carty Reservoir Vicinity (basal Elephant Mountain)	NA	NA	0.4	0.1	0.044	0.022	0.045	0.028
Shallow Basalt Wells: PGE Ash Disposal Area (Pomona)	NA	NA	0.3	<0.1	0.224	0.016	0.067	0.023
Shallow Basalt Wells Near Interstate 84 UMA 179 and UMA 197	<0.05	<0.05	0.04	<0.03	0.06	0.02	<0.03	<0.03

NA: Not Analyzed
Sources: Project Reconnaissance and Synoptic Data (July 1990 through July 1992)
Carter, 1987, 1988, 1989, 1990, 1991, 1992
Note: Alluvial groundwater data for the Simplot Feedlot wastewater lagoon vicinity is missing, because these constituents were apparently not analyzed.

Higher calcium, chloride, sulfate, bromide, and total phosphate concentrations occur in some Sixmile Canyon alluvial groundwater samples, and shallow basalt water bearing zone samples from the Taggares Farm vicinity and PGE ash disposal area. The pattern of occurrence suggests human activity in the area locally influences alluvial and shallow basalt water bearing zone groundwater chemistry.

Graphical Analyses: Nitrate versus Time

Graphical analysis of Threemile Canyon and Sixmile Canyon area groundwater data included reviewing nitrate versus time graphs. Data used for the analysis came from Portland General Electric (Carter 1987, 1988, 1989, 1990, 1991, 1992) and the J.R. Simplot confined animal feeding operation (DEQ Water Quality File 81591). This analysis included comparing the nitrate versus time graphs to available groundwater versus time and/or other constituent versus time graphs.

Figure 4.19 shows nitrate-nitrogen concentrations versus time in Threemile Canyon alluvial groundwater samples collected from three wells adjacent to the Simplot Feedlot wastewater lagoons. The concentration versus time patterns are not similar. This suggests different local influences. These influences may relate to different histories for the 8 cells comprising the lagoon. No groundwater elevation or other constituent data over time was found for comparison.

Figure 4.20 shows nitrate-nitrogen concentrations versus time in Sixmile Canyon alluvial and shallow basalt water bearing zone groundwater samples collected near or within Taggares Farm. The concentration versus time patterns are similar despite location, groundwater source, and concentration differences. The peak nitrate concentration for each time series similarly occurs during 1989. These similarities suggest a common nitrate influence. For example, the 1989 peak nitrate concentrations follow the resumption of land applying Simplot animal waste at Taggares Farm, and it coincides with a J-U-B Engineers (1989) recommendation to increase the application rate from 300 to 450 pounds per acre. Further analysis found the nitrate versus time graphs did not relate well to sodium, total dissolved solids (TDS), or groundwater elevation versus time graphs. This lack of similarity suggests other influences affected sodium, TDS, and groundwater elevations. For example, Carty Reservoir influences groundwater elevations in the Sixmile Canyon vicinity, and nitrogen sources applied to adjacent land may include both commercial fertilizer and animal waste. Different nitrogen sources can influence sodium and TDS differently.

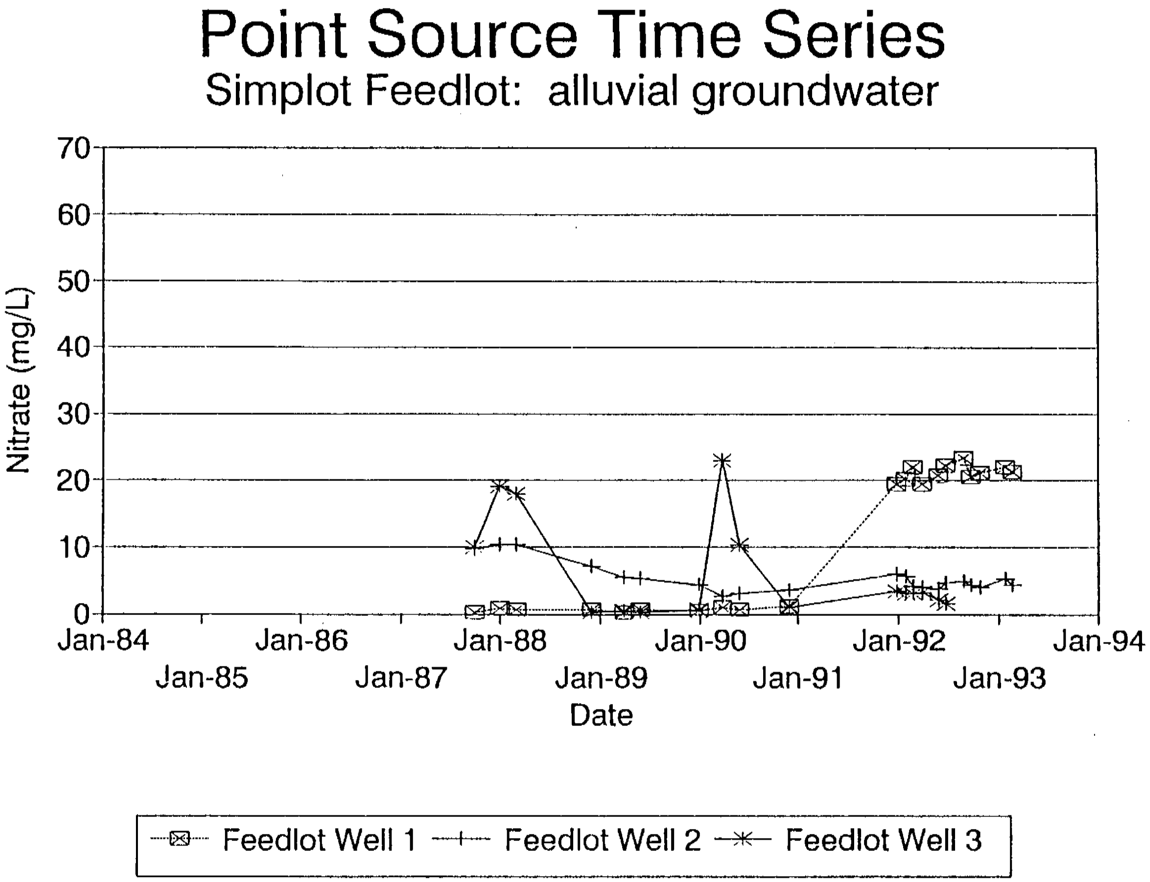


Figure 4.19 Nitrate-nitrogen versus time in Threemile Canyon alluvial groundwater sampled near the J.R. Simplot Company confined animal feedlot wastewater lagoons.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

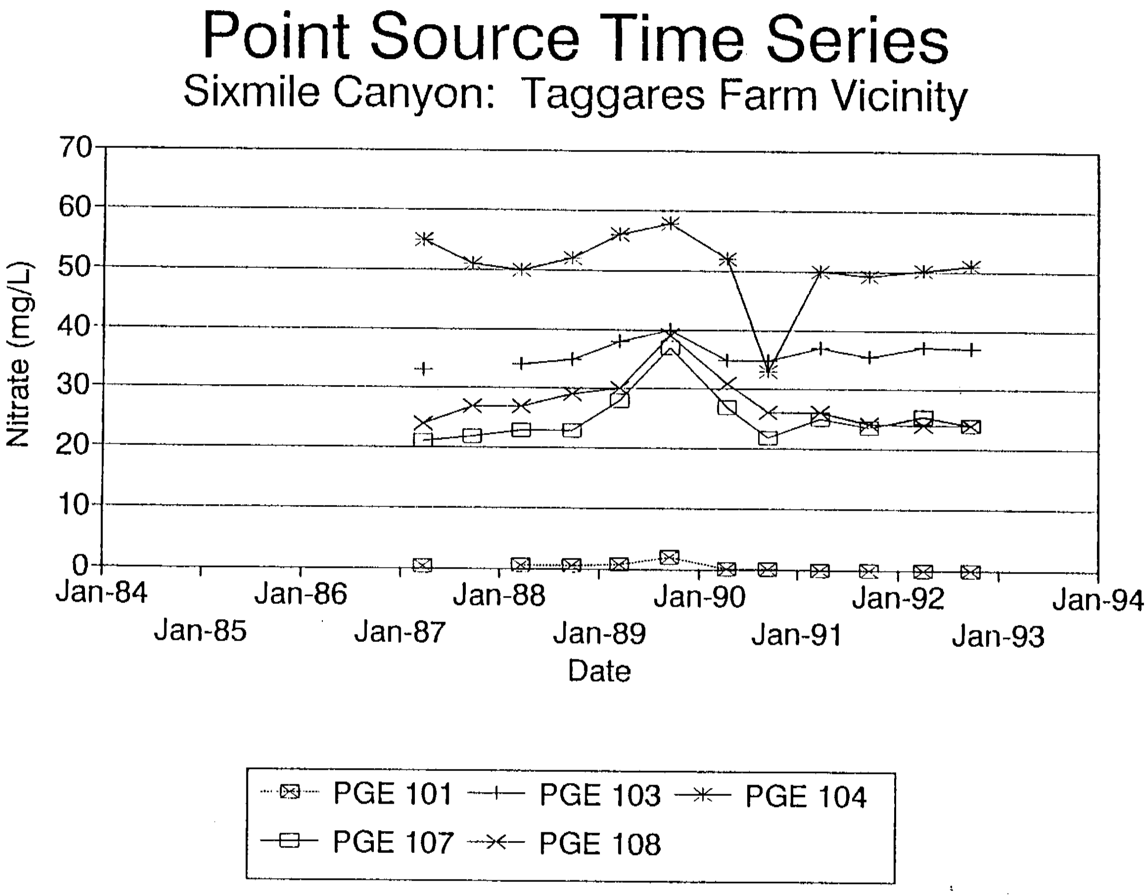


Figure 4.20 Nitrate-nitrogen versus time in Sixmile Canyon alluvial and shallow basalt water bearing zone groundwater sampled near or within Taggares Farm.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Figure 4.21 shows nitrate-nitrogen concentrations versus time in shallow basalt water bearing zone groundwater samples collected within the PGE ash disposal area. The concentration versus time patterns have some differences and similarity. The similarity relates to peak nitrate concentrations occurring during 1989. These peak concentrations coincide with peak nitrate concentrations observed in alluvial and shallow basalt water bearing zone groundwater samples collected near or within Taggares Farm. The differences may relate to dilution influences from Carty Reservoir. Further analysis found the nitrate versus time graphs generally did not relate well to sodium, total dissolved solids (TDS), or groundwater elevation versus time graphs. The general lack of similarity suggests other influences affected sodium, TDS, and groundwater elevations. One exception may be nitrate concentrations and groundwater elevations at PGE well 052. Nitrate concentration variations may lag groundwater elevation variations by 19 months.

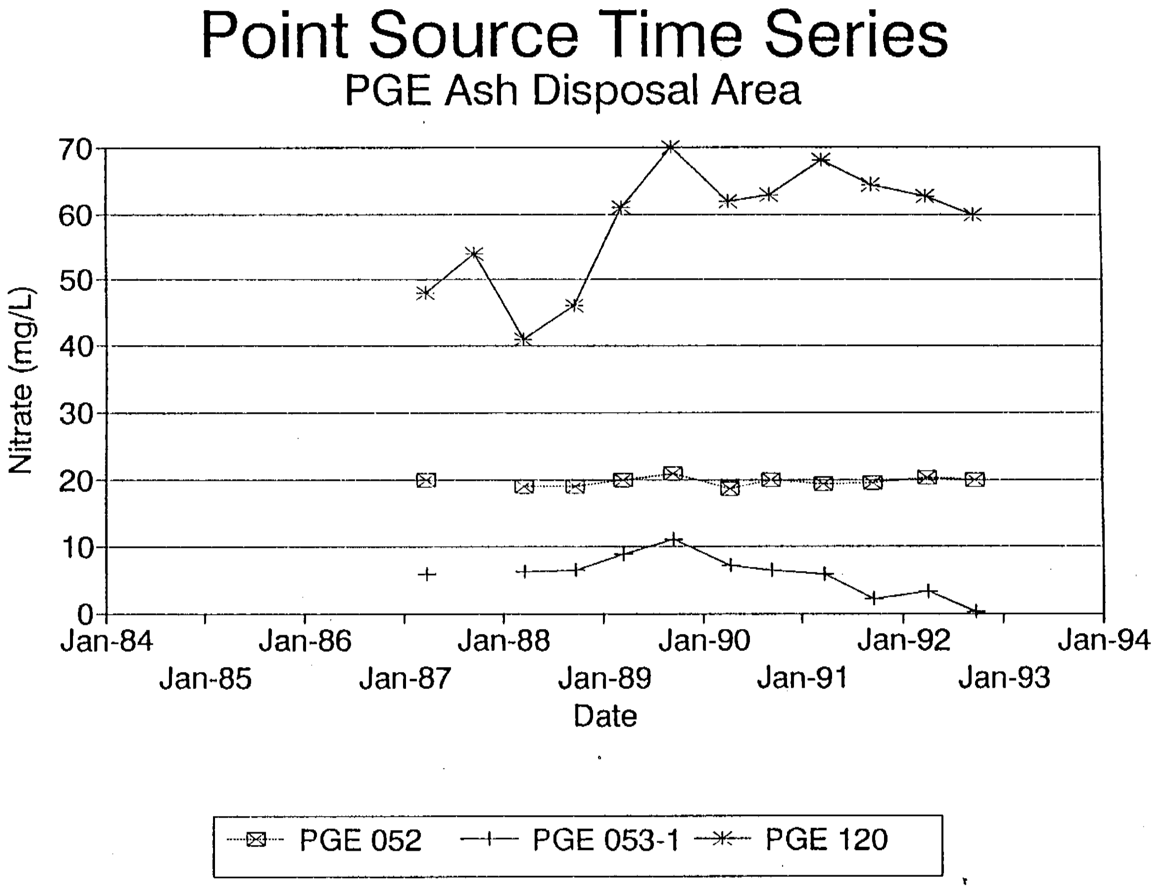


Figure 4.21 Nitrate-nitrogen versus time in Sixmile Canyon shallow basalt water bearing zone groundwater sampled within the Portland General Electric ash disposal area.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Graphical Analyses: Piper Trilinear Graphs and Schoeller Diagrams

Project synoptic sampling data related to the Threemile Canyon and Sixmile Canyon area were plotted on Piper trilinear graphs and Schoeller diagrams. Nearly all the data graphed as a water type different from most of the basin. Additionally, data representing alluvial groundwater graphed differently from each other, and data representing various basalt groundwater graphed differently from each other. However, data representing alluvial groundwater graphed weakly similar to some data representing basalt groundwater.

Piper trilinear graphs were used to determine the water type for each synoptic sample graphed and to determine whether any major proportion variation trends correlated to tabulated nitrate concentrations. The Threemile Canyon and Sixmile Canyon data showed no major ion variation trends.

Table 4.13 shows the water type for each sample graphed, the source of groundwater, the sampling location, and the nitrate concentration in the sample. Most Lower Umatilla Basin groundwater graphed as mixed-cation/bicarbonate dominant or calcium/bicarbonate dominant water. Only one Threemile Canyon and Sixmile Canyon area synoptic sample graphed as mixed cation/bicarbonate dominant water. That sample came from a shallow basalt water bearing zone through well UMA 179 located at Wilson Golf Course. The remaining samples graphed as sodium or potassium/bicarbonate dominant, sodium or potassium/sulfate dominant, mixed-cation/chloride dominant, and no dominant type water. Those samples came from alluvial sediments and various basalt water bearing zones via wells located along or near Sixmile Canyon.

Synoptic samples with similar nitrate concentrations graphed as somewhat similar water types on the trilinear graphs. For example, two samples with elevated nitrate+nitrite-nitrogen concentrations graphed as mixed-cation/chloride dominant and no dominant type water. The no dominant type water sample graphed nearly as mixed-cation/chloride dominant water. One sample came from alluvial sediments at well UMA 275 located along Sixmile Canyon and the other from a shallow basalt water bearing zone at well UMA 271 located in the southeast portion of Taggares Farm. Two samples with nitrate+nitrite-nitrogen concentrations below detection limits graphed as sodium or potassium/bicarbonate dominant water. One sample came from alluvial sediments at well UMA 274 located in the northern portion of Sixmile Canyon and the other from deeper basalt water bearing zones at well UMA 272 near Carty Reservoir.

Table 4.13 Threemile Canyon and Sixmile Canyon area groundwater characteristics.

Sampling Site ID	General Location	Well Depth (feet)	Groundwater Source	Water Type	Nitrate+Nitrite-Nitrogen (mg/L)
UMA 179	Near Interstate 84 (more than 6 miles east of Sixmile Canyon)	100.0	Shallow Basalt Water Bearing Zone (basal Elephant Mountain/Rattlesnake Ridge)	mixed-cation/bicarbonate	0.89
UMA 271 (PGE 107)	Taggares Farm SE Corner Vicinity	43.5	Shallow Basalt Water Bearing Zone (basal Elephant Mountain)	mixed-cation/chloride	26.00
UMA 272 (PGE 001)	Carty Reservoir Vicinity	564.5	Multiple Basalt Water Bearing Zones	sodium or potassium/ bicarbonate	<0.02
UMA 273 (PGE 104?)	questioned			sodium or potassium/ sulfate	0.10
UMA 274 (PGE 101)	Sixmile Canyon	25.0	Aeolian Sand	sodium or potassium/ bicarbonate	<0.02
UMA 275 (PGE 103)	Sixmile Canyon	67.7	Aeolian Sand	no dominant type (almost mixed-cation/chloride)	32.00

Note: Water type was determined by graphing synoptic sampling data on Piper trilinear graphs
Note: Nitrate+nitrite-nitrogen concentrations came from synoptic sampling data
Note: Field sampling sheets indicate UMA 273 corresponds to PGE 104. However, UMA 273 data corresponds poorly to PGE 104. The data corresponds best to PGE 018.

Schoeller diagrams were used to observe any constituent to constituent relationship patterns. Little similarity between individual sample patterns was observed. An inverse correlation between nitrate and phosphate may exist for the six-mile canyon samples.

Graphical Analyses: Constituent Versus Constituent

Constituent versus constituent graphs were used to distinguish nitrate sources as described in the evidence of potential nitrate sources discussion within the preceding general observations and interpretations section. Data analyzed came from project synoptic sampling data (see Appendix 4F) and data submitted by Portland General Electric (Carter 1987, 1988, 1989, 1990, 1991, 1992). The synoptic sampling data was reviewed using chloride versus potassium, bromide versus potassium, chloride/bromide versus chloride, magnesium versus calcium, and sulfate versus magnesium graphs. The PGE data was reviewed using the chloride versus potassium graphs. No single nitrate influence was identified. A combination of nitrate sources and natural processes would account for how the data graphed.

Groundwater Flow Path Analysis

The available groundwater data was insufficient for groundwater flow path data analysis.

Groundwater Chemistry Computer Modeling

No groundwater chemistry computer modeling was conducted for the Threemile and Sixmile Canyon area.

Nitrogen Isotopic Analysis

No nitrogen isotope groundwater sampling occurred within the Threemile Canyon and Sixmile Canyon area.

Threemile Canyon and Sixmile Canyon Area Summary and Conclusions

Analysis of Threemile Canyon and Sixmile Canyon groundwater chemistry data led to the following observations and interpretations:

- Nitrate concentrations in Threemile Canyon and Sixmile Canyon area groundwater ranges from non-detect to 70 mg/L.

- Nitrate concentrations remained below 1 mg/L in groundwater samples collected from basalt wells constructed more than 500 feet deep.

- Nitrate concentrations were detected below 2 mg/L in shallow basalt water bearing zone groundwater samples collected near Interstate 84 east of Sixmile Canyon.

- Nitrate concentrations exceeding 10 mg/L were detected in alluvial and shallow basalt water bearing zone groundwater samples collected near the J.R. Simplot Feedlot wastewater lagoons, near or within Taggares Farm along Sixmile Canyon, and the PGE ash disposal area.

- A review of available nitrate, ammonia and Total Kjeldahl Nitrogen (TKN) data and local land uses indicates animal waste or another organic nitrogen source influences groundwater in the J.R. Simplot Feedlot wastewater lagoon vicinity and the PGE 101 (UMA 274) vicinity at least.

- Graphical analyses indicate a combination of nitrate sources and natural processes influences groundwater along Sixmile Canyon.

- Graphical analyses indicate Taggares Farm activity contributes nitrate to alluvial and shallow basalt water bearing zone groundwater within the farm vicinity. Past and/or current farm activity includes land application of animal waste and center pivot crop irrigation.

- Carty Reservoir appears to dilute shallow basalt water bearing zone groundwater near the reservoir.

- The nitrate source in groundwater within PGE's ash disposal area remains unresolved. Ash from the electric generating coal fired plant appears not to be a nitrate source, and Carty Reservoir separates the ash disposal area from Taggares Farm. Agricultural activity occurs south of the ash disposal area, but no data from that area was obtained for comparison analyses.

- Total dissolved solids (TDS) concentrations in local groundwater are among the highest detected in the Lower Umatilla Basin.

- Arsenic concentrations in alluvial groundwater sampled from UMA 275 (PGE 103) approached the drinking water standard of 0.05 mg/L.

- Sodium concentrations in local groundwater generally exceeded the 20 mg/L limit recommended for persons with a physician prescribed sodium restricted diet.

- Chloride concentrations exceeded the 250 mg/L secondary (aesthetic) drinking water standard in some Taggares vicinity and PGE ash disposal area shallow basalt water bearing zone groundwater samples.

- Some sulfate concentrations measured in local groundwater samples are among the highest concentrations detected in the Lower Umatilla Basin.

Boardman to West Umatilla

The Boardman to west Umatilla area includes Ranges 25, 26, and 27 East and Townships 3, 4, and 5 North. Groundwater generally flows northwesterly through the area with exceptions. Saturated alluvial sediments end south and west of Boardman. Historic and current land uses in the area include:

- City of Boardman and Irrigon municipal areas;

- City of Boardman sewage treatment facility and wastewater land application site;

- City of Irrigon sewage treatment facility infiltration beds;

- Unsewered rural residential home developments and mobile home parks;

- Port of Morrow Industrial Park and wastewater land application areas;
- Finley Butte Landfill;
- Crop agriculture using a variety of irrigation methods;
- Pastured and confined livestock operations;
- John Day Wildlife Management Area;
- Umatilla and Irrigon Fish Hatcheries;
- U.S. Army Umatilla Depot Activity; and U.S. Navy Boardman Bombing Range.

This section presents analyses of project and facility data. The Port of Morrow and Finley Butte Landfill regularly collect groundwater samples from facility wells and report the results to DEQ. The U.S. Army reports Depot groundwater sampling results to the U.S. Environmental Protection Agency and Oregon DEQ. Project groundwater sampling in the area includes reconnaissance, bimonthly, and synoptic sampling. Areas north, west, and southwest of the Depot have sparse data due to very few wells in those areas.

Map and Data Set Observations: Nitrate

Table 4.14 and Plates 4.2 and 4.3 show the nitrate+nitrite-nitrogen concentration range and distribution in the Boardman to west Umatilla area. Table 4.14 shows local concentration ranges detected by this project or reported by local facilities. Plate 4.3 shows the distribution of maximum concentrations this project detected in alluvial and basalt groundwater samples. Plate 4.2 shows the June-July 1992 concentration distribution in regional alluvial groundwater based upon project synoptic sampling. Nitrate+nitrite-nitrogen concentrations detected in shallow unconfined alluvial groundwater samples and basalt groundwater samples are printed next to each sampling location.

The shape and extent of each concentration range contoured on Plate 4.2 was derived by linear interpolation between data locations. Data control was sparse north, west, and southwest of the U.S. Army Depot. This needs to be considered to avoid misinterpreting nitrate sources and nitrate movement when reviewing the sparse data areas. This is especially true for contours north and northwest of the Army Depot and the northeast corner of the U.S. Navy Bombing Range.

Elevated nitrate+nitrite-nitrogen concentrations were detected in groundwater sampled south of Boardman between Interstate 84 and the U.S. Navy Bombing Range. Samples with the highest concentrations came from basalt and "alluvial"/top of basalt wells located within and immediately north of a primarily center pivot crop irrigation area north of the U.S. Navy Bombing Range. Plates 4.2 and 4.3 show increasing concentrations toward that area. A major portion of the area converted to Port of Morrow wastewater land application after 1990.

Table 4.14 Nitrate concentration ranges detected in alluvial and basalt groundwater sampled from the Boardman to West Umatilla area.

Area	Groundwater Source	Dominant Land Uses (Historic and Current)	Nitrate-N (mg/L)	
			Maximum	Minimum
Boardman Area: North (north of Interstate-84) (Project Sampling)	Alluvial	municipal	21.00	7.00
Boardman Area: South (Interstate-84 to West Extension Canal) (Project Sampling)	Alluvial	rural residential animal operations irrigated crops nearby	25.00	15.00
Boardman Area: South (Interstate-84 to West Extension Canal) (Project Sampling)	Basalt (shallow)	rural residential animal operations irrigated crops nearby	64.00	<0.02
Boardman Area: South (West Extension Canal to U.S. Navy Bombing Range) (Project Sampling: UMA 233)	Basalt Top	Irrigated crops converted to Port of Morrow wastewater land application	31.00	---
Boardman Area: South (West Extension Canal to U.S. Navy Boardman Bombing Range) (Port of Morrow Sampling)	Basalt top	irrigated crops converted to Port of Morrow wastewater land application	35.40	1.90
U.S. Navy Boardman Bombing Range: (Project Sampling: UMA 170)	Basalt (deep)	bombing range	9.60	9.00
Port of Morrow Land Application Area (east of Boardman and north of Interstate-84) (Project Sampling)	Alluvial	wastewater land application crop irrigation nearby Boardman sewage treatment facility nearby	29.00	4.70
Port of Morrow Area (east of Boardman and north of Interstate-84) (Port of Morrow Sampling)	Alluvial	wastewater land application crop irrigation nearby Boardman sewage treatment facility nearby	29.30	0.10

Crop Irrigation Area (east of Boardman: Range 26) (Project Sampling)	Alluvial	irrigated crops	76.00	1.00
Finley Butte Landfill (south end of Range 26) (Finley Butte Landfill and DEQ Solid Waste Division Sampling)	Alluvial	landfill	0.35	<0.02
Irrigon Vicinity (Project Sampling)	Alluvial	rural residential	22.00	0.02
Irrigon Vicinity (Project Sampling)	Basalt (shallow)	rural residential	3.00	0.02
Irrigon Sewage Treatment Facility Area (Project Sampling)	Alluvial	sewage treatment with infiltration beds irrigated crops and cemetery nearby	41.00	20.00
Irrigon Sewage Treatment Facility Area (City of Irrigon Sampling)	Alluvial	sewage treatment with infiltration beds irrigated crops and cemetery nearby	40.80	3.83
Irrigon Sewage Treatment Facility Area (Project Sampling: UMA 269)	Basalt (shallow)	sewage treatment with infiltration beds irrigated crops nearby	0.05	—
Irrigon to West Umatilla (along Highway 730) (Project Sampling)	Alluvial	rural residential small orchards and animal operations irrigated crops to south	35.00	9.80
Irrigon to West Umatilla (along Highway 730) (Project Sampling)	Basalt (shallow)	rural residential small orchards and animal operations irrigated crops to south	0.28	<0.02
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial	wastewater land application Depot's active landfill nearby	22.00	0.18
Lamb-Weston, Inc. Land Application Area (Adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial (Shallow Unconfined)	wastewater land application Depot's active landfill nearby	36.00	21.00
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Lamb-Weston, Inc. Sampling)	Alluvial	wastewater land application Depot's active landfill nearby	74.00	0.18

Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Lamb-Weston, Inc. Sampling)	Alluvial (Shallow Unconfined)	wastewater land application Depot's active landfill nearby	65.00	<1.0
U.S. Army Umatilla Activity: West (Ammunition Demolition and Deactivation Furnace Areas) (Project Sampling)	Alluvial	ordnance activity irrigated crops nearby	27.00	0.12
U.S. Army Umatilla Depot Activity: West (Ammunition Demolition and Deactivation Furnace Areas) (U.S. Army Sampling)	Alluvial	ordnance activity irrigated crops nearby	60.00	0.01
U.S. Army Umatilla Depot Activity: Central Explosive Washout Lagoons Area) (Project Sampling)	Alluvial	ordnance activity	47.00	6.70
U.S. Army Umatilla Depot Activity: Central (Explosive Washout Lagoons Area) (U.S. Army Sampling)	Alluvial	ordnance activity	150.00?	<0.01
U.S. Army Umatilla Depot Activity: Northeast (Active Landfill Area) (Project Sampling)	Alluvial	landfill wastewater land application nearby	18.00	6.20
U.S. Army Umatilla Depot Activity: Northeast (Active Landfill Area) (U.S. Army Sampling)	Alluvial	landfill wastewater land application nearby	17.00	4.70
U.S. Army Umatilla depot Activity: South (Administrative, Inactive Landfill, and Sewage Treatment Areas) (Project Sampling)	Alluvial	sewage treatment facility with drainfield inactive landfills irrigated crop agriculture nearby animal operations nearby	11.00	5.10
U.S. Army Umatilla Depot Activity: South (Administrative, Inactive Landfill, and Sewage Treatment Areas) (U.S. Army Sampling)	Alluvial	sewage treatment facility with drainfield inactive landfills irrigated crop agriculture nearby animal operations nearby	22.00	<5.00
U.S. Army Umatilla Depot Activity: General (all other areas) (Project Sampling)	Alluvial	ordnance activity	18.00	6.10

U.S. Army Umatilla Depot Activity: General (all other areas) (U.S. Army Depot Sampling)	Alluvial	ordnance activity	16.80	<0.01
Crop Irrigation Area (south of the U.S. Army Umatilla Depot Activity) (Project Sampling)	Alluvial	irrigated crops	41.00	0.74
Crop Irrigation Area (south of the U.S. Army Umatilla Depot Activity) (Project Sampling)	Basalt (shallow and deep)	irrigated crops animal operations	9.30	0.25

Note: Project sampling reports nitrate concentrations as nitrate+nitrite-nitrogen.
Note: Shallow refers to wells less than 300 feet deep.
Note: Deep refers to wells 300 feet or more deep.

Sources:
Project Sampling
DEQ file: Solid Waste Disposal Facility Permit Number 394
DEQ Water Quality File 42490
DEQ Water Quality File 48780
Finley Buttes Landfill, 1992b
Hemphill, 1992
Port of Morrow, 1993a
SCM Consultants, Inc., 1990
Torrisi, 1992

Basalt groundwater samples had concentrations that reached 64 mg/L. This indicates a route for nitrate to travel to basalt water bearing zones exists.

Port sampling detected nitrate-nitrogen concentrations up to 35.5 mg/L in groundwater from wells completed in the brecciated and fractured top of basalt which grades into the overlying alluvial sediments. Port sampling also detected TKN primarily between 1 and 3 mg/L (Port of Morrow, 1993a). That indicates a possible contribution from an organic nitrogen source. However, irrigated crop agriculture appears to be the primary source given the local land use history, the distribution of the higher nitrate concentrations, and the detection of Atrazine at UMA 003.

Other south Boardman basalt and alluvial groundwater samples with elevated nitrate+nitrite-nitrogen concentrations came from wells primarily located downgradient of the irrigated crop area and near animal operations and/or rural residential homes. Analyses indicate the septic systems and animal operations do influence local groundwater but at relatively lower concentrations.

Plates 4.2 and 4.3 show elevated nitrate+nitrite-nitrogen concentrations occur in alluvial groundwater west and northwest of the U.S. Army Umatilla Depot Activity. Concentrations increase from Irrigon, the Columbia River, the Army Depot, the Port of Morrow, and Interstate 84 toward Western Empires Corporation Farm where center pivot irrigation currently occurs and nitrate+nitrite-nitrogen concentrations reach 76 mg/L. Analysis of land use, nitrate concentration distribution, and nitrogen isotopes strongly indicate irrigated crop agriculture is the nitrate source for concentrations exceeding 30 mg/L.

Several sources appear responsible for the nitrate concentrations less than 30 mg/L in the area. Nitrogen isotopic analyses indicate sources in addition to irrigation contribute nitrate to alluvial groundwater in the vicinity of UMA 161 and UMA 173. Graphical and concentration distribution analyses indicate elevated nitrate concentrations along the Depot's western boundary comes from irrigated crop agriculture activity west of the Army Depot. Nitrate and TKN concentration distribution analyses indicate Port of Morrow wastewater land application activity locally dominates nitrate in the alluvial groundwater.

Elevated nitrate+nitrite-nitrogen concentrations occur in alluvial groundwater between Irrigon and the Umatilla River. Although locally sparse, the data is sufficient to indicate concentrations increase from the U.S. Army Depot to areas along Highway 730 (see Plate 4.2).

Nitrate concentrations in the Irrigon sewage treatment facility area range from 41 mg/L to 20 mg/L in samples collected from up- to downgradient of the facility, respectively. This indicates facility wastewater infiltration locally dilutes the nitrate concentration in groundwater while remaining a significant source of nitrate itself. SCM Consultants, Inc. (1990) report 1 to 52 mg/L total nitrogen in the effluent leaving the facility's infiltration beds to groundwater. This project used facility data to calculate 4,550 pounds total nitrogen per acre per year loading from the infiltration beds to groundwater. Land uses up gradient of the sewage treatment facility include irrigated crop agriculture and a cemetery.

Further east of Irrigon, nitrate concentrations in alluvial groundwater increase downgradient from 19 mg/L in a sample collected near the West Extension Canal (UMA 097) to 35 mg/L in a sample collected 0.3 miles east and immediately north of Highway 730 (UMA 096). Graphical analyses (Appendix 4H) suggest mixed sources influence the groundwater chemistry at UMA 097 and UMA 096.

The West Extension Canal and the Depot's active landfill are not likely major contributors. Canal water nitrate+nitrite-nitrogen concentrations measured less than 5 mg/L, and nitrate concentrations increased between the Depot's landfill and UMA 097.

The groundwater chemistry at UMA 097 appears to reflect the influence of activity upgradient (south) of the canal. That activity includes irrigated crop agriculture and Lamb-Weston Incorporated wastewater land application. The groundwater chemistry at UMA 096 appears to reflect the influence of land use activity both south and north of the canal. Nitrate+nitrite versus time and Piper trilinear graphs for UMA 096 compare similarly to irrigated agriculture influences. However, a review of local land uses and a NETPATH groundwater chemistry computer model analysis indicates septic systems north of the canal contribute more than 90 percent to the groundwater chemistry observed at UMA 096.

Plates 4.2 and 4.3 show elevated nitrate+nitrite-nitrogen concentrations occur in alluvial groundwater in the northeast corner area of the U.S. Army Umatilla Depot Activity where a groundwater mound exists. The shape and extent of the concentration contours north of the Depot is not well defined due to sparse data from that area. The highest concentration areas correspond to the Lamb-Weston Incorporated food processing wastewater land application area and the Depot's active landfill.

Hydrogeologic and groundwater chemistry evaluations identify wastewater land application as the source of nitrate in groundwater at the Lamb-Weston site. The site straddles the groundwater mound crest. No other activity is upgradient. Additionally, project and facility TKN data indicates a significant organic nitrogen source at the land application site. The detected and reported TKN concentrations range from non-detect to 18 mg/L.

The active landfill is located downgradient of the Lamb-Weston site, which is evident in the groundwater chemistry graphs reviewed. However, the landfill appears primarily responsible for the higher nitrate concentrations in its vicinity for several reasons.

- Data related to the landfill and Lamb-Weston sites graph in adjacent but separate areas on some groundwater chemistry graphs.
- An area of lower nitrate concentrations in alluvial groundwater appears to separate the Lamb-Weston and active landfill sites.
- Total dissolved solids concentrations in groundwater are higher at the landfill site than the Lamb-Weston site.
- Alluvial groundwater TKN concentrations increase downgradient across the landfill site. They increase from 0.5 mg/L to 1.3 and 2.4 mg/L.
- Disposal of dried sewage sludge at the landfill is a possible TKN and nitrate source.

Elevated nitrate+nitrite-nitrogen concentrations occur in alluvial groundwater within the central portion of the U.S. Army Umatilla Depot Activity (see Plate 4.2). The highest concentrations came from samples collected in the explosive washout lagoon area. Nitrogen isotope analysis of groundwater sampled near the washout lagoons found delta ^{15}N values consistent with contamination from explosives. Dawson and others (1982) and Ritchie and others (1992) identified the washout lagoon as a groundwater contamination source. The U.S. Army has begun implementing a groundwater clean-up plan at the site.

Plate 4.2 shows an apparent nitrate plume extending from the washout lagoons toward the south, then west and northwest of the washout lagoon area. The apparent plume may be real or a contouring artifact. Arguments against a real plume include:

- The November 1981 nitrate concentration distribution (50 to 400 mg/L) at the lagoon site indicating a net plume movement toward the south-southeast (Dawson and others, 1982);
- February 1991 groundwater flow directions (Plate 2.4) which suggest a plume emanating from the lagoons should move south and east;
- The 18 mg/L concentration at UMA 216 appears somewhat separated from similar nitrate concentrations closer to the lagoon site; and
- Nitrate concentrations greater than 20 mg/L appear much less dispersed (they remain close to the lagoon site) than the lower nitrate concentrations.

Arguments supporting a real plume include:

- Information provided by Dawson and others (1982):
    - The 1981 seasonal groundwater flow directions appear to locally change from northwesterly in April to south-southwesterly in October;
    - A projected net contaminant movement from the lagoon area toward the west-northwest; and
    - The 1981 RDX explosive concentration distribution at the lagoon site indicating a net plume movement toward the northwest;
- Current groundwater flow direction reversals and complexities in the area as described in the hydrogeology chapter; and
- Piper trilinear, Schoeller Diagram, and constituent versus constituent graphical analyses suggesting a chemical relationship between alluvial groundwater at the explosive washout lagoon vicinity and wells UMA 228, UMA 216, and UMA 218.

The nitrate distribution around the washout lagoons provides important information about the time required for groundwater contamination to flush through the alluvial groundwater system. Washout lagoon activity occurred from the mid-1950s through the mid-1960s. If the apparent plume extending through UMA 216 on Plate 4.2 is real, nitrate from the washout lagoons has moved less than four miles over three to four decades. If that plume is not real, nitrate from the washout lagoons has moved less than 0.5 mile over three to four decades.

Elevated nitrate+nitrite-nitrogen concentrations also occur in alluvial groundwater south of the U.S. Army Depot. Historic and current land use activities in the area include livestock operations, irrigated crops, and the Depot's administrative, sewage treatment, and inactive landfill facilities.

Analyses indicates activities outside the Depot are the prominent nitrate sources. A review of Plate 4.2 indicates the highest nitrate concentrations occur south of the Depot with groundwater flow near the Depot carrying the nitrate north-northeast onto the Depot. This nitrate transport interpretation is consistent with the complex alluvial groundwater flow conditions in the area.

Several analyses indicate multiple sources are responsible for the nitrate concentration in the area. Graphical analyses suggest mixed nitrogen sources. The highest nitrate concentration area on Plate 4.2 occurs in the vicinity of the former Hansell Brothers Incorporated hog operation, which suggests an animal waste source. Nitrogen isotopic analyses indicate animal waste influences alluvial groundwater at UMA 133 located near a horse pen and a former dairy and turkey operation. Additionally, project groundwater sampling in July 1994 found Dacthal acid, a chemical from the agricultural pesticide Dacthal, in groundwater sampled from UMA 133. That detection indicates an irrigated crop influence.

Lower nitrate concentrations were also detected in the Boardman to west Umatilla area. Groundwater with nitrate concentrations below 10 mg/L occurs within the general Boardman area, west of Irrigon along the Columbia River, south of Irrigon through the western portion of the U.S. Army Depot, and southeast of the Interstate 84 and Interstate 82 interchange through Lost Lake. River water dilution appears responsible for lower concentrations adjacent to the Columbia River. Lower nitrogen and/or hydraulic loading appears responsible for lower nitrate concentrations south of Irrigon and within the U.S. Army Depot. Rural residential home and ordnance activities occur within those areas. Background conditions, lower nitrogen loading, and/or dilution from High Line Canal and Lost Lake appear responsible for the lower concentrations southeast of the Interstate 84 and Interstate 82 interchange.

Map and Data Set Observations: Total Dissolved Solids

Plates 4.4 and 4.5 show the total dissolved solids (TDS) concentration distribution in the Boardman to west Umatilla area based upon project groundwater sampling. Plate 4.5 shows the distribution of maximum concentrations detected in alluvial and basalt groundwater samples. Plate 4.4 shows the June-July 1992 TDS concentration distribution in alluvial groundwater based upon project synoptic sampling. The shape and extent of each concentration range contoured was derived by linear interpolation between data locations. TDS concentrations detected in basalt groundwater samples are printed next to each sampling location.

Elevated versus lower TDS concentration distribution in the general area is similar to the nitrate concentration distribution with some exceptions. Concentrations exceeding the secondary (aesthetic) drinking water standard of 500 mg/L occurred in groundwater sampled within and south of Boardman, at Finley Butte Landfill, between Boardman and Irrigon, east Irrigon, the U.S. Army depot active landfill area, the immediate vicinity of the explosive washout lagoon area, and the agricultural area south of the Depot. Concentrations below 350 mg/L occurred in groundwater sampled west of Irrigon along the Columbia River, south of Irrigon, at Finley Butte Landfill, within the U.S. Army Depot, between the Depot's active landfill and the Lamb-Weston wastewater land application area, and northwest of Lost Lake. River water dilution appears responsible for the lower TDS concentrations adjacent to the Columbia River. Dilution from Lost Lake appears responsible for the lower TDS concentration northwest of the lake.

Map and Data Set Observations: Other Constituents

Project sampling detected arsenic in many Boardman to west Umatilla groundwater samples collected primarily north of Township 3 North. Plate 4.6 shows the maximum concentration distribution. Detected concentrations generally remained well below the drinking water standard of 0.050 mg/L. Groundwater samples containing arsenic greater than 0.025 mg/L came from multiple sites in the northwest portion of the U.S. Army Depot, and individual sites at the Irrigon sewage treatment site, the Depot's active landfill area, and the Lamb-Weston land application area. Several Depot sites and the Lamb-Weston site yielded samples with arsenic concentrations exceeding the drinking water standard.

Plate 4.7 shows the maximum concentration distribution for sodium. Concentrations in local groundwater sampled commonly exceeded the 20 mg/L limit currently recommended for persons on a sodium restricted diet. Samples with sodium exceeding 50 mg/L came from sites near and south of Boardman, along Highway 730, within the U.S. Army Depot northwest corner and explosive washout lagoon area, within the Irrigon sewage treatment facility vicinity, within the Lamb-Weston land application area, and south of the Depot. Some samples collected west of Irrigon near the Columbia River had sodium concentrations below 20 mg/L. The lower concentrations suggest dilution from the Columbia River.

Plate 4.8 shows the maximum concentration distribution for chloride. Concentrations in all area groundwater sampled by this project remained within the 250 mg/L secondary (aesthetic) drinking water standard. The greatest concentrations detected were 190 mg/L and 160 mg/L measured in basalt groundwater sampled from UMA 003 and UMA 029, respectively. Both wells are located south of Boardman. Well UMA 029 is located in a rural residential area nearly enclosed by irrigated crop agriculture. Well UMA 003 is located immediately downgradient of an irrigated crop area converted to Port of Morrow wastewater land application after 1990.

Plate 4.9 shows the maximum concentration distribution for total phosphate. This project generally measured concentrations below 0.10 mg/L in local groundwater samples. Groundwater samples with relatively higher (0.10 mg/L or greater) maximum total phosphate concentrations came from wells located within the Port of Morrow wastewater land application area east of Boardman, the Irrigon area, most of the U.S. Army Depot, south of the Depot, and the Lamb-Weston land application area. Samples with relatively lower total phosphate concentrations often came from within or near irrigated crop agriculture areas.

Plates 4.10, 4.11, 4.12 show the maximum concentration distribution for boron, bromide, and vanadium. Boron detections appear limited to the northern portion of the Boardman to west Umatilla area. Plate 4.10 does not show boron concentrations in groundwater at the U.S. Army Depot and several other areas, because project synoptic sampling did not include laboratory analysis for boron. Bromide was detected in most samples except some areas near the Columbia River.

Samples with relatively higher maximum bromide concentrations generally came from across the Depot's north central area as well as the Lamb-Weston site adjacent to the Depot, Boardman, south of Boardman, Port of Morrow, and south Irrigon vicinities. Samples with relatively lower concentrations came from irrigated crop agriculture areas west and southwest of the Depot, the southern Depot area, rural residential development near Irrigon, and the northern portion of the Lamb-Weston site next to the Depot.

Vanadium detections appear limited to samples collected from the central portion of the Boardman to west Umatilla area. The highest concentrations occurred in samples collected across the central portion of the Depot and the eastern portion of the Lamb-Weston site next to the Depot.

Table 4.15 lists and Plate 4.13 shows the Boardman to west Umatilla sites where project sampling detected volatile organic compounds and/or pesticides. A complete listing is presented in Appendix 4G. Table 4.16 shows the areas where U.S. Army Depot sampling detected explosives, pesticides, organic compounds, and other constituents. The occurrence of explosives, volatile organic compounds and pesticides strongly indicate the influence of human activity.

Table 4.15 Volatile organic compounds and pesticides detected in the groundwater from Boardman to west Umatilla Area.

Site	Groundwater Source	Location	Constituent	Concentration	Nitrate+Nitrite-Nitrogen Concentration (mg/L)
UMA 003	Basalt	south Boardman	Atrazine	3.00 ug/L	40.00 - 40.00
UMA 133	Alluvial	south of U.S. Army Depot	Dacthal acid	0.4 ppb	17.00 - 21.00
UMA 144	Alluvial	south Irrigon	Toluene	0.0013 mg/L	2.00 - 22.00
UMA 162	Alluvial	Western Empire Farm near Irrigon	Atrazine	0.4 ppb	12.00 - 12.00
UMA 198	Alluvial	Lamb-Weston site next to Depot	Chloroform	0.0009 mg/L	5.80 - 16.00

Note: Laboratory methods can occasionally cause chloroform detections at low concentrations
Note: Data from Lower Umatilla Basin project sampling.

Table 4.16 Types of contamination detected at selected U.S. Army Umatilla Depot Activity sites as identified by other investigators.

Site	Site #	Soil					Groundwater					
		Metals	Explosives	Nitrate/ Nitrite	Pesticide	Other Organics	Metals	Explosives	Nitrate/ Nitrite	Pesticide	Other Organics	No GW Sampling
Above ground open detonation area	17	X	X									X
Acid pit	8	X		X			X	X	X			
Active firing range	60	X										X
Aniline pit	7											X
Borrow/burn/disposal area	58	X										X
Dunnage pits	18	X			X	X						
Flare & fuse disposal area / bird cage area	14	X		X			X					
Former pit area locations	57	X	X				X					
GB/VX decontamination solution burial areas	41	X		X			X					
GB/VX decontamination solution disposal areas	59											
Missile fuel storage areas	21			X								X
Munitions crate burn area	56	X										X
Open burning trays	32	X	X	X								X
Open burning trenches pads	19	X	X	X		X	X		X		X	

Open detonation pits	16	X	X	X			X					
Pesticide pits	31	X	X	X	X	X	X	X	X		X	
Pit field area	38	X	X	X					X			
Smoke canister disposal area	13	X	X	X		X	X					
TNT sludge burial & burn area	15	X	X	X		X	X		X			
Trench/burn field	55	X	X				X					
Deactivation furnace	1	X	X	X								X
Disposal pit & graded areas	80					X						X
Former raw materials storage location I	81	X										X
Hazardous waste storage facility (bldg 203)	3											X
Malathion storage leak area	35				X							X
Metal ingot stockpiles	26	X										X
Metal ore piles location I	25	X										X
Bldg 131 paint sludge discharge area	37	X				X						X
Paint spray & shot blast areas	34	X		X		X						X
Railcar unloading area	46	X				X						X
Road oil application/disposal site location I	44					X						X
Boiler/laundry effluent discharge site	47	X			X	X	X	X				
Bldg 493 paint sludge discharge area	36	X		X		X						X
Bldg 493 brass cleaning operation area	67	X					X					
Coyote Coulee discharge gullies	52	X	X									X
Explosive washout plant (bldg 489)	5		X	X								X

Explosive washout lagoons	4		X					X	X			
Pipe discharge area	48	X		X	X	X						X
Sewage treatment plant	6	X		X	X	X						X
Stormwater discharge area	30	X			X	X						X
Defense re-utilization marketing office area	22	X			X	X						X
Pesticide storage building	27	X			X	X						X
Road oil application/disposal sites location II	44					X						X
Inactive landfills	12	X			X	X	X	X	X			
Railroad landfill areas	50	X				X	X	X	X		X	
Active landfill	11						X	X	X		X	
Building 433 collection sump/cistern and disposal area	53	X				X						X
Building 612 and bldg 617 boiler discharge areas	45	X										X
Drill transfer site	49											X
Former agent H storage area	10	X				X						X
Former gravel pit/disposal location	82					X						X
Former raw materials storage location II	81											X
Gravel pit disposal area	33											X
Metal ore piles - location II	25	X										X
QA function range	39	X		X								X
Remote munitions disassembly/GB bomb disassembly area	9	X	X	X								X

Septic tanks	29	X				X						X
Storage igloos	2											X
Sources:	Dawson, and others, 1982 Ritchie, and others, 1992 Mahannah, and others, 1993 Machacek, and others, 1993 Woodland, and others, 1993 Brown, and others, 1993											

Project sampling detected the agricultural pesticide atrazine in one basalt groundwater sample from UMA 003 and one alluvial groundwater sample from UMA 162. Well UMA 003 is immediately north of an irrigated crop agriculture area south of Boardman. Well UMA 162 is located in the northeast portion of Western Empire Farms. Nitrate+nitrite-nitrogen measured 40 mg/L in the sample collected from UMA 003 and 12 mg/L in the sample collected from UMA 162.

Project sampling also detected a pesticide related chemical, Dacthal acid, in an alluvial groundwater sample from UMA 133. Nitrate+nitrite-nitrogen measured 17 mg/L in the sample. The well is located along County Line Road south of the U.S. Army Depot.

Project sampling detected the constituent toluene in an alluvial groundwater sample collected from UMA 144 located south of Irrigon. Project staff observed a disassembled engine in the vicinity of the well. Nitrate+nitrite-nitrogen measured 18 mg/L in the sample.

Project sampling also detected chloroform in an alluvial groundwater sample from UMA 198 located at the Lamb-Weston site next to the U.S. Army Depot. A chloroform source is uncertain. Laboratory methods can occasionally cause very low concentration chloroform detections.

Graphical Analyses: Nitrate versus Time

Graphical analysis of Boardman to Irrigon area groundwater data included reviewing nitrate versus time graphs. Data used for the analysis came from project bimonthly sampling, the Port of Morrow (1993a), and Lamb-Weston, Incorporated (DEQ Water Quality File 48780). The analysis of bimonthly sampling data included comparing the nitrate versus time graphs to other constituent versus time graphs. Analysis of some Port of Morrow and Lamb-Weston data included comparing the nitrate versus time graphs to available groundwater elevation versus time graphs.

Figure 4.22 shows nitrate+nitrite-nitrogen concentrations versus time in basalt and alluvial groundwater sampled by this project in the Boardman and Port of Morrow areas. Table 4.17 presents groundwater source and land use information about each sampling site. Table 4.18 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. The nitrate data related to each sampling site graphed differently as shown in Figure 4.22, and they compared differently to the other constituent versus time graphs as summarized in Table 4.18.

The differences make sense given the different locations, land uses, and sources of water associated with each site. Nitrate access to basalt groundwater at UMA 028 and UMA 029 appear locally different. The difference may relate to well construction. Small nitrate fluctuations occur in alluvial groundwater at UMA 085 and UMA 201. A combination of influences may be responsible for the small fluctuations. Small concentration fluctuations are consistent with a constant loading source, a distant nitrate source, and/or a reservoir of nitrate accumulated in groundwater.

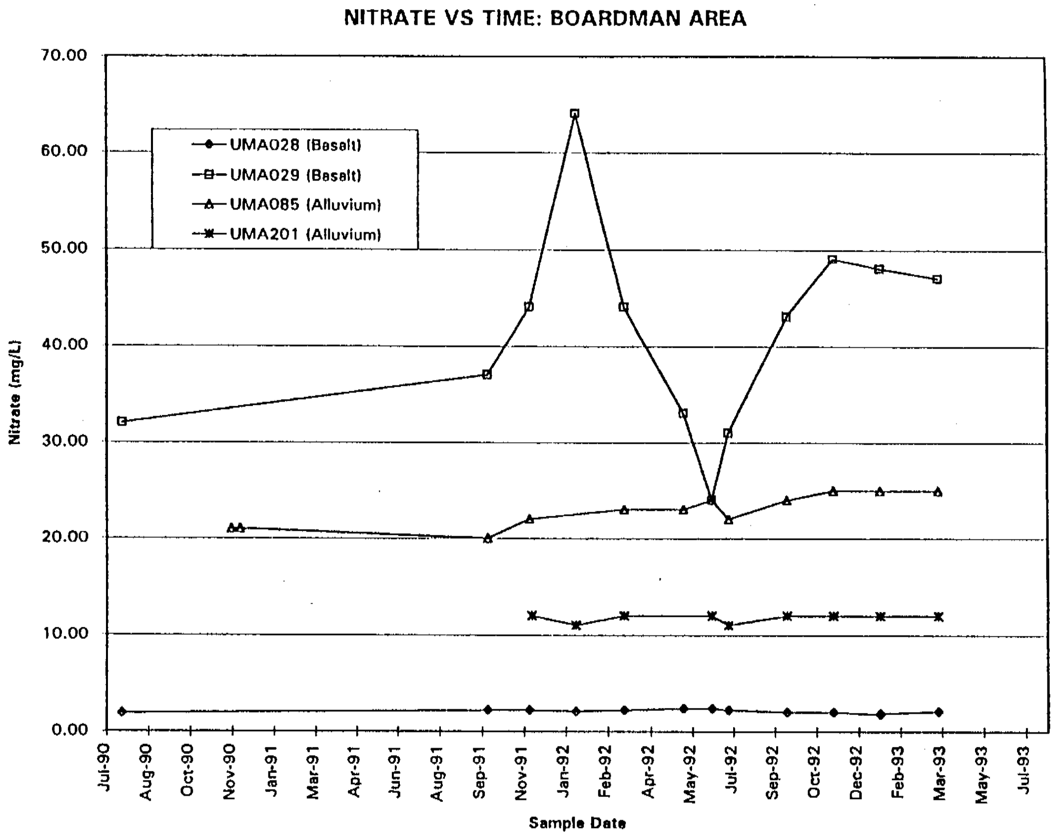


Figure 4.22 Nitrate+nitrite-nitrogen versus time in Boardman area alluvial and basalt groundwater at project bimonthly sampling sites.

Note: A 1 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.17 Groundwater source and location information related to project bimonthly sampling sites in the Boardman area.

Sampling Site	Groundwater Source	Location and Surrounding Land Uses
UMA 028	Basalt basal Elephant Mountain	south Boardman, north of Wilson Road rural residential with fields and pasture nearby
UMA 029	Basalt basal Elephant Mountain	south Boardman near West Extension Irrigation Canal rural residential area adjacent to irrigated crops
UMA 085	Alluvial	south Boardman, north of Wilson Road and east of Ripee Road surrounded by fields and several active and inactive animal operations
UMA 201	Alluvial	Port of Morrow wastewater land application area north of Interstate 84

Table 4.18 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to Boardman area project bimonthly groundwater sampling sites.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 028	WS		S	WS	NS	I	WS	I
UMA 029	S	S	S	I	S	WS	I	S
UMA 085	WS	S and I	S and I	S and I	S and I	WS and I	NS	
UMA 201	I	I	S	S	WS	S	I	I

Note: Comparisons were qualitative rather than quantitative.
Note: S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph

This project reviewed Port of Morrow groundwater data for the Port's two wastewater land application sites using nitrate-nitrogen and groundwater versus time graphs. The nitrate-nitrogen versus time graphs show seasonal fluctuations with some exceptions. The fluctuations indicate seasonal influences. Fluctuations associated with sites within the land application area north of Interstate 84 often correlate or weakly correlate to groundwater elevation fluctuations. This suggests a relatively short travel time from land surface to groundwater in that area. A short travel time is reasonable given the local soils, unsaturated zone, and aquifer materials.

Groundwater nitrate concentrations often correlate inversely to groundwater elevation fluctuations at the land application area south of Boardman. Nitrate concentrations appear to increase when groundwater elevations decline and vice versa. This may relate to a travel time lag for nitrate to reach local groundwater. The sampling period was too short to confirm or determine any time lag.

Figure 4.23 shows nitrate+nitrite-nitrogen concentrations versus time in alluvial and basalt groundwater sampled by this project in the Irrigon vicinity. Each sampling site is located in or near a predominantly rural residential area. Table 4.19 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. A review of Figure 4.23 and Table 4.19 indicates similarities and differences between sampling sites. Nitrate data related to most sites graphed with relatively low concentrations and small fluctuations. The small concentration fluctuations in alluvial groundwater are consistent with a nearly constant loading source such as septic systems. The higher nitrate concentrations and larger fluctuations related to UMA 144 indicate a seasonal influence. Well UMA 144 is located adjacent to an irrigated field.

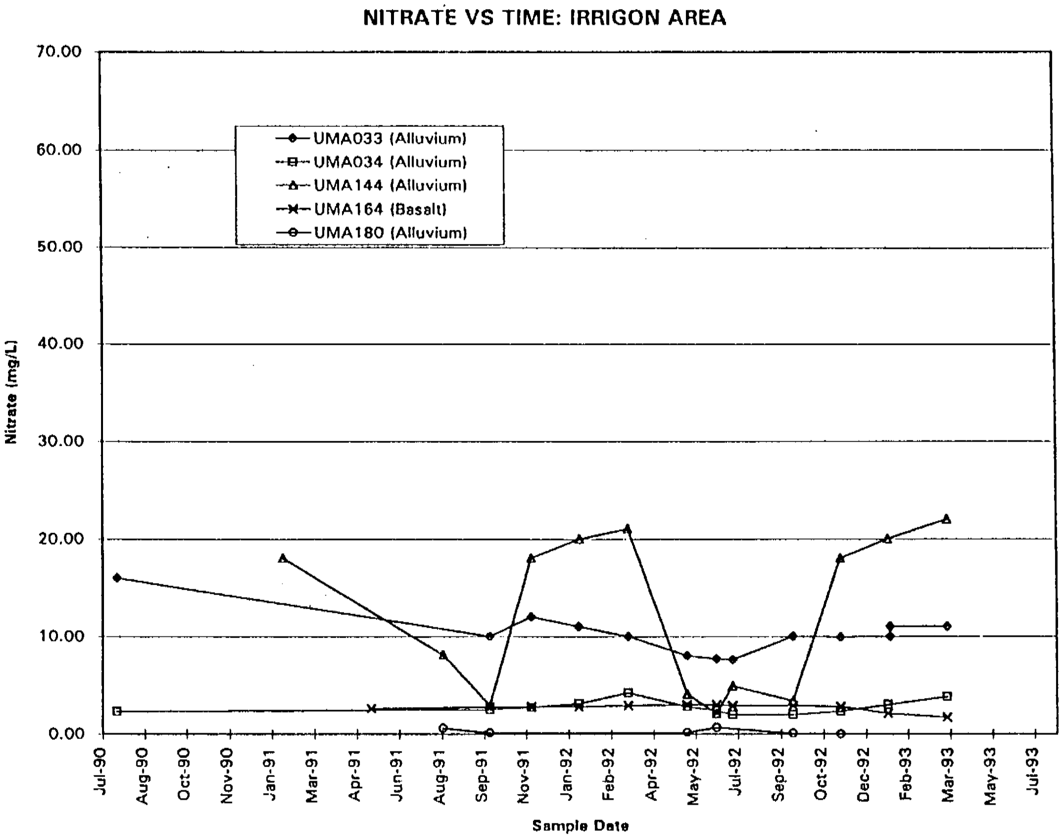


Figure 4.23 Nitrate+nitrite-nitrogen versus time in Irrigon area alluvial and basalt groundwater at project bimonthly groundwater sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.19 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Irrigon area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 033 (Alluvial)	S			NS	WS			
UMA 034 (Alluvial)	S	S	S	S	S		NS	
UMA 144 (Alluvial)	S	S	S	S	S	S	I	WS
UMA 180 (Alluvial)	NS	S and I	S and I	I	I	I	NS	WS
UMA 164 (Basalt)	NS	WS	I	I	S and I	NS	WS	

Note: Comparison were qualitative rather than quantitative.
Note: S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph

Figure 4.24 shows nitrate+nitrite-nitrogen concentrations versus time in alluvial groundwater sampled between Irrigon and the Umatilla River by this project. Table 4.20 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. Differences characterize Figure 4.24 and Table 4.20. Differences between sampling sites should be expected given the different locations and land uses related to each sampling site. Well UMA 198 is located in an upgradient area in the vicinity of a food processing wastewater pond and land application area. Irrigated crop agriculture occurs upgradient of both UMA 096 and UMA 103. However, more rural residential septic systems are located in the immediate vicinity of UMA 096, and more small agricultural activity appears present in the immediate vicinity of UMA 103. The higher nitrate concentrations and larger fluctuations in groundwater at UMA 096 are greater than expected for septic system influences.

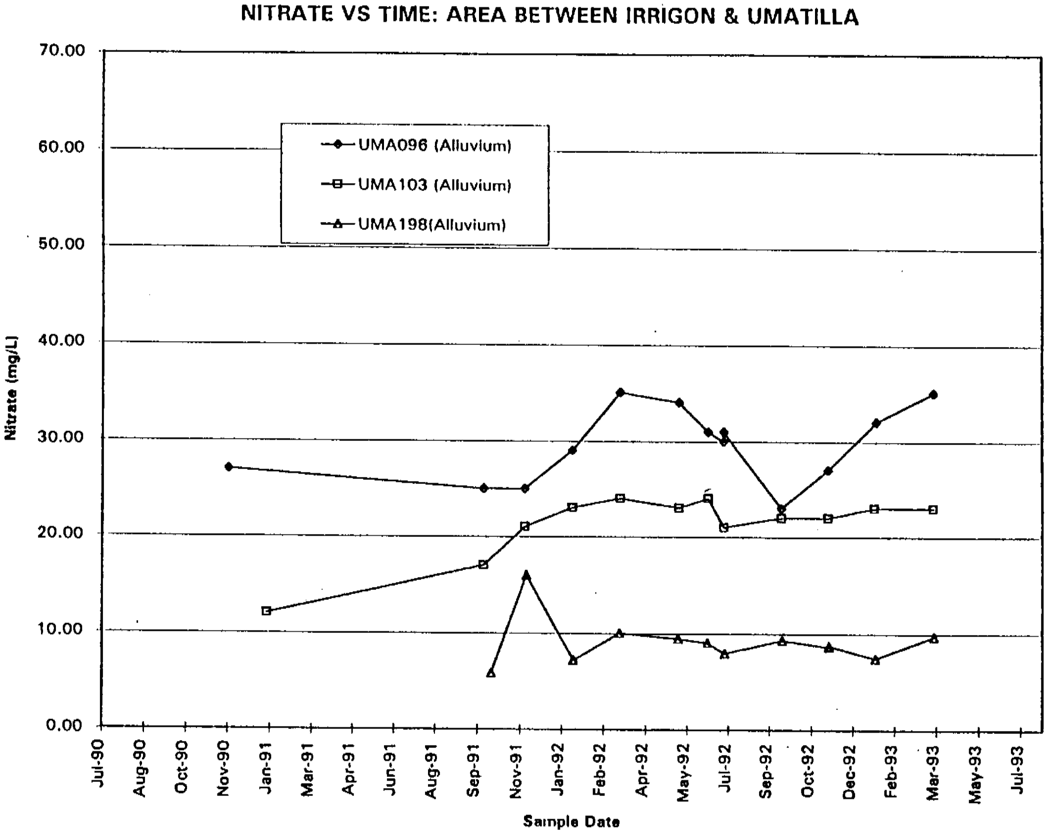


Figure 4.24 Nitrate+nitrite-nitrogen versus time in alluvial groundwater between Irrigon and the Umatilla River at project bimonthly groundwater sampling sites.

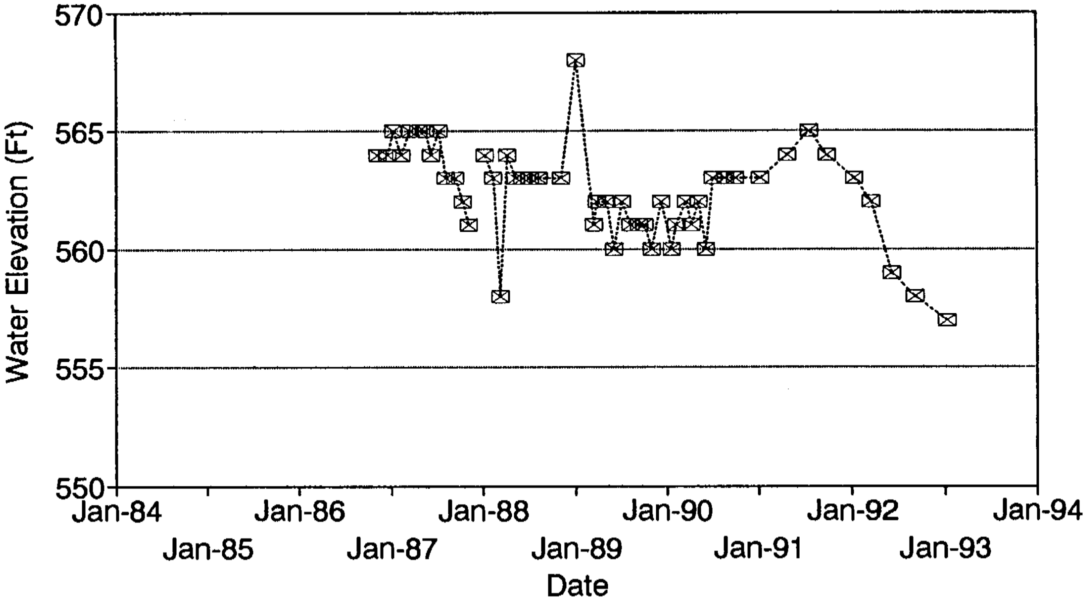
Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.20 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Irrigon to Umatilla River area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 096 (Alluvial)	S	S	S	I	NS	WS	NS	I
UMA 103 (Alluvial)	S and I	I	I	S and I	S and I	I	I	
UMA 198 (Alluvial)	S	S	S	S	S	S	I	

Note: Comparison were qualitative rather than quantitative.
Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph

This project reviewed Lamb-Weston, Incorporated alluvial groundwater data for the land application site adjacent to the U.S. Army Umatilla Depot Activity using nitrate-nitrogen and groundwater elevation versus time graphs. The nitrate-nitrogen versus time graphs generally show fluctuations that indicate seasonal influences. A comparison of those graphs to the groundwater elevation versus time graphs indicate some correlation. Figure 4.25 provides an example. Time lags ranging from less than 1 month to possibly 18 months were observed between unique groundwater elevation and nitrate concentration peaks. This time lag appears related to the time required for nitrate to travel to groundwater.



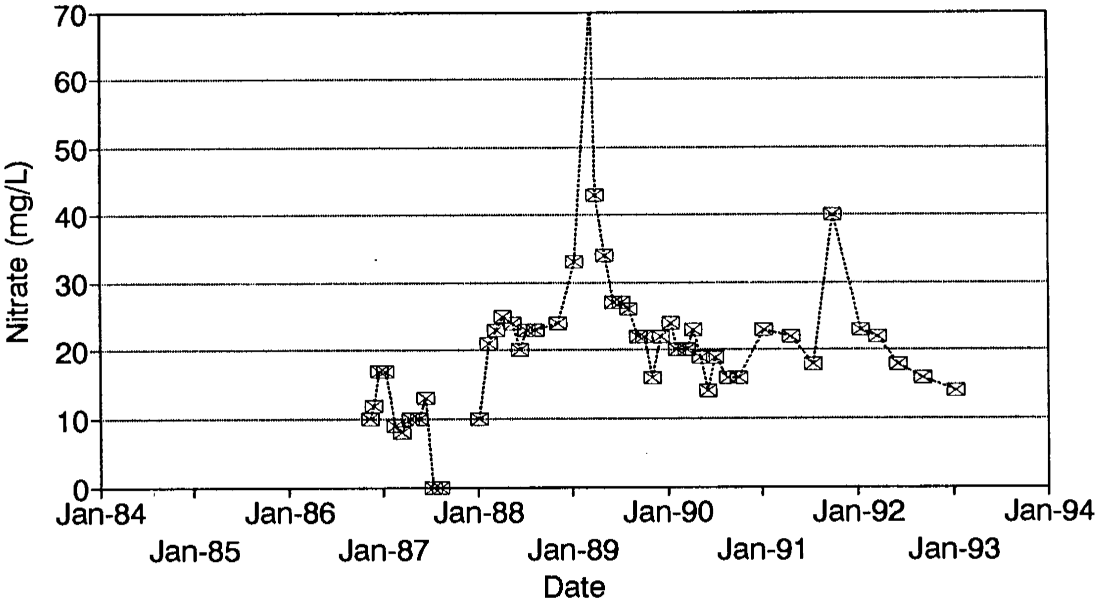


Figure 4.25 Groundwater elevation versus time and nitrate concentration versus time at UMA 243 (UMAT 5365, Lamb-Weston MW-5).

Figure 4.26 shows nitrate+nitrite-nitrogen concentrations versus time in alluvial groundwater sampled by this project south of the U.S. Army Depot. Table 4.21 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site.

Similarity characterizes Figure 4.26 and Table 4.21. The nitrate concentration fluctuations at each site are generally small, and the nitrate versus time graphs generally correlate to the other constituent versus time graphs. The dominance of irrigated crops in the area with some former and existing animal operations rather than diverse land uses would account for similarities. The small nitrate fluctuations may relate to the relatively low groundwater hydraulic gradients and groundwater flow reversals in the area. Those conditions can allow nitrate to accumulate in local groundwater and dampen seasonal fluctuations. Additionally, the small nitrate fluctuation at UMA 112 may also relate to septic system discharges providing a constant nitrate source. Graphical analyses (Appendix 4H) suggest a local septic system influence.

Sampling site location relative to local land use would account for the higher versus lower nitrate concentrations observed. Well UMA 133 is located within the irrigated crop area and near former and existing livestock operations. Nitrate concentrations in the alluvial groundwater at the site range from 17.00 mg/L to 21.00 mg/L. Wells UMA 112 and UMA 168 are located along the margins of the active agricultural area. Additionally, alluvial groundwater at UMA 112 and UMA 168 may be experiencing some dilution from High Line Canal and possibly Lost Lake, respectively. Their nitrate concentrations range from 4.40 mg/L to 5.80 mg/L and 3.80 mg/L to 5.80 mg/L, respectively.

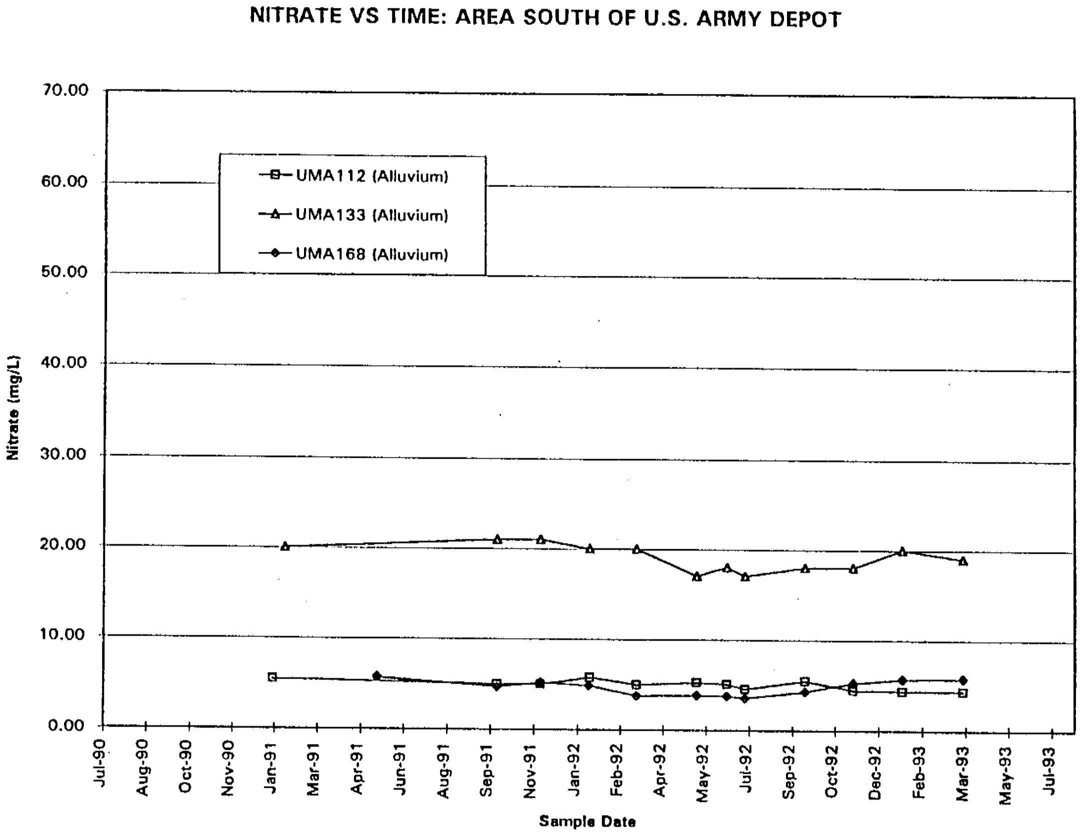


Figure 4.26 Nitrate+nitrite-nitrogen versus time in alluvial groundwater south of the U.S. Army Umatilla Depot Activity at project bimonthly groundwater sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.21 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the area south of the U.S. Army Umatilla Depot Activity.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 112 (Alluvial)	S	S	S	S	S	S	WS	WS
UMA 133 (Alluvial)	S	S	S	S	S	S	WS	WS
UMA 168 (Alluvial)	S	WS	S	S	S and I	S	NS	

Note: Comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph

Graphical Analyses: Piper Trilinear Graphs and Schoeller Diagrams

Project bimonthly and synoptic groundwater sampling data related to the Boardman to west Umatilla area were plotted on Piper trilinear graphs and Schoeller diagrams. Generally, variation or lack of variation observed on the graphs correlated with nitrate variation or lack of variation. The trilinear graphs proved very useful for classifying the groundwater chemistry at different locations and for distinguishing nitrate source influences at neighboring sites. The groundwater chemistry classifications observed by location and groundwater source are presented in Table 4.22.

Table 4.22 Observed piper trilinear water chemistry classification of alluvial and basalt groundwater sampled in the Boardman to Irrigon area.

Area	Groundwater Source	Groundwater Chemistries Observed
Boardman Area: North (north of Interstate-84) (Project Sampling)	Alluvial	mixed-cation/bicarbonate
Boardman Area: South (Interstate-84 to West Extension Canal) (Project Sampling)	Alluvial	mixed-cation/bicarbonate no dominant type
Boardman Area: South (Interstate-84 to West Extension Canal) (Project Sampling)	Basalt	mixed-cation/bicarbonate sodium + potassium/bicarbonate mixed-cation/chloride no dominant type
Boardman Area: South (West Extension Canal to U.S. Navy Bombing Range) (Project Sampling: UMA 233)	Basalt Top	no dominant type
U.S. Navy Boardman Bombing Range: (Project Sampling: UMA 170)	Basalt	mixed-cation/bicarbonate
Port of Morrow Land Application Area (east of Boardman and north of Interstate-84) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Crop Irrigation Area (east of Boardman: Range 26) (Project Sampling)	Alluvial	calcium/bicarbonate calcium/mixed-anion
Irrigon Vicinity (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Irrigon Vicinity (Project Sampling)	Basalt	calcium/bicarbonate
Irrigon Sewage Treatment Facility Area (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate calcium/mixed-anion
Irrigon Sewage Treatment Facility Area (Project Sampling: UMA 269)	Basalt	sodium + potassium/bicarbonate
Irrigon to West Umatilla (along Highway 730) (Project Sampling)	Alluvial	mixed-cation/bicarbonate
Irrigon to West Umatilla (along Highway 730) (Project Sampling)	Basalt	sodium + potassium/bicarbonate
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial	mixed-cation/bicarbonate sodium + potassium/bicarbonate

Lamb-Weston, Inc. Land Application Area (Adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial (Shallow Unconfined)	mixed-cation/bicarbonate
U.S. Army Umatilla Activity: West (Ammunition Demolition Area) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate sodium + potassium/bicarbonate calcium/mixed-anion
U.S. Army Umatilla Depot Activity: Central Explosive Washout Lagoons Area) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate calcium/mixed-anion
U.S. Army Umatilla Depot Activity: Northeast (Active Landfill Area) (Project Sampling)	Alluvial	mixed-cation/bicarbonate no dominant type
U.S. Army Umatilla depot Activity: South (Administrative, Inactive Landfill, and Sewage Treatment Areas) (Project Sampling)	Alluvial	calcium/bicarbonate
U.S. Army Umatilla Depot Activity: General (all other areas) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate magnesium/mixed-anion
Crop Irrigation Area (south of the U.S. Army Umatilla Depot Activity) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate no dominant type
Crop Irrigation Area (south of the U.S. Army Umatilla Depot Activity) (Project Sampling)	Basalt (shallow and deep)	mixed-cation/bicarbonate calcium/bicarbonate

Note: Project bimonthly and synoptic groundwater sampling data was used for the groundwater chemistry classifications
Note: Shallow refers to wells less than 300 feet deep.
Note: Deep refers to wells 300 feet or more deep.

Nitrate variation by location or over time appears to correlate to the water chemistry variation observed on the trilinear graphs and Schoeller diagrams. Figures 4.27 through 4.34 provide examples.

The west Irrigon data graphed with little variation (Figures 4.27 and 4.28), which correlates to a smaller variation in nitrate+nitrite-nitrogen concentrations detected in samples from that area. The concentrations ranged from 2.50 mg/L to 7.70 mg/L. Similarly, figures 4.29 and 4.30 show project bimonthly sampling data for an alluvial groundwater sampling site, UMA 034, located in west Irrigon. The data graphed with small variation over time. Nitrate+nitrite-nitrogen concentrations in samples from the site ranged from 2.00 to 8.50 mg/L.

Figures 4.31 and 4.32 show project synoptic sampling data for alluvial groundwater in the irrigated crop agriculture area between Boardman and Irrigon. The data graphed with variations in the anion chemistry that correlates to nitrate concentration variations. Nitrate+nitrite-nitrogen concentrations in the samples ranged from 1 mg/L to 67 mg/L. Similarly, figures 4.33 and 4.34 show project bimonthly data for an alluvial groundwater site, UMA 144, located south of Irrigon and adjacent to an irrigated field. Nitrate+nitrite-nitrogen concentrations in samples from the site ranged from 2.10 mg/L to 22 mg/L. Both graphs show a distinct bimodal groundwater chemistry pattern. Additionally, figure 4.34 shows an inverse correlation between total phosphate and the other constituents.

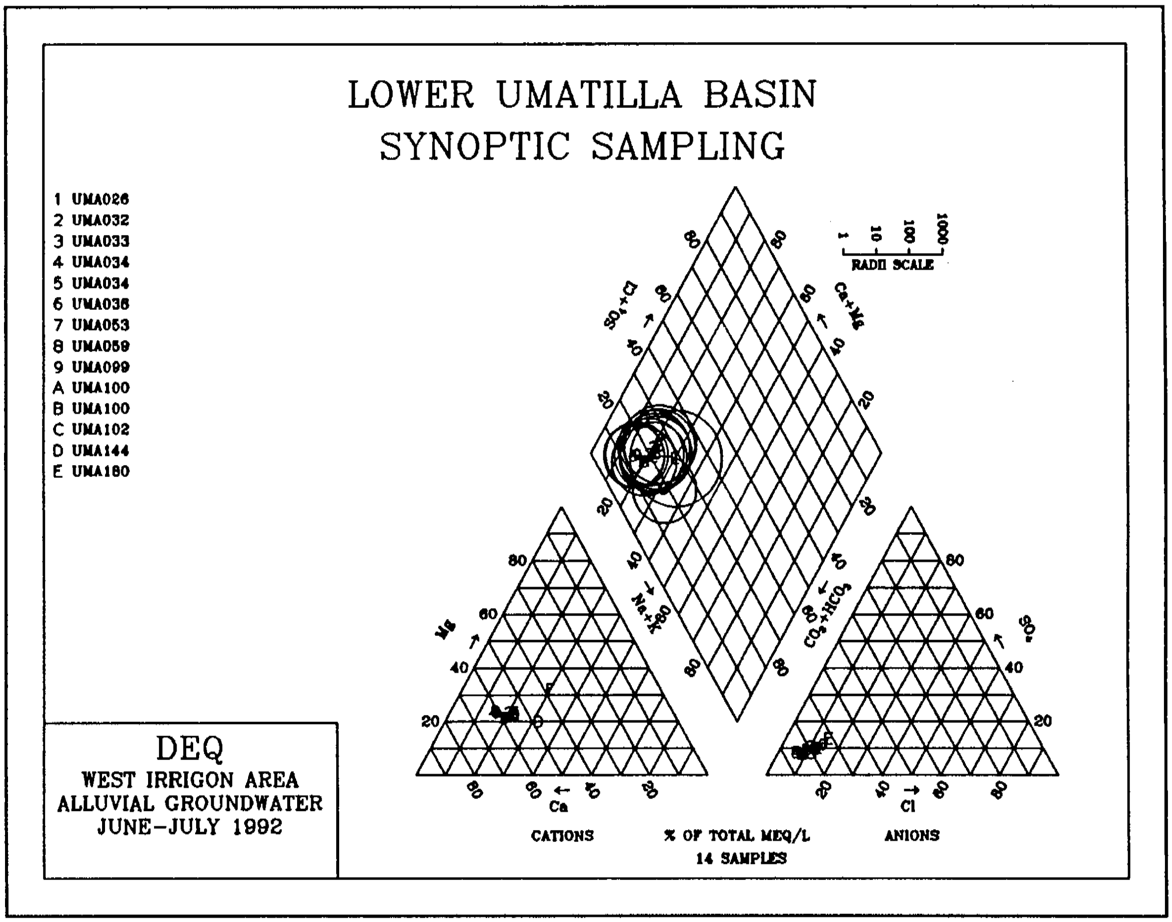


Figure 4.27 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the Irrigon vicinity.

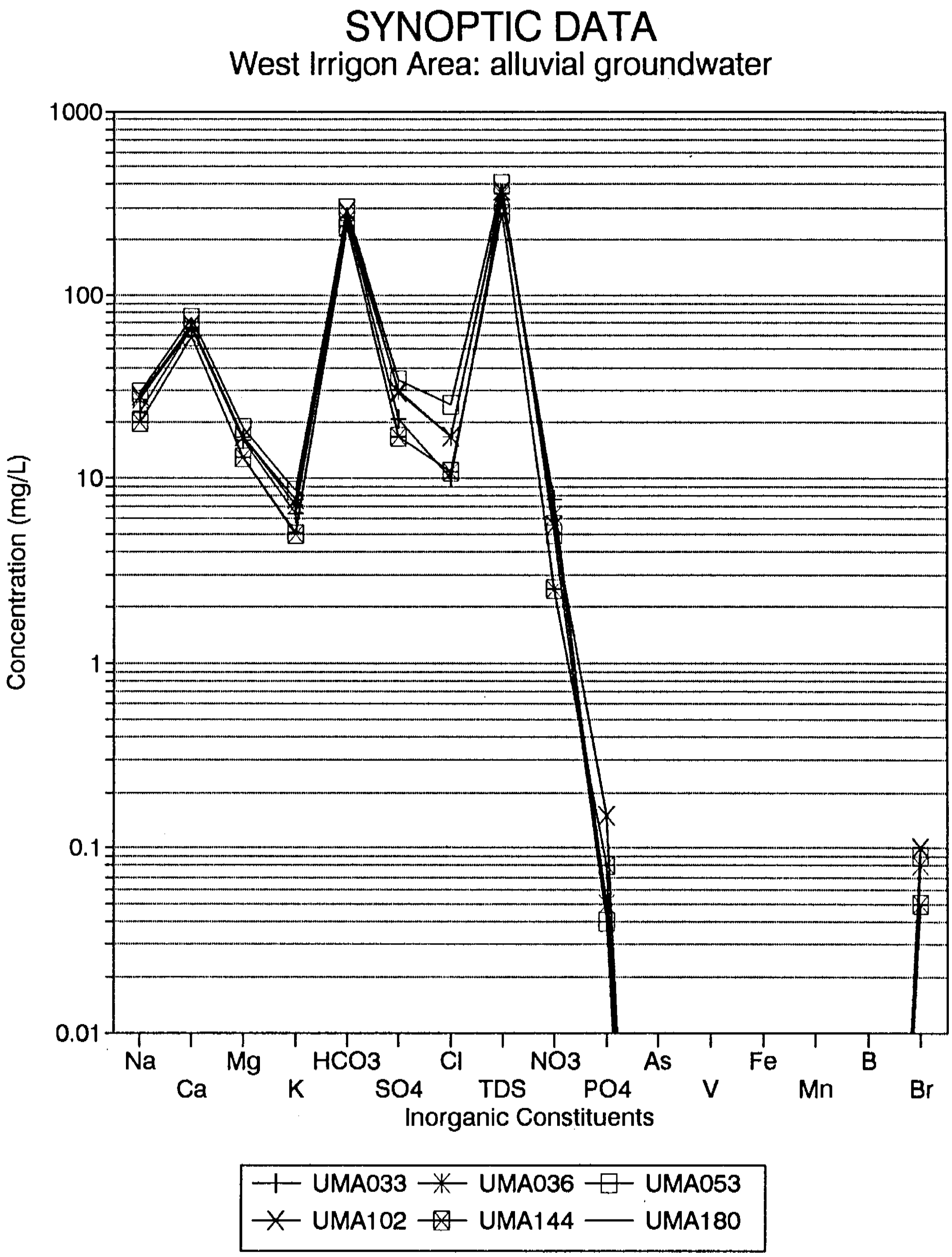


Figure 4.28 Schoeller Diagram of synoptic sampling data for alluvial groundwater collected in the Irrigon vicinity.

Note: The variation across the area is small.

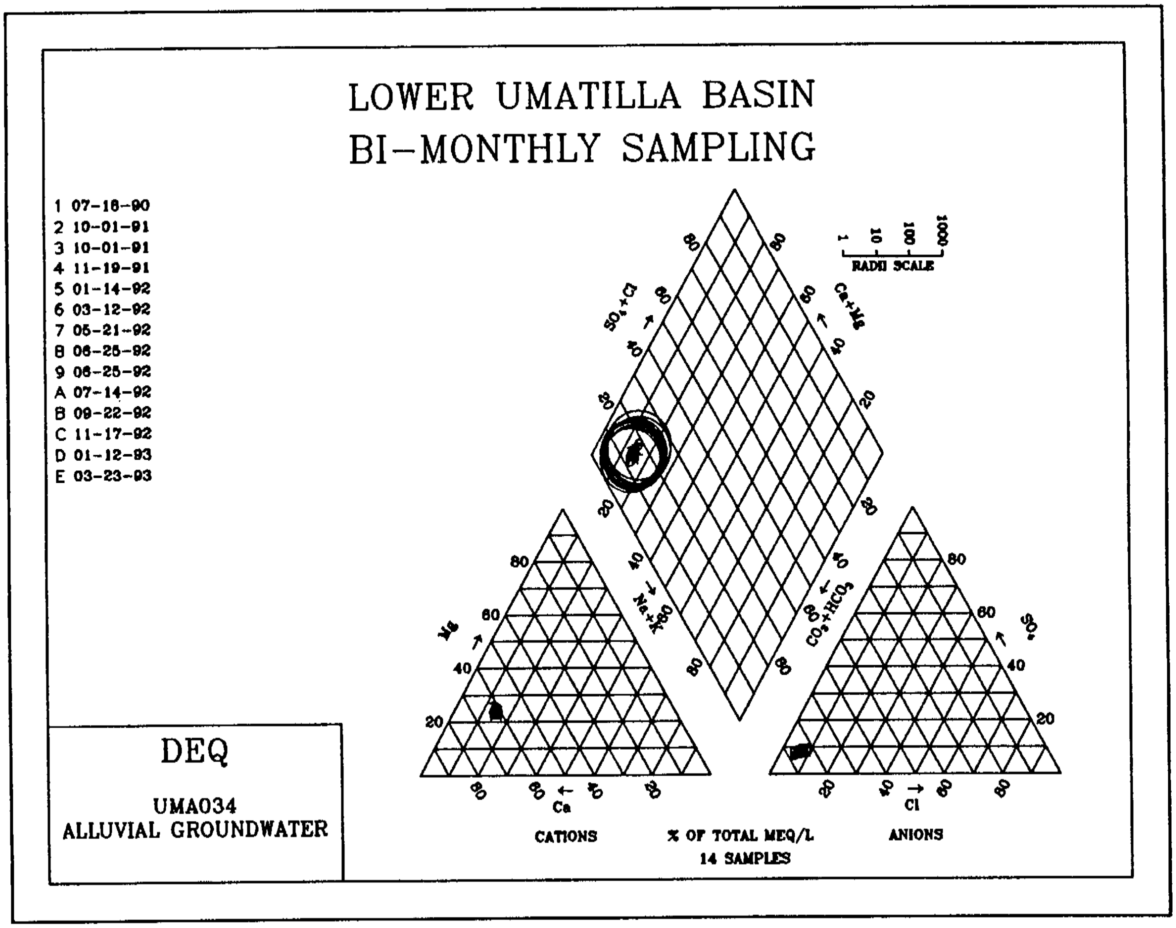


Figure 4.29 Piper Trilinear Graph of project bimonthly sampling data for alluvial groundwater collected at UMA 034 located west of Irrigon.

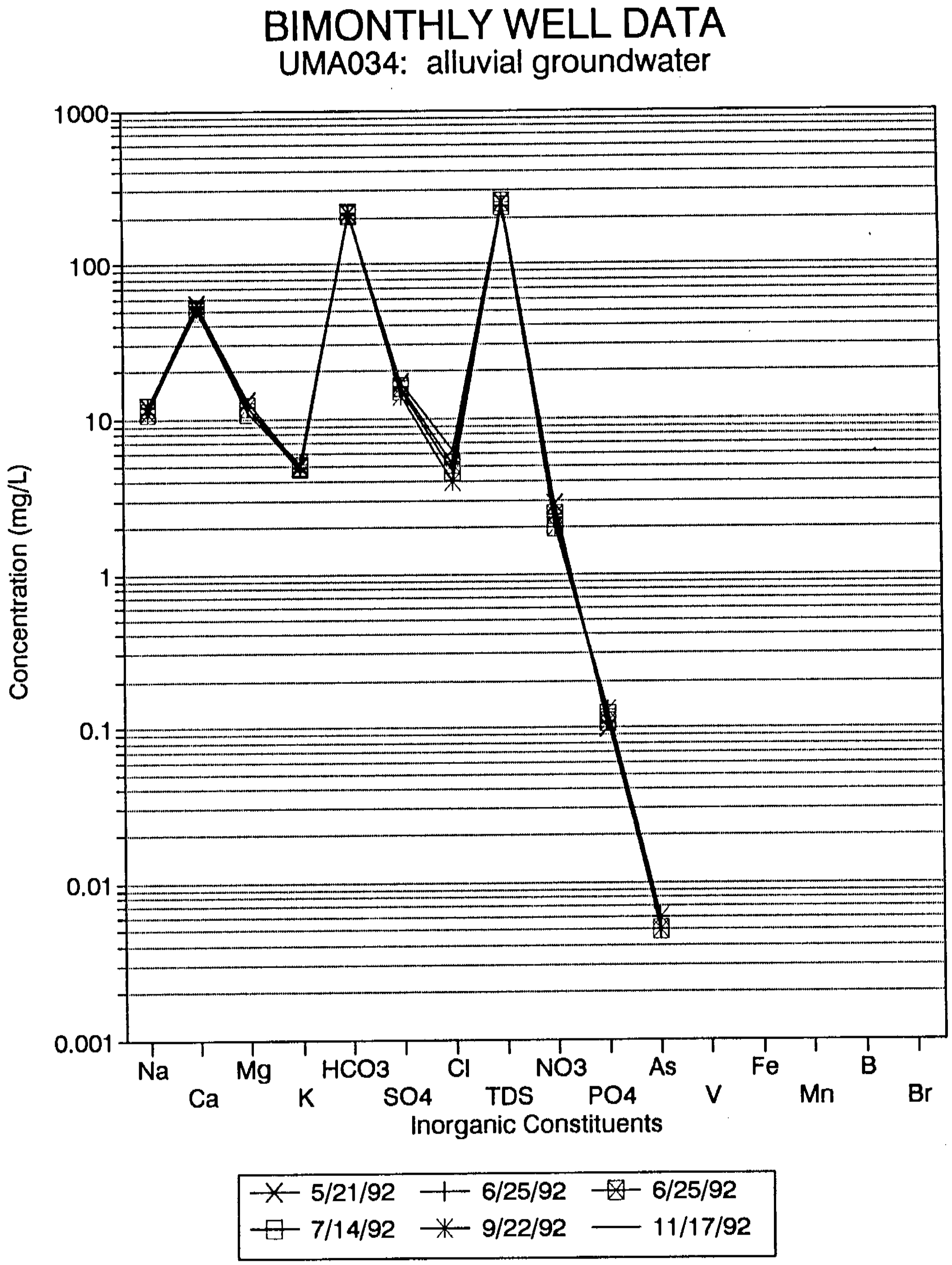


Figure 4.30 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 034 located west of Irrigon.

Note: The variation with time for this site is small.

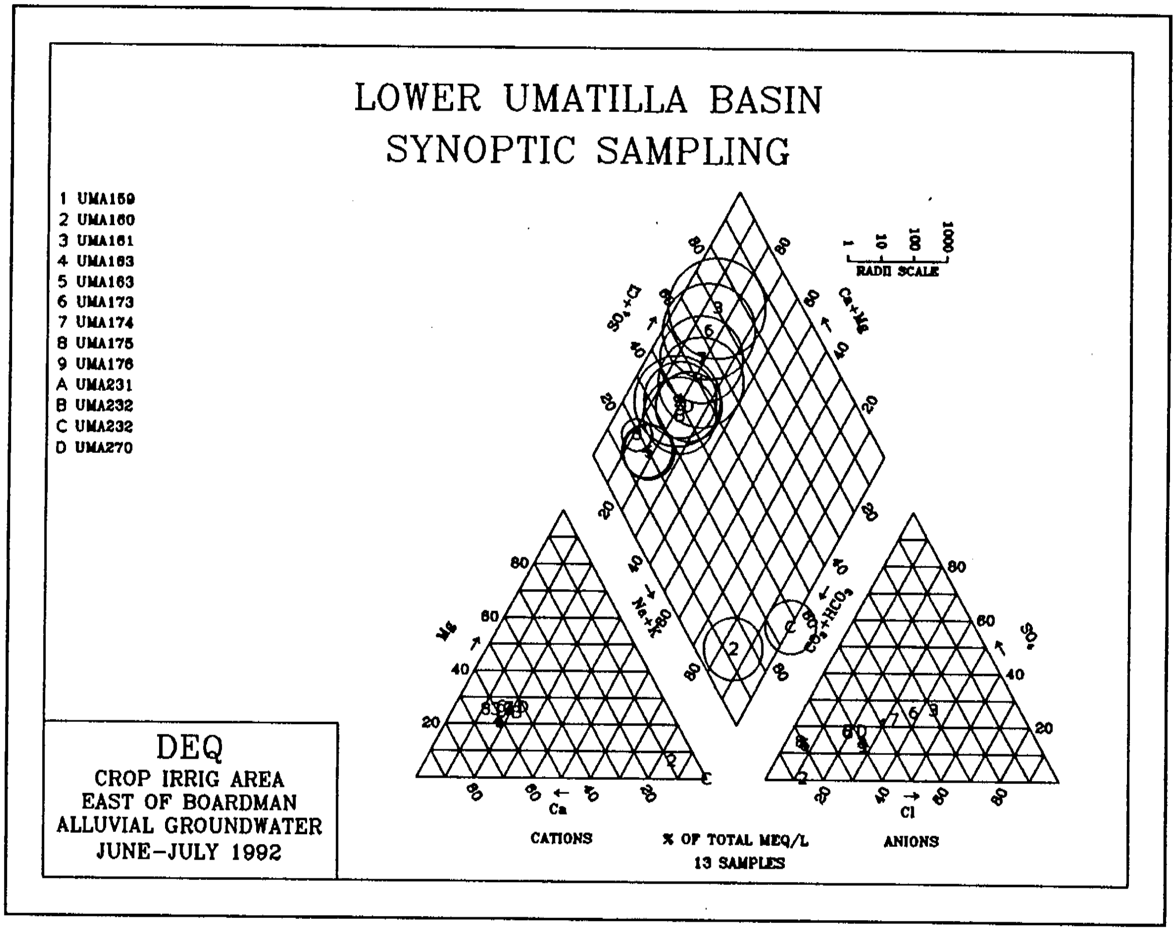


Figure 4.31 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the crop irrigation area between Boardman and Irrigon.

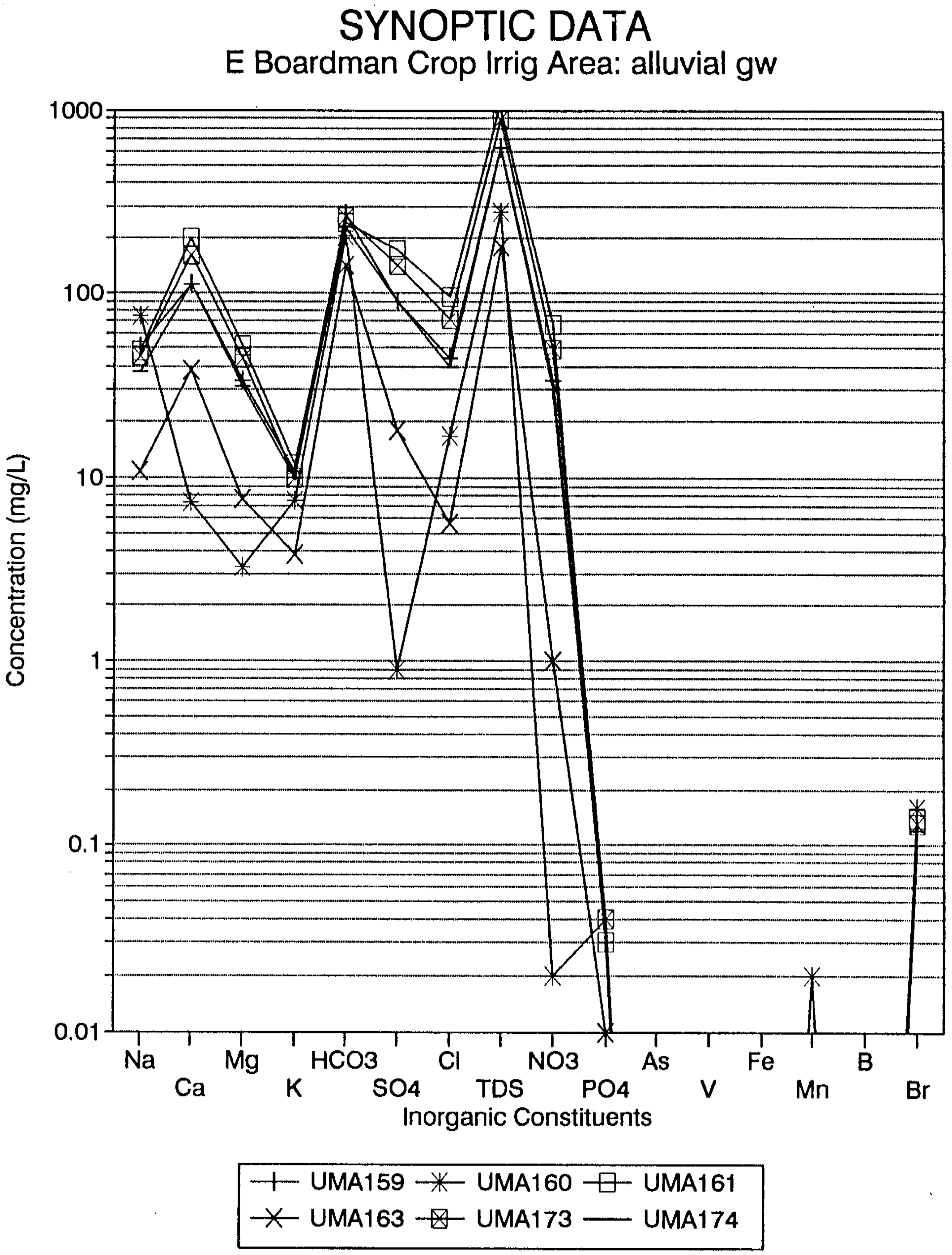


Figure 4.32 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected in the crop irrigation area between Boardman and Irrigon.

Note: The variation across this area is large, and there is significant differences in the compositional pattern.

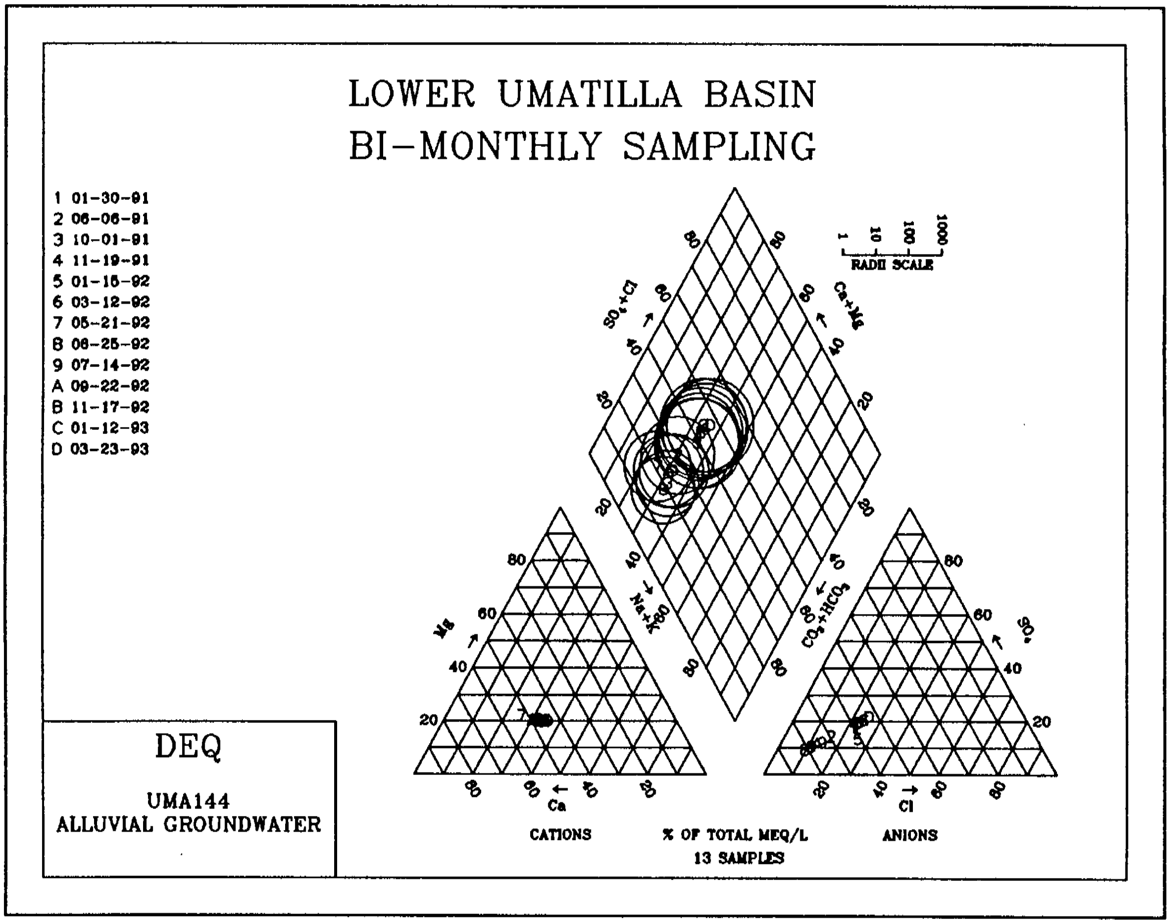


Figure 4.33 Piper Trilinear Graph of project bimonthly sampling data for alluvial groundwater collected at UMA 144 located south of Irrigon and adjacent to an irrigated field.

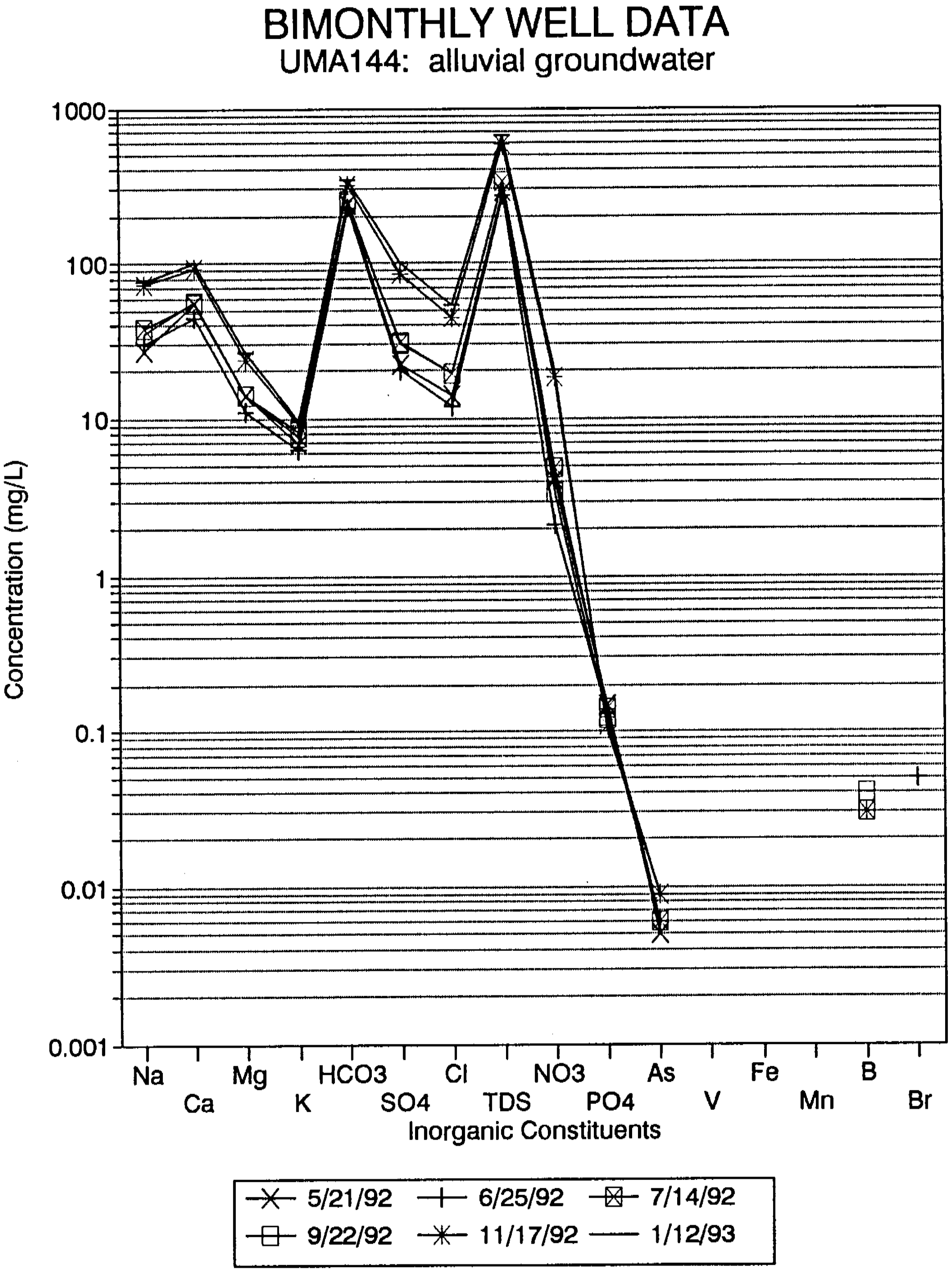


Figure 4.34 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 144 located south of Irrigon and adjacent to an irrigated field.

Note: The variation is larger, and suggests a bimodal pattern.

Piper trilinear graphs were used to distinguish the likely source of elevated nitrate in areas where the source may be questioned. Graphs of synoptic sampling data related to western, southern, and northeastern areas within the U.S. Army Umatilla Depot Activity were compared to graphs for data related to neighboring areas outside the Depot. Additionally, graphs of synoptic sampling at the Port of Morrow site east of Boardman were compared to graphs of related to neighboring irrigated crop agriculture. The results of those analyses follow.

Project synoptic groundwater sampling detected elevated nitrate concentrations at UMA 214 and UMA 204 located immediately inside the Depot's western boundary. Trilinear graphical analysis compared figures 4.35 and 4.31. That analysis indicates the alluvial groundwater chemistry at UMA 214 and UMA 204 is displaced away from the groundwater chemistry at nearby Depot sites having lower nitrate concentrations toward the groundwater chemistry at neighboring irrigated crop agriculture area sites having high nitrate concentrations. This indicates irrigated crop agriculture west of the Depot is the source of the elevated nitrate in groundwater at UMA 214 and UMA 204.

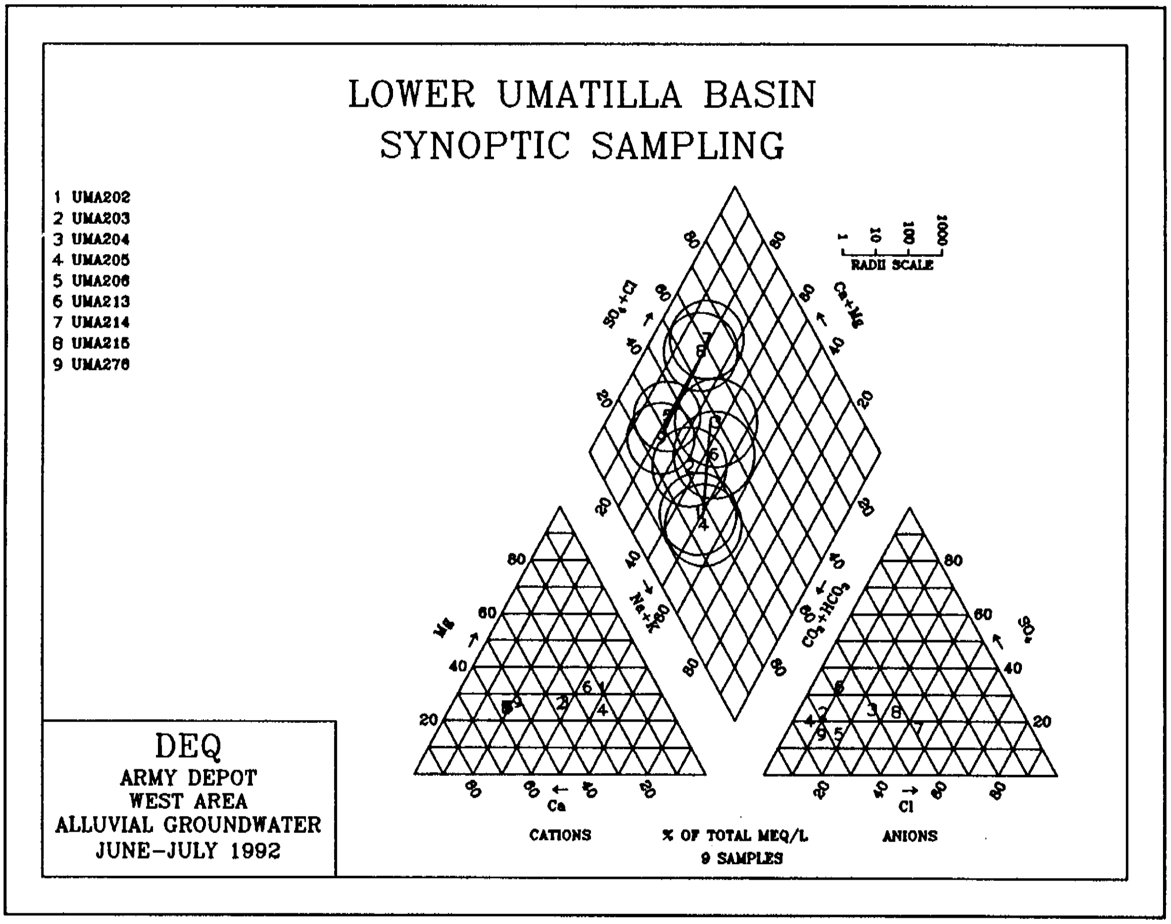


Figure 4.35 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the western portion (Ammunition Demolition Area) of the U.S. Army Umatilla Depot Activity.

Note: The two mixing lines are UMA 205 - UMA 202 - UMA 213 - UMA 204 and UMA 276 - UMA 206 - UMA 215 - UMA 214.

Project synoptic groundwater sampling detected elevated nitrate concentrations in alluvial groundwater samples from the U.S. Army Depot's active landfill area. The area is located downgradient from the Lamb-Weston food processing wastewater pond and land application area. Trilinear graphical analysis comparing figures 4.36 and 4.37 indicates groundwater at the landfill site is related but displaced from the groundwater chemistry at the Lamb-Weston site. The greatest displacement relates to landfill area samples having higher nitrate concentrations. The displacement combined with nitrate and TDS concentration distributions observed on Plates 4.2 and 4.4, TKN distribution analysis, and comparison of bromide versus potassium graphs (next section) suggests the Lamb-Weston land application activity is not responsible for the elevated nitrate observed at the Depot's active landfill. Instead, the active landfill or another Depot activity appears to be the nitrate source.

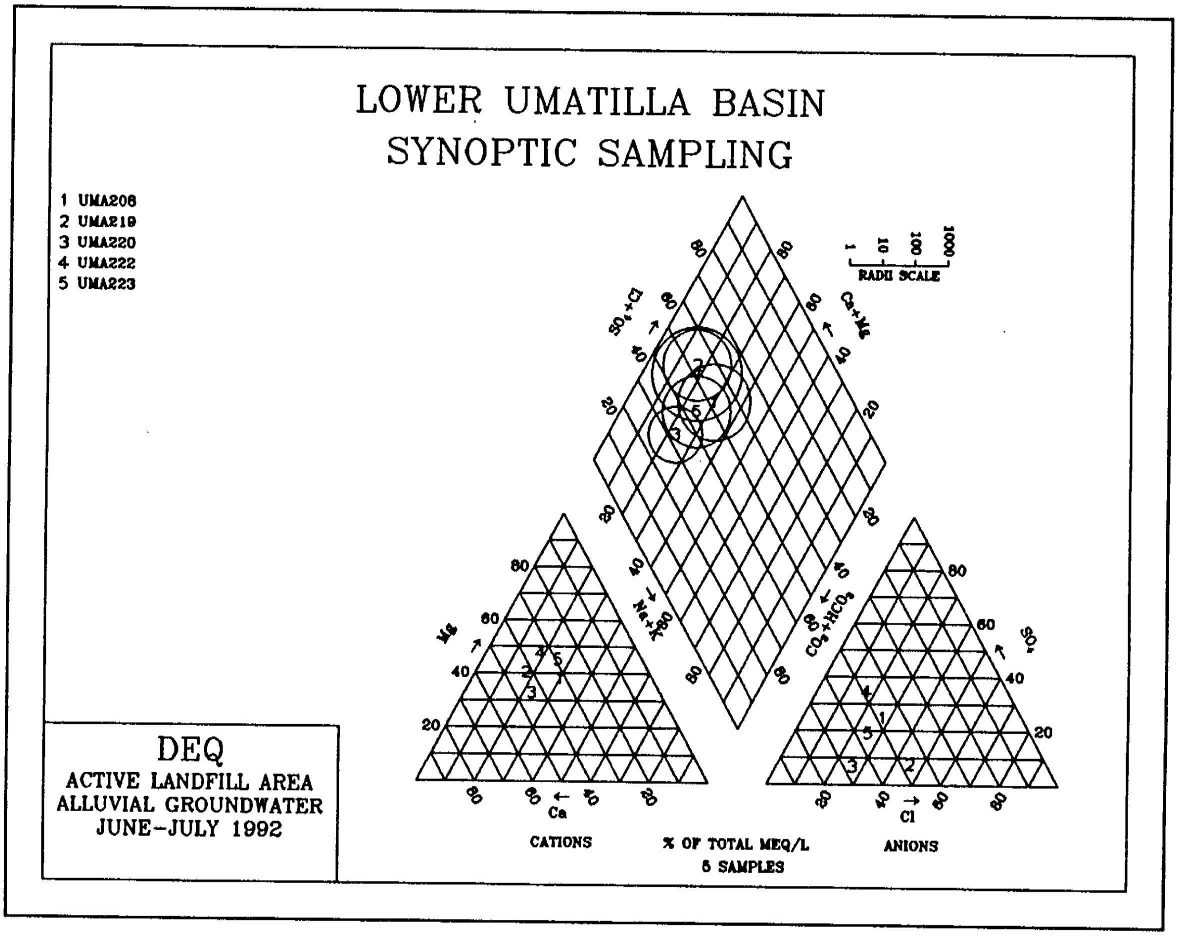


Figure 4.36 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in active landfill area (northeast portion) of the U.S. Army Umatilla Depot Activity.

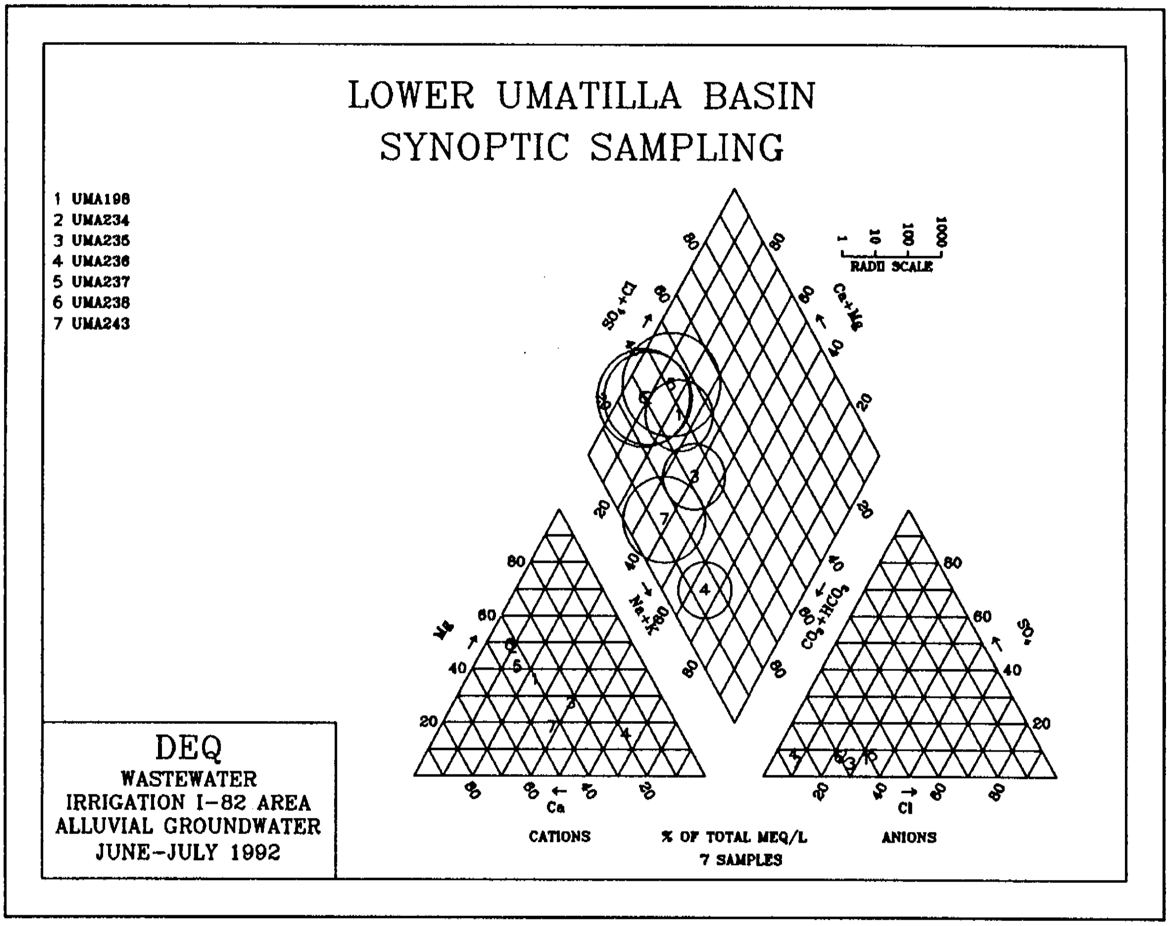


Figure 4.37 Piper Trilinear Graph of project synoptic sampling data for shallow unconfined and regional alluvial groundwater collected in the Lamb Weston Inc. wastewater land application area adjacent to the U.S. Army Depot's northeast corner.

Questions exist about the source of nitrate in the alluvial groundwater along the southern boundary of the U.S. Army Depot. Trilinear graphs were used to compare project synoptic sampling data related to southern U.S. Army Depot alluvial groundwater sites to data related to sites further inside the Depot and sites within the agricultural area south of the Depot (Figures 4.38, 4.39, 4.40 and 4.41). All the data graphed along a common mixing line indicating chemical continuity between groundwater south of the Depot to groundwater within the central portions of the Depot. Constituent graphical analysis suggesting an irrigation influence combined with hydrogeologic (flow toward the Depot) and nitrate distribution (higher concentrations south of the Depot) analyses indicate alluvial groundwater within the southern portion of the Depot is influenced by activity south of the Depot rather than vice versa.

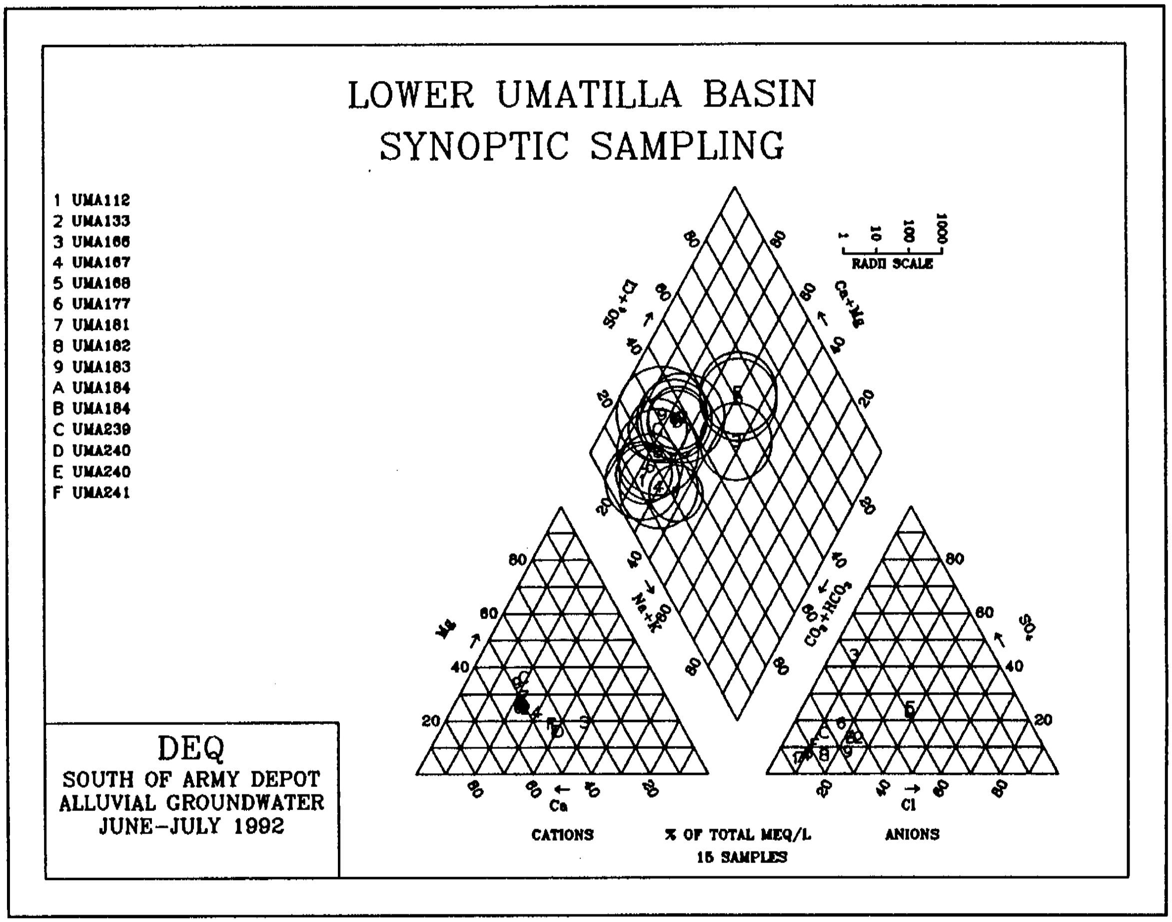


Figure 4.38 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected south of the U.S. Army Umatilla Depot Activity.

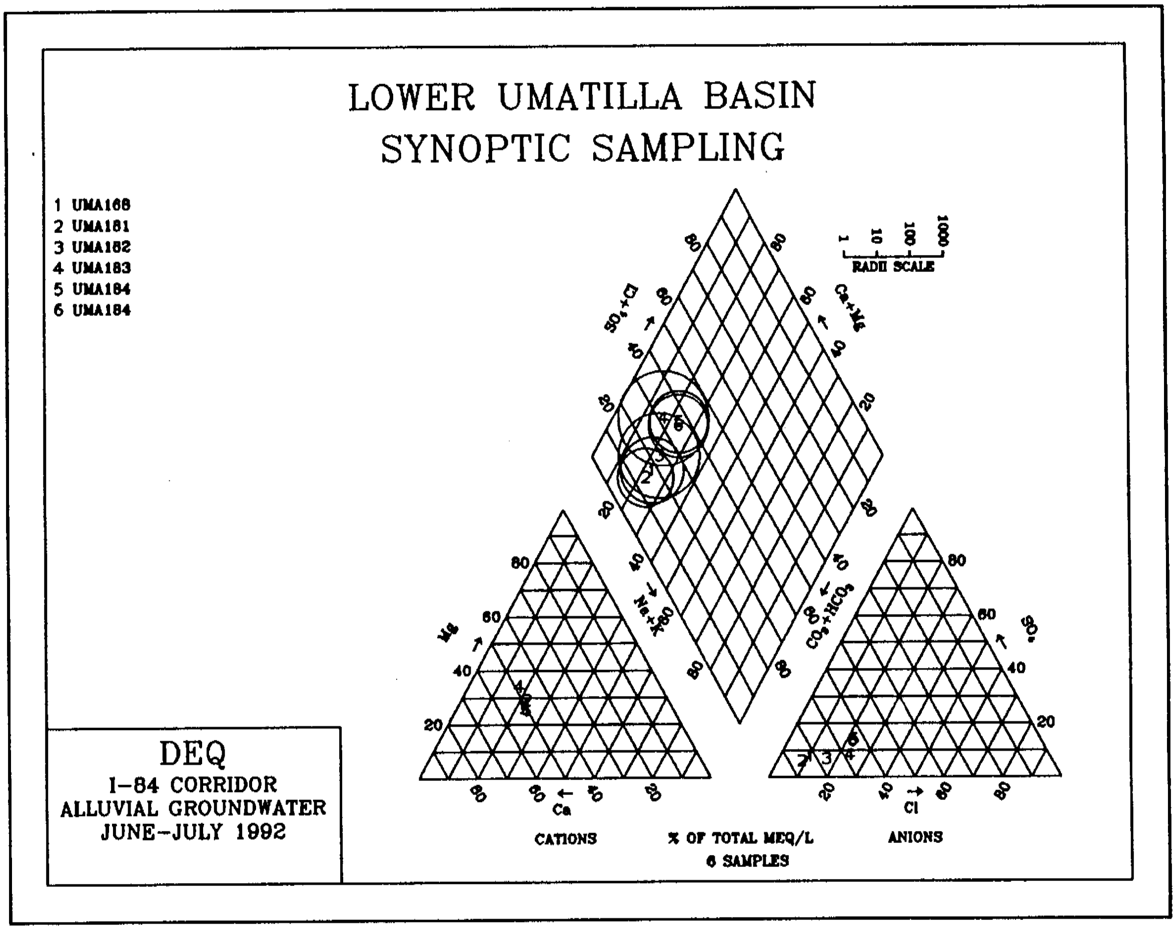


Figure 4.39 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected along Interstate 84 south of the U.S. Army Umatilla Depot Activity.

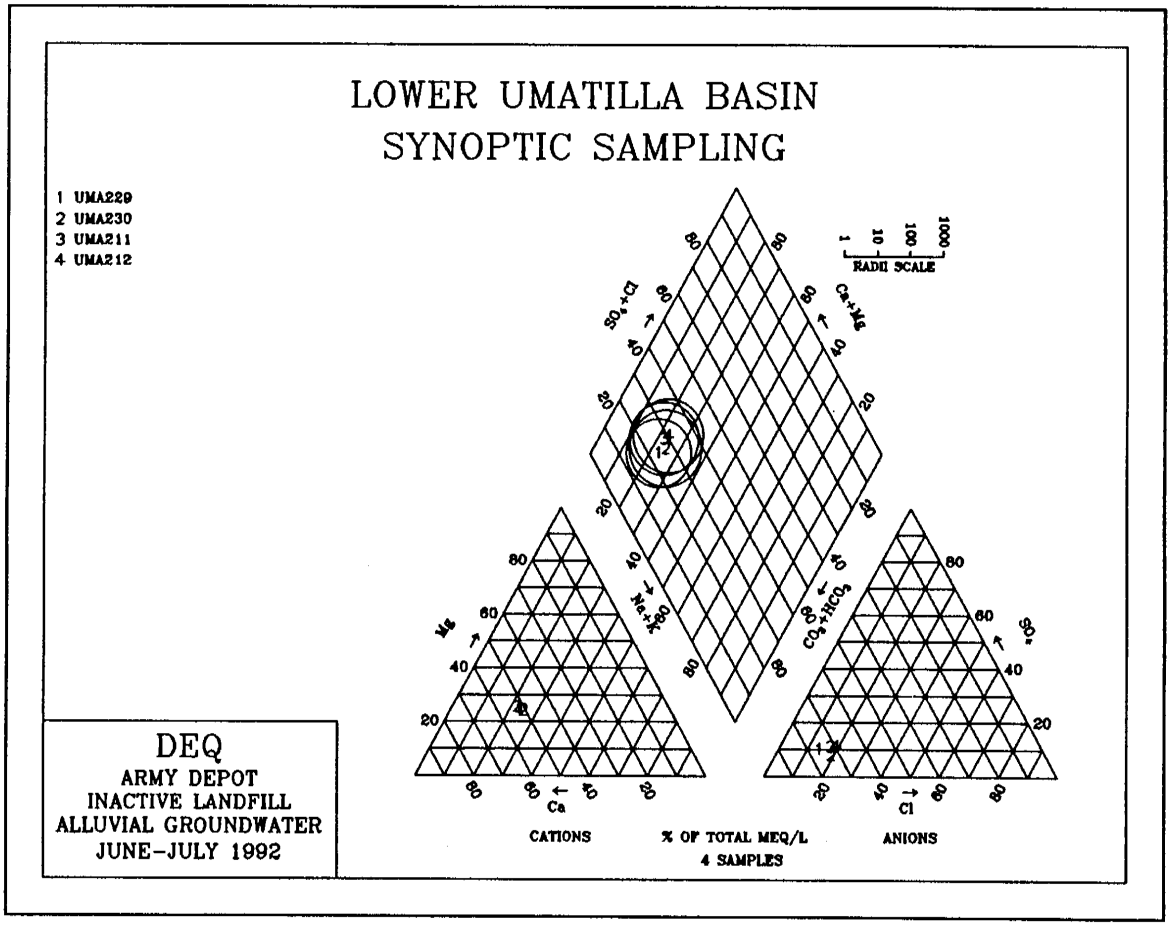


Figure 4.40 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the inactive landfill area (southern portion) of the U.S. Army Umatilla Depot Activity.

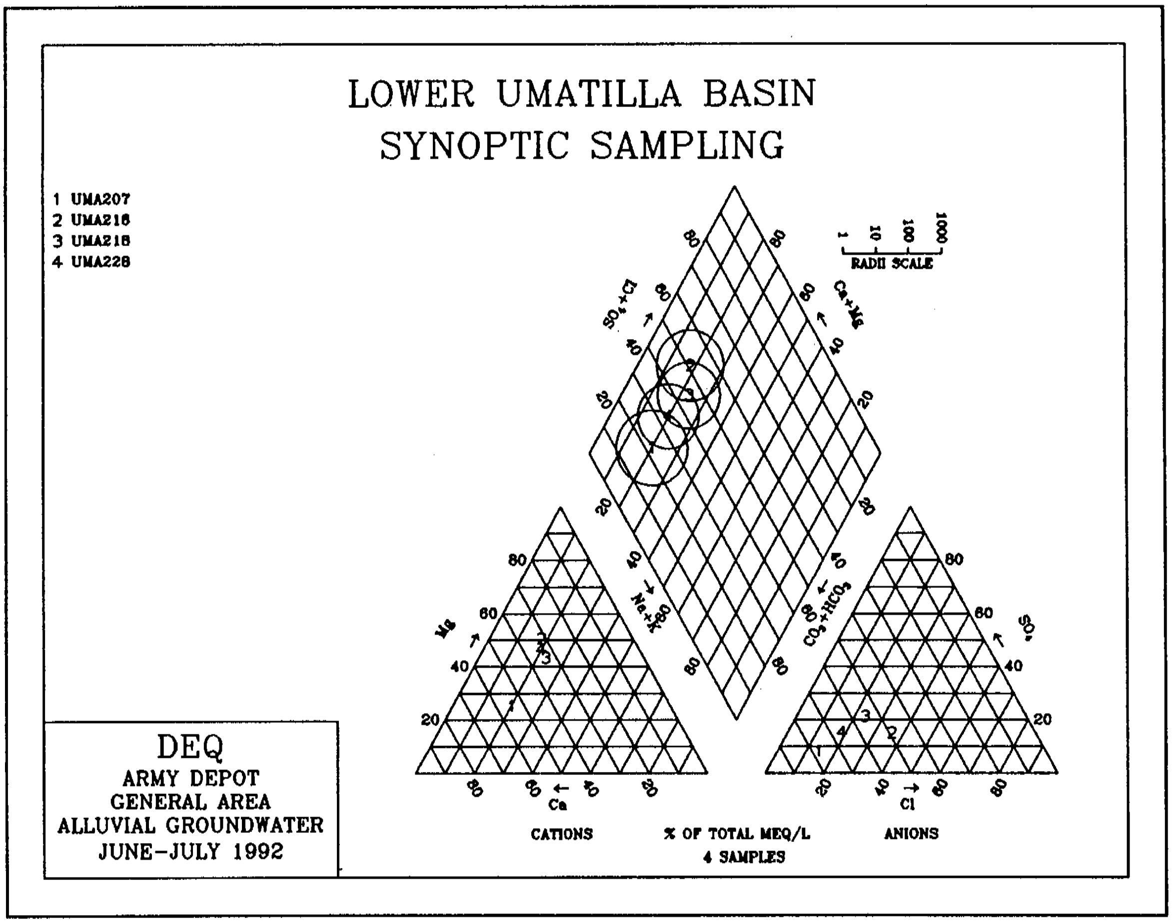


Figure 4.41 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected at general sites in the U.S. Army Umatilla Depot Activity.

Questions also exist about the source of nitrate within alluvial groundwater at the Port of Morrow land application area east of Boardman. Trilinear graphs (Figures 4.42 and 4.31) were used to compare project synoptic groundwater sampling data related to Port of Morrow and neighboring irrigated crop agriculture sites. All the data graphed along a common mixing line indicating chemical continuity between alluvial groundwater at the Port of Morrow and the irrigated crop agriculture areas. Constituent graphical analysis combined with hydrogeologic, nitrate distribution, Total Kjeldahl Nitrogen distribution, and nitrogen isotope analyses indicate wastewater land application or another organic nitrogen source is primarily responsible for the occurrence of nitrate in groundwater at the Port's land application site. Similarly, the analyses indicate irrigated crop agriculture is primarily responsible for the occurrence of elevated nitrate within the irrigated crop areas.

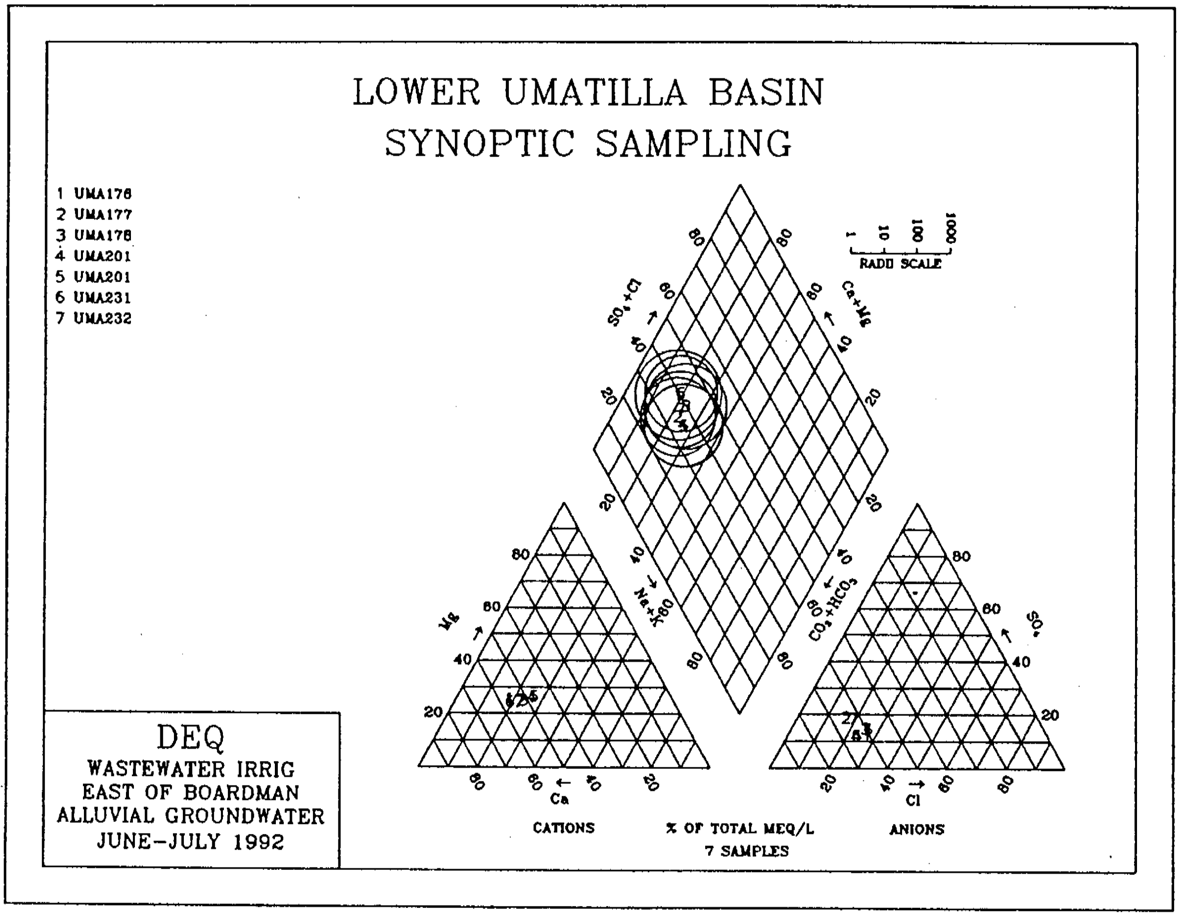


Figure 4.42 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the Port of Morrow wastewater land application area east of Boardman.

Graphical Analyses: Constituent Versus Constituent

Constituent versus constituent graphs were used to distinguish nitrate sources. The analysis primarily used synoptic sampling data. Graphs reviewed included chloride versus potassium, bromide versus potassium, and chloride/bromide versus chloride. Generally, the analyses indicate a variety of land uses influence the groundwater chemistry in the Boardman to Irrigon area (see Appendix 4H). Noteworthy results include the following:

- Alluvial groundwater chemistry data for the U.S. Army Depot active landfill area and the neighboring Lamb-Weston Inc. wastewater land application area graph in separate but adjacent fields on some constituent versus constituent graphs as shown by comparing figures 4.43 and 4.44. This observation combined with nitrate and TDS concentration distributions observed in Plates 4.2 and 4.4, TKN distribution analysis, and Piper Trilinear analysis suggests the active landfill or another Depot activity is responsible for elevated nitrate at the landfill instead of Lamb-Weston.

- Irrigation by crop agriculture and/or by the food processing industry influencing groundwater chemistry was observed for the south Boardman area, Port of Morrow wastewater land application area, areas south, north, and west of the U.S. Army Depot, and the Lamb-Weston wastewater land application area. Other analyses were necessary to distinguish between general food processing wastewater versus irrigated crop agriculture influences.

- Analyses suggest animal operation activity locally influences groundwater in the south Boardman area and south of the U.S. Army Depot.

- The analyses also suggest some animal waste influence upon groundwater between Irrigon and the Umatilla River. However, project investigators have not observed or confirmed any animal waste use in the area. A portion of the U.S Army depot is reserved for grazing livestock (Mahannah and others, 1993).

- Analysis suggest septic systems generally influence the groundwater chemistry in the Irrigon vicinity, and locally influence the groundwater chemistry in other areas.

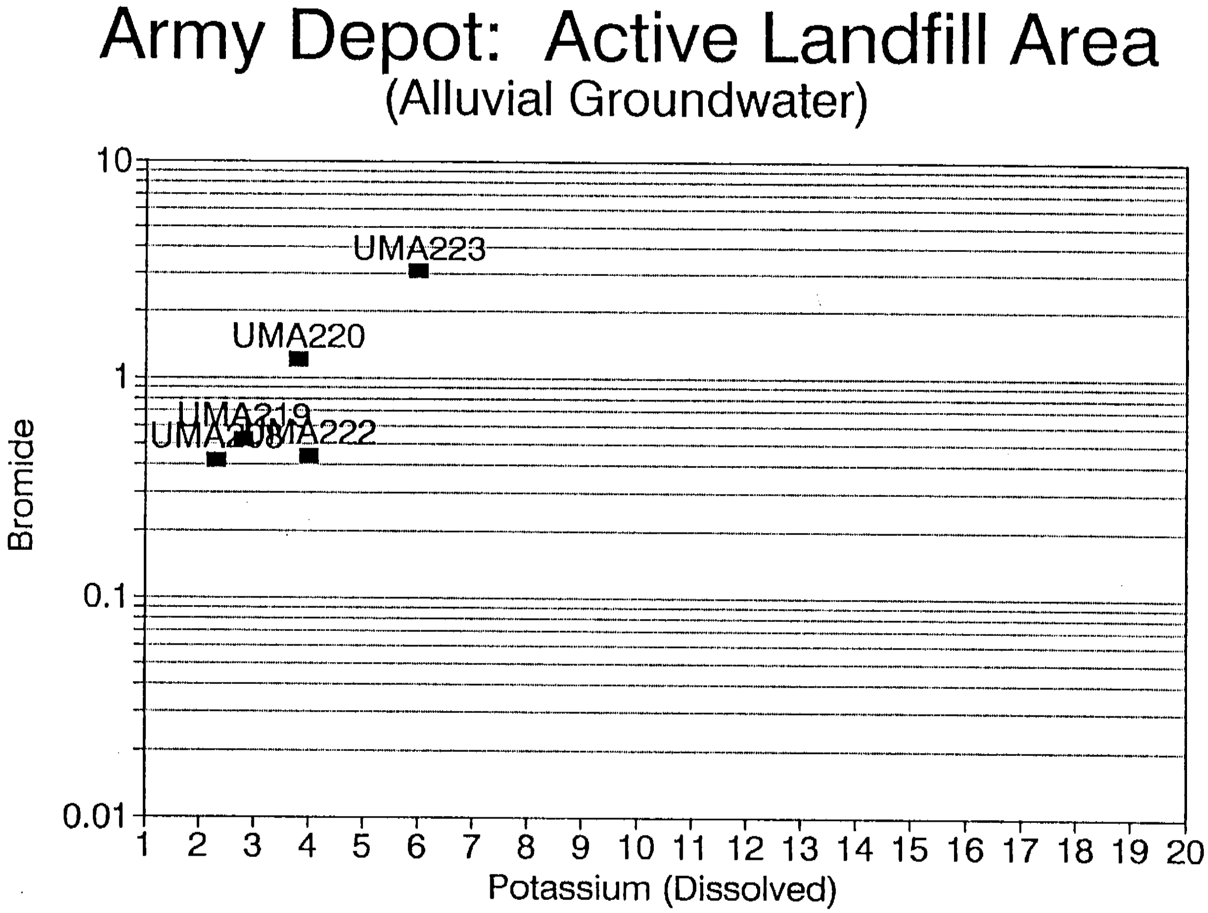


Figure 4.43 Bromide versus potassium graph of project synoptic sampling data for alluvial groundwater collected in the active landfill area (northeast portion) of the U.S. Army Umatilla Depot Activity.

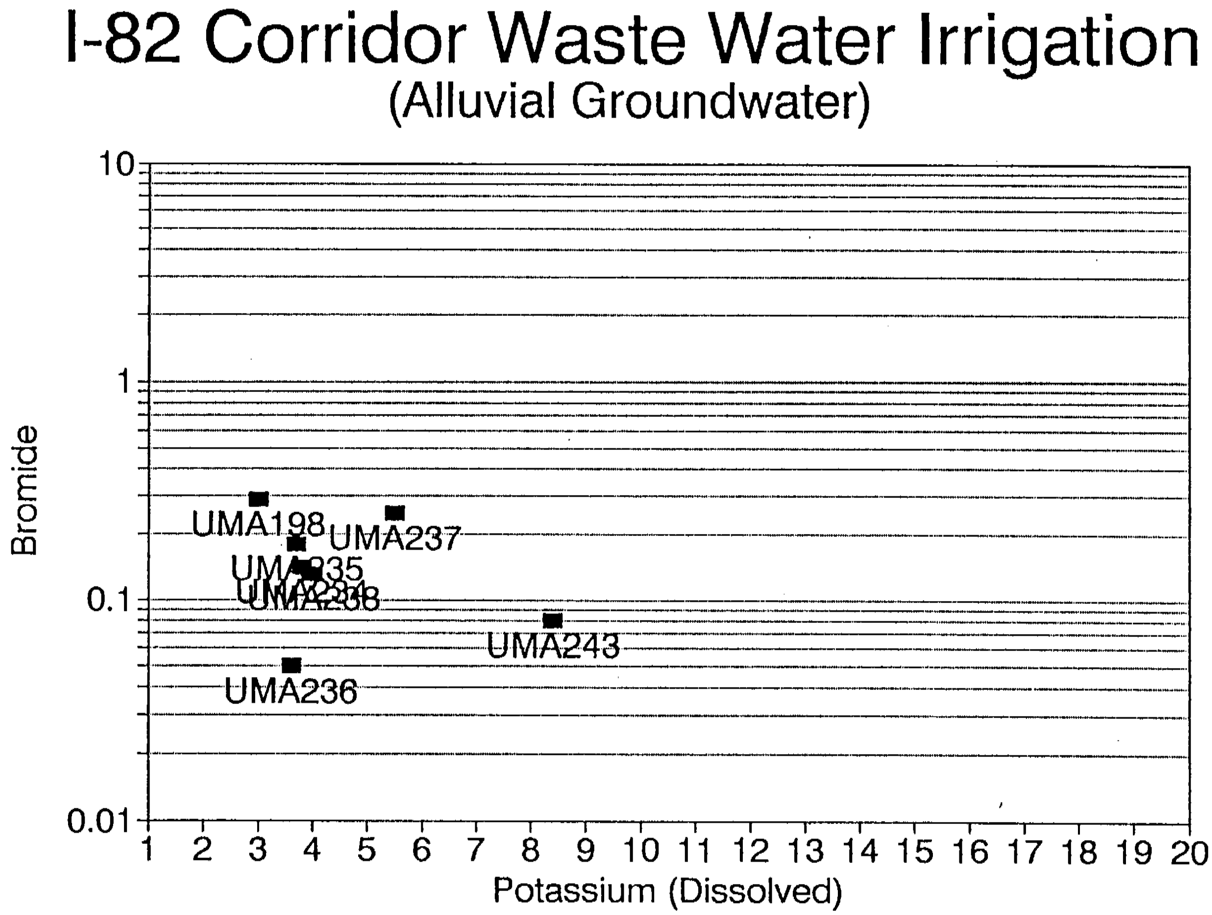


Figure 4.44 Bromide versus potassium graph of project synoptic sampling data for shallow unconfined and regional alluvial groundwater collected in the Lamb Weston Inc. wastewater land application area adjacent to the U.S. Army Depot's northeast corner.

Groundwater Flow Path Analysis

Project analysis included analyzing the groundwater chemistry along a groundwater flow path passing through the U.S. Army Umatilla Depot Activity. The concentration of nitrate and other constituents varies along that groundwater flow path. Figure 4.45 shows the variation of calcium and chloride. The nitrate variations correlated better with calcium and chloride than sodium and sulfate. The variations suggest more than one nitrate and total dissolved solids source influences groundwater along the flow path.

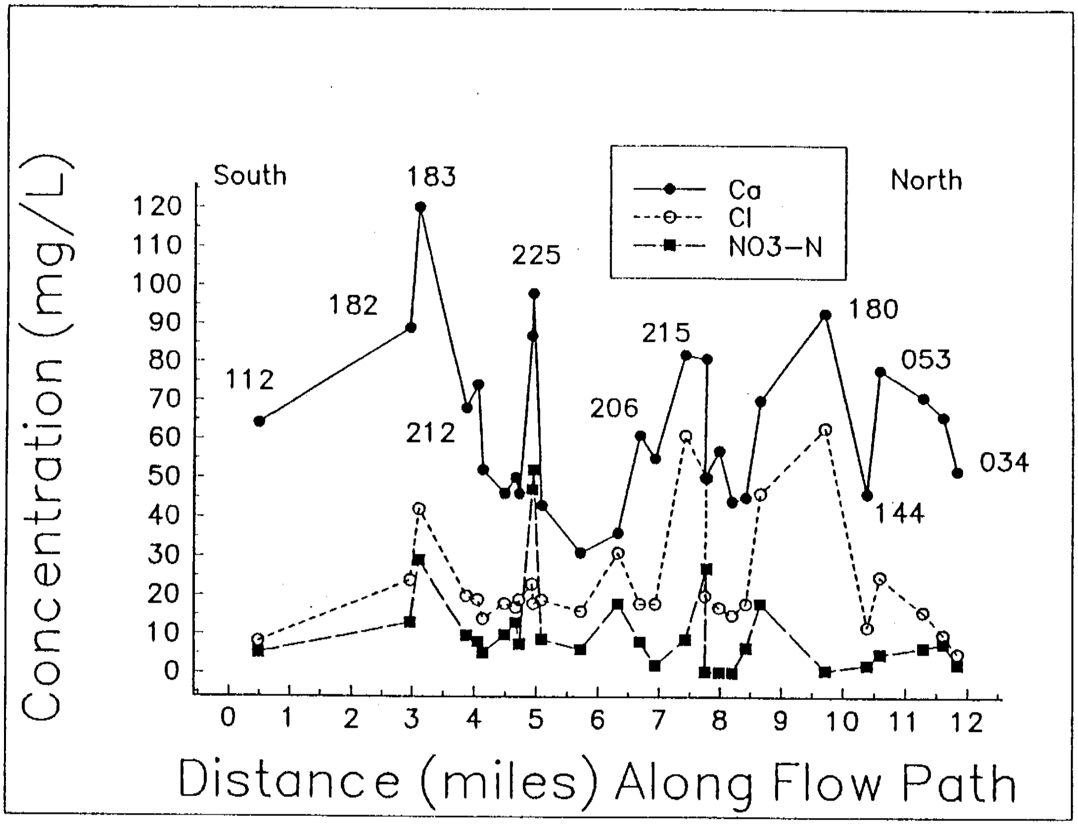


Figure 4.45 Calcium, chloride, and nitrate-nitrogen variation along a composite groundwater flow path passing through the U.S. Army Umatilla Depot Activity.

Note: The flow path begins at UMA 112 and ends at UMA 034. It crosses Interstate 84 between UMA 183 and UMA 212.

Note: Numbers identifying selected sites is shown for reference.

Groundwater Chemistry Computer Modeling

The NETPATH groundwater chemistry computer model was used to evaluate the source of increasing nitrate concentrations in alluvial groundwater within the vicinity of UMA 097 and UMA 096. The sites are located between Irrigon and the Umatilla River along Highway 730. Well UMA 097 is located close to the West Extension Canal. Well UMA 096 is located less than 0.5 miles east of UMA 097 and north of Highway 730.

Project sampling detected nitrate concentrations increasing from 19 mg/L at UMA 097 to 31 mg/L at UMA 096. Crop Irrigation and food processing wastewater land application occur upgradient of both sites. Rural residential homes with septic systems are located between UMA 096 and the West Extension Canal. Constituent versus constituent graphical analyses suggest both septic systems and food processing wastewater influence the groundwater chemistry at UMA 097 and UMA 096.

NETPATH was used to better identify influences upon the groundwater chemistry at UMA 096. The mixing of groundwater moving down gradient from the Lamb-Weston land application site with local groundwater as well as water rock reactions was evaluated. The modeling results indicate mixed sources influence the groundwater chemistry in the area:

UMA 096 = [7.10 percent food processing area groundwater (UMA 258)]
+ [92.90 percent septic system area groundwater (UMA 053)]
+ [17.95 basalt glass] + [0.22 gypsum]
- [1.79 cation exchange (sodium for calcium)]
- [1.66 illite] - [2.09 magnesium calcite]

The model yielded similar mixing proportions when other end members and target wells were used. The mixing proportions were independently evaluated by comparing the predicted barium and bromide concentrations for UMA 096 to observed concentrations. Concentrations predicted for barium and bromide were 0.10 mg/L and 0.06 mg/L, respectively agreed with observed barium and bromide concentrations observed in UMA 096 groundwater.

Nitrogen Isotopic Analyses

The Stable Nitrogen Isotope Analysis section presents the nitrogen isotopic data and data analysis discussion.

Analysis of nitrogen isotopic data related to the Boardman to west Umatilla area found the following:

- A commercial fertilizer influence is clearly evident from the delta ^{15}N values for groundwater sampled from three irrigation wells located north of Highway 730 between Boardman and Irrigon. The delta ^{15}N values remained constant over time despite nitrate+nitrite-nitrogen concentration fluctuations. That indicates the nitrogen source remains uniform and hydraulic flushing of nitrate is very slow. The delta ^{15}N values for the eastern wells are higher. That indicates an additional nitrate source influence is possible.

- The influence of animal waste appears evident from the delta ^{15}N values related to groundwater sampled from well UMA 133. This well is located along County Line Road approximately 2 miles south of Interstate 84. Historic and current animal waste sources are located nearby.

- Delta ^{15}N values related to groundwater sampled from wells near the U.S. Army Umatilla Depot Activity explosive washout lagoons indicates most of the nitrate in the groundwater came from explosive contaminants.

Boardman to West Umatilla Area Summary and Conclusions

This project used a variety of techniques to analyze the Boardman to west Umatilla area groundwater chemistry data. The data came from project sampling, or it was reported or provided by local facilities. The analyses led project investigators to the following observations and interpretations:

- Groundwater nitrate concentrations detected by this project or reported by local facilities range from non-detect to more than 100 mg/L.

- Groundwater with nitrate concentrations exceeding 10 mg/L occurs in large areas located:
    - south of Boardman,
    - between Boardman and Irrigon,
    - between Irrigon and the Umatilla River,
    - the northeast corner area of the U.S. Army Umatilla Depot Activity,
    - the Depot's washout lagoons area, and
    - south of the Depot.

- Elevated nitrate concentrations in groundwater south of Boardman appear to come primarily from irrigation activity with some contribution from animal operations and septic systems.

- Port of Morrow and Lamb-Weston wastewater land application activity east of Boardman and adjacent to the U.S. Army Depot, respectively, appear responsible for the elevated nitrate concentrations at their respective sites.

- Irrigated agriculture appears responsible for elevated nitrate concentrations detected in groundwater between the Port of Morrow and Irrigon and the elevated nitrate concentrations detected along the U.S. Army Depot's western boundary.

- Irrigation activity and septic systems appear responsible for the elevated nitrate concentrations detected in groundwater north of the U.S. Army Depot. Analyses also suggest an animal waste influence. However, this investigation has no information to confirm or refute usage of animal waste in this area.

- Elevated groundwater nitrate concentrations detected in the U.S. Army Depot active landfill area appears derived from a Depot source rather than from the upgradient Lamb-Weston wastewater land application site. Dried domestic sludge disposed at the landfill is a potential source.

- Past activity at the U.S. Army Depot washout lagoons appears responsible for elevated groundwater nitrate concentrations detected in the central part of the Depot. Nitrate movement away from the lagoons is less than four miles over three to four decades if the apparent plume on Plate 4.2 is real. Otherwise, nitrate has moved less than 0.05 mile over the same period.

    - Irrigated agriculture and animal operations appear primarily responsible for the elevated nitrate concentrations detected in groundwater south of the U.S. Army Depot.

- Groundwater nitrate concentrations below 10 mg/L were detected in samples from sites west of Irrigon along the Columbia River, south of Irrigon through the western portion of the U.S. Army Depot, and the Lost Lake vicinity.

- Total dissolved solids concentrations exceeded the 500 mg/L secondary (aesthetic) drinking water standard in groundwater:
    - south of Boardman,
    - between Boardman and Irrigon,
    - the east Irrigon area,
    - the U.S. Army Depot active landfill area,
    - the immediate vicinity of the Depot's explosive washout lagoons, and
    - south of the Depot.

- Sodium concentrations in the Boardman to west Umatilla area groundwater commonly exceed the 20 mg/L limit recommended for persons on a physician prescribed sodium restricted diet.

- Arsenic concentrations exceeded the drinking water standard of 0.050 mg/L in groundwater at several U.S. Army Depot sites and at a Lamb-Weston wastewater land application area site.

- Groundwater samples with relatively high (0.10 mg/L or greater) maximum total phosphate concentrations came from wells located within the Port of Morrow wastewater land application area east of Boardman, the Irrigon area, most of the U.S. Army Depot, south of the Depot, and the Lamb-Weston land application area.

- Samples with relatively low total phosphate concentrations often came from within or near irrigated crop agriculture areas.

- Agricultural chemicals have been sporadically detected in Boardman to west Umatilla area groundwater samples. Atrazine was detected in groundwater sampled south of Boardman and between the Port of Morrow and Irrigon. Dacthal acid was detected in groundwater sampled south of the U.S. Army Depot.

- Nitrate movement through the area appears slow. Decades may be required for nitrate to move through the local alluvial groundwater system.

- Explosives are present in groundwater at some U.S. Army Depot sites.

Butter Creek to City of Umatilla Area

The Butter Creek to City of Umatilla area includes the west half of Range 28 East and Townships 3, 4, and 5 North. Groundwater converges in the area and flows north toward the Columbia River. Historic and current land uses in the area include:

- City of Umatilla and western Hermiston municipal areas;

- City of Umatilla sewage treatment facility;

- City of Hermiston sewage treatment facility and land application area;

- Land application of City of Portland and Unified Sewerage Agency (Washington County) sludge;

- Unsewered rural residential homes;

- Multiple food processing plants, wastewater ponds, and land application sites;

- Confined animal operations with some wastewater ponds and land application sites;

- Irrigated crop agriculture.

Analysis of project and facility data is presented in this section. Lamb-Weston, Inc. and the J.R. Simplot Company regularly collect groundwater samples from facility wells and report the results to the Oregon Department of Environmental Quality. Project groundwater sampling in the area includes reconnaissance, bimonthly, and synoptic sampling.

Map and Data Set Observations: Nitrate

Table 4.23 and Plates 4.2 and 4.3 show the nitrate+nitrite-nitrogen concentration range and distribution in the Butter Creek to City of Umatilla area. Table 4.23 shows local concentration ranges detected by this project or reported by local facilities. Plate 4.3 shows the distribution of maximum concentrations this project detected in alluvial and nearby basalt groundwater samples. Plate 4.2 shows the June-July 1992 concentration distribution in regional alluvial groundwater based upon project synoptic sampling. Nitrate+nitrite-nitrogen concentrations detected in shallow unconfined alluvial groundwater samples and basalt groundwater samples are printed next to each sampling location.

The shape and extent of each concentration range contoured on Plate 4.2 was derived by linear interpolation between data locations. Data control was sparse in Township 5 North. This should be considered to avoid misinterpreting the source and movement of nitrate in that area.

Table 4.23 Nitrate concentration ranges detected in alluvial and basalt groundwater sampled in the Butter Creek to City of Umatilla area.

Area	Groundwater Source	Dominant Land Uses (Historic and Current)	Nitrate-N (mg/L)	
			Maximum	Minimum
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Project Sampling)	Alluvial	irrigated crop agriculture food processing wastewater land application municipal sludge land application in area pasture	2.80	<0.02
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Lamb-Weston Sampling)	Alluvial	irrigated crop agriculture food processing wastewater land application municipal sludge land application in area pasture	8.00	5.00
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Project Sampling)	Alluvial (Shallow Unconfined)	irrigated crop agriculture food processing wastewater land application municipal sludge land application in area pasture	11.00	2.80
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Lamb-Weston and J.R. Simplot Company Sampling)	Alluvial (Shallow Unconfined)	irrigated crop agriculture food processing wastewater land application municipal sludge land application in area pasture	16.00	1.10
Butter Creek Highway Area: South (south of Interstate 84 and east of Highway 207) (Project Sampling)	Alluvial	food processing wastewater land application confined animal operation	26.00	13.00
Butter Creek Highway Area: South (south of Interstate 84 and east of Highway 207) (J.R. Simplot Company Sampling)	Alluvial	food processing wastewater land application confined animal operation	26.50	0.40
Butter Creek - Umatilla River Confluence Area (Project Sampling)	Alluvial	irrigated crop agriculture food processing wastewater land application confined animal operations nearby	23.00	0.72
Butter Creek - Umatilla River Confluence Area (J.R. Simplot Company Sampling)	Alluvial	irrigated crop agriculture food processing wastewater land application confined animal operations nearby	10.90	<0.04

Butter Creek - Umatilla River Confluence Area (Project sampling)	Alluvial (Shallow Unconfined)	irrigated crop agriculture food processing wastewater land application confined animal operations nearby	21.00	0.03
Butter Creek - Umatilla River Confluence Area (J.R. Simplot Company Sampling)	Alluvial (Shallow Unconfined)	irrigated crop agriculture food processing wastewater land application confined animal operations nearby	100.00	<0.05
Butter Creek Highway Area: North (north of Interstate 84 and east of Umatilla River) (Project Sampling)	Alluvial	confined animal operation irrigated crop agriculture rural residential homes Hermiston STP and land application at north	25.00	0.75
Butter Creek Highway Area: North (north of Interstate 84 and west of Umatilla River) (Project Sampling)	Alluvial	irrigated crop agriculture Hermiston STP land application	14.00	2.00
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial	wastewater land application Depot's active landfill nearby	22.00	0.18
Lamb-Weston, Inc. Land Application Area (Adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial (Shallow Unconfined)	wastewater land application Depot's active landfill nearby	36.00	21.00
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Lamb-Weston, Inc. Sampling)	Alluvial	wastewater land application Depot's active landfill nearby	74.00	0.18
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Lamb-Weston, Inc. Sampling)	Alluvial (Shallow Unconfined)	wastewater land application Depot's active landfill nearby	65.00	<1.0
City of Umatilla Area (Project Sampling)	Alluvial	municipal Umatilla sewage treatment facility	4.20	1.70

Note: Project sampling reports nitrate concentrations as nitrate+nitrite-nitrogen.

Sources:
Project Sampling
DEQ Water Quality File 81590
DEQ Water Quality File 48780
Barlow, Urban, and Scott, 1992
EMCON Northwest, Inc., 1992
Hemphill, 1992

Food processing facility sampling of shallow unconfined alluvial groundwater west of Highway 207 and south of Interstate 84 has occasionally detected nitrate-nitrogen concentrations exceeding 10 mg/L (see Table 4.23). They also report Total Kjeldahl Nitrogen (TKN) concentrations generally less than 3 mg/L (DEQ Water Quality Files 81590 and 48780, Barlow and others, 1992, EMCON Northwest, Inc., 1992, Hemphill, 1992). This TKN presence indicates a local organic nitrogen source influences the shallow unconfined groundwater. Determining the organic source from the nitrate and TKN data is difficult, because the facility data reviewed coincides with a period of land use transition from animal activity to food processing land application.

Project sampling detected elevated nitrate+nitrite-nitrogen concentrations in alluvial groundwater sampled at the J.R. Simplot land application site south of Interstate 84 and east of Highway 207. Wastewater land application appears to be the nitrate source given the local hydrogeology and groundwater chemistry. The site is located on the west flank of a groundwater divide, and it appears to be a local source of groundwater recharge. Project synoptic sampling data show nitrate+nitrite-nitrogen concentrations increasing downgradient across the site. Additionally, facility TKN data indicates an organic nitrogen source exists at the site. TKN concentrations detected by project or Simplot sampling ranged from non-detect to 35.50 mg/L.

Elevated nitrate+nitrite-nitrogen concentrations occur in shallow unconfined and regional alluvial groundwater within the Butter Creek-Umatilla River confluence vicinity. Land use versus nitrate concentration distribution and groundwater chemistry data analyses indicate local food processing wastewater is the likely nitrate source. The greatest nitrate concentrations detected and reported came from samples collected in the vicinity of the J.R. Simplot Company food processing wastewater land application area north of the Umatilla River. Simplot TKN data indicates an organic nitrogen influence at the site. TKN concentrations detected by project or Simplot sampling ranged from non-detected to possibly more than 25 mg/L. Nitrogen isotopic analysis of shallow unconfined alluvial groundwater sampled from UMA 258 clearly indicated an organic waste influence. Well UMA 258 is located in the confluence vicinity within the Simplot wastewater land application area north of the Umatilla River.

Project sampling detected elevated nitrate concentrations in some alluvial groundwater sampled west of C&B Livestock, Incorporated. Rural residential homes and crop irrigation occurs in the sampled area. C & B Livestock appears responsible for higher nitrate concentrations near the facility given the local hydrogeology, nitrate concentration distribution, and land use distribution.

Groundwater locally flows from the C&B Livestock area toward the Umatilla River. The highest nitrate concentrations detected in local alluvial groundwater came from sampling sites located closest to C&B Livestock. Nitrate concentrations generally ranged from 14 mg/L to 24 mg/L at these sites during project synoptic sampling. The concentrations generally decreased to below 10 mg/L in samples collected downgradient within the rural residential and crop irrigation areas. Canal leakage may be responsible for some of that decrease.

A comparison of C&B Livestock vicinity groundwater data with groundwater samples collected near animal operations south of Boardman also indicate an animal waste source in the C & B Livestock vicinity. The data from the two areas plot similarly on constituent versus constituent graphs, which indicates a common influence. They graph in an area adjacent but separate from septic system influences. (See Figures 4.14 and 4.15) This similarity indicates an animal waste influence.

Irrigated crop agriculture also appears responsible for elevated nitrate in alluvial groundwater sampled further west and downgradient of C&B Livestock. Evidence comes from Dacthal acid detected in alluvial groundwater sampled from UMA 119, located northwest of C&B Livestock and the rural residential homes near C & B Livestock. Nitrate concentrations in samples collected from UMA 119 range from 6 to 17 mg/L. Local groundwater flow directions preclude crop agriculture activity in this area from being responsible for the elevated nitrate concentrations detected in groundwater sampled closer to C & B Livestock.

Project synoptic sampling detected nitrate+nitrite-nitrogen concentrations exceeding 10 mg/L in an area between the Umatilla River and Agnew Road south of Bridge Road. Concentrations detected over time range from 8 mg/L to 13 mg/L. Determining the source is not conclusive. Rural residential home and irrigated crop land uses occur in the area. The shape of the greater than 10 mg/L nitrate+nitrite-nitrogen contoured area on Plate 4.2 coincides well with three irrigation circles observed on a LANDSAT photograph. However, constituent versus constituent graphical analyses (Appendix 4H) consistently indicate a septic system influence in the vicinity.

Plates 4.2 and 4.3 show elevated nitrate+nitrite-nitrogen concentrations occur in alluvial groundwater in the northeast corner area of the U.S. Army Umatilla Depot Activity where a groundwater mound exists. The concentration contours north of the Depot are not well defined due to sparse data from that area. The elevated concentration area corresponds to the Lamb-Weston Inc. food processing wastewater land application area.

Hydrogeologic and groundwater chemistry evaluations indicate wastewater land application is groundwater nitrate source at the Lamb-Weston site. The site straddles the groundwater mound crest. No other activity is upgradient. Additionally, project and facility TKN data indicates an organic nitrogen source at the land application site. Detected and reported TKN concentrations range from non-detect to 18 mg/L.

Project sampling detected relatively low nitrate+nitrite-nitrogen concentrations in regional alluvial groundwater sampled:

- along the Butter Creek drainage,
- west of the Simplot food processing plant,
- west and north of Hermiston, and
- east of the Lamb-Weston wastewater irrigation site near the U.S. Army Depot.

Lower concentrations in alluvial groundwater at the south end of the Butter Creek area may reflect background conditions. Lower nitrate concentrations further north in the Butter Creek drainage and west of the Simplot food processing plant may relate to dilution from surface water and/or canal leakage. The low concentration area west of Hermiston appears related to Hermiston basin groundwater with low nitrate concentrations discharging from the basin toward the Umatilla River. Lower nitrate concentrations east of the Lamb-Weston land application site may relate to dilution from canal leakage.

Map and Data Set Observations: Total Dissolved Solids

Plates 4.4 and 4.5 show the total dissolved solids (TDS) concentration distribution in the Butter Creek to City of Umatilla area based upon project groundwater sampling. Plate 4.5 shows the maximum concentrations detected in alluvial and nearby basalt groundwater samples. Plate 4.4 shows the June-July 1992 TDS concentration distribution in regional alluvial groundwater based upon linear interpolation of project synoptic sampling data. TDS concentrations detected in shallow unconfined alluvial groundwater samples and basalt groundwater samples are printed next to each sampling location.

The distribution of elevated versus lower TDS concentrations is similar to the nitrate concentration distribution. Concentrations exceeding the secondary (aesthetic) drinking water standard of 500 mg/L occurred east of Highway 207 and south of Minnehaha Road.

Some lower TDS concentration areas appear related to canal and/or surface water leakage, because the shape of their contoured area appear similar to the distribution pattern of some canals. The low concentration area west of Hermiston appears related to Hermiston basin groundwater with lower TDS concentrations discharging from the basin toward the Umatilla River.

Map and Data Set Observations: Other Constituents

Project sampling detected arsenic in groundwater sampled from a few Butter Creek to City of Umatilla sampling sites. Plate 4.6 shows the maximum concentration distribution. The arsenic detections generally remained well below the drinking water standard of 0.050 mg/L. However, a sample from the Lamb-Weston land application site next to the U.S. Army Depot did contain arsenic exceeding the drinking water standard.

Plate 4.7 shows the maximum concentration distribution for sodium. Concentrations in project groundwater samples frequently exceeded the 20 mg/L limit currently recommended for persons on a physician prescribed sodium restricted diet. Groundwater samples with sodium concentrations exceeding 50 mg/L came primarily from sites within or near food processing land application areas, as well as along Westland Road, along Highway 207, and within the City of Umatilla.

Plate 4.8 shows the maximum concentration distribution for chloride. Concentrations in all project groundwater samples collected in the area remained within the 250 mg/L secondary (aesthetic) drinking water standard. Project samples with chloride concentrations exceeding 100 mg/L came from UMA 251, UMA 252, and UMA 237. All three sites are located within food processing land application areas.

Plate 4.9 shows the maximum concentration distribution for total phosphate based upon project sampling. The distribution of lower concentrations versus relatively higher concentrations is nearly divided. Groundwater samples with lower concentrations generally came from sites located north of Interstate 84 and west of the Umatilla River with some exceptions. Crop irrigation generally occurs in this area. Samples with relatively higher total phosphate concentrations came primarily from sites along or near Highway 207 south of Hermiston. Other sites with higher concentrations include the City of Umatilla and the northeast portion of the Lamb-Weston land application site next to the U.S. Army Depot.

Plate 4.10, 4.11, and 4.12 show the maximum concentration distribution for boron, bromide, and vanadium in the area based upon project sampling. Groundwater samples with detected boron came from a limited area north of Interstate 84 and two City of Umatilla sites. Samples with relatively higher concentrations came from sites located along Highway 207 and within the City of Umatilla.

Bromide was detected in groundwater sampled from most sites in the area. Samples with relatively higher concentrations came from sites located within the Simplot wastewater land application areas east of Highway 207, near Highway 207 south of Minnehaha Road, the southeastern portion of the Lamb-Weston land application area next to the Army Depot, and the City of Umatilla.

Vanadium detections were limited to groundwater samples collected near the U.S. Army Depot's northeast corner, the Simplot plant site land application area, and near Highway 207 south of Interstate 84. Local samples with the highest vanadium concentrations came from the east side of the Lamb-Weston land application area located adjacent to the Army Depot.

Table 4.24 and Plate 4.13 shows the Butter Creek to City of Umatilla sites where project sampling detected volatile organic compounds and/or pesticides. Appendix 4G provides a complete listing. The occurrence of these constituents indicate the influence of human activity.

Table 4.24 Volatile organic compounds and pesticides detected in the Butter Creek to City of Umatilla area.

Site	Groundwater Source	Location	Constituent	Concentration	Nitrate+Nitrite-Nitrogen Concentration (mg/L)
UMA 062	Alluvial	Westland Estates (Agnew Rd south of Westland Rd)	Tetrachloroethylene	0.0009 mg/L	13.00 - 13.00
UMA 094	Alluvial	Agnew Rd north of Westland Rd	Chloroform	0.0007 mg/L	8.00 - 14.00
UMA 119	Alluvial	SW Hermiston near Highway 207	Dacthal acid	0.1 ppb	6.00 - 17.00
UMA 198	Alluvial	Lamb-Weston site next to Depot	Chloroform	0.0009 mg/L	5.80 - 16.00

Note: Laboratory methods can occasionally cause chloroform detections at low concentrations
Note: The UMA 062 tetrachloroethylene detection was not repeated in a laboratory duplicate analysis
Note: Data from Lower Umatilla Basin project sampling.

Graphical Analyses: Nitrate versus Time.

Graphical analysis of Butter Creek to City of Umatilla area groundwater data included reviewing nitrate versus time graphs. Data analyzed came from project bimonthly sampling, the J.R. Simplot Company (DEQ Water Quality File 81590, Barlow, Urban, and Scott, 1992, EMCON Northwest, Inc., 1992) and Lamb-Weston, Inc. (Hemphill, 1992, DEQ Water Quality File 48780). Analysis of the bimonthly sampling data included comparing the nitrate versus time graphs to other constituent versus time graphs. Analysis of some Simplot and Lamb-Weston data included comparing the nitrate versus time graphs to available groundwater elevation versus time graphs.

Figure 4.46 shows nitrate+nitrite nitrogen concentrations versus time in regional alluvial groundwater sampled by this project within the Butter Creek drainage. Irrigated crop agriculture and animal activity were the primary land uses within the drainage. Much of the area has converted to food processing wastewater land application with municipal sewage sludge land application nearby. Groundwater nitrate concentrations remain low at these sampling sites. However, Lamb-Weston and Simplot report higher nitrate concentrations in the shallow unconfined alluvial groundwater. Table 4.25 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. The graphs were generally incomparable due to the consistently low nitrate concentrations.

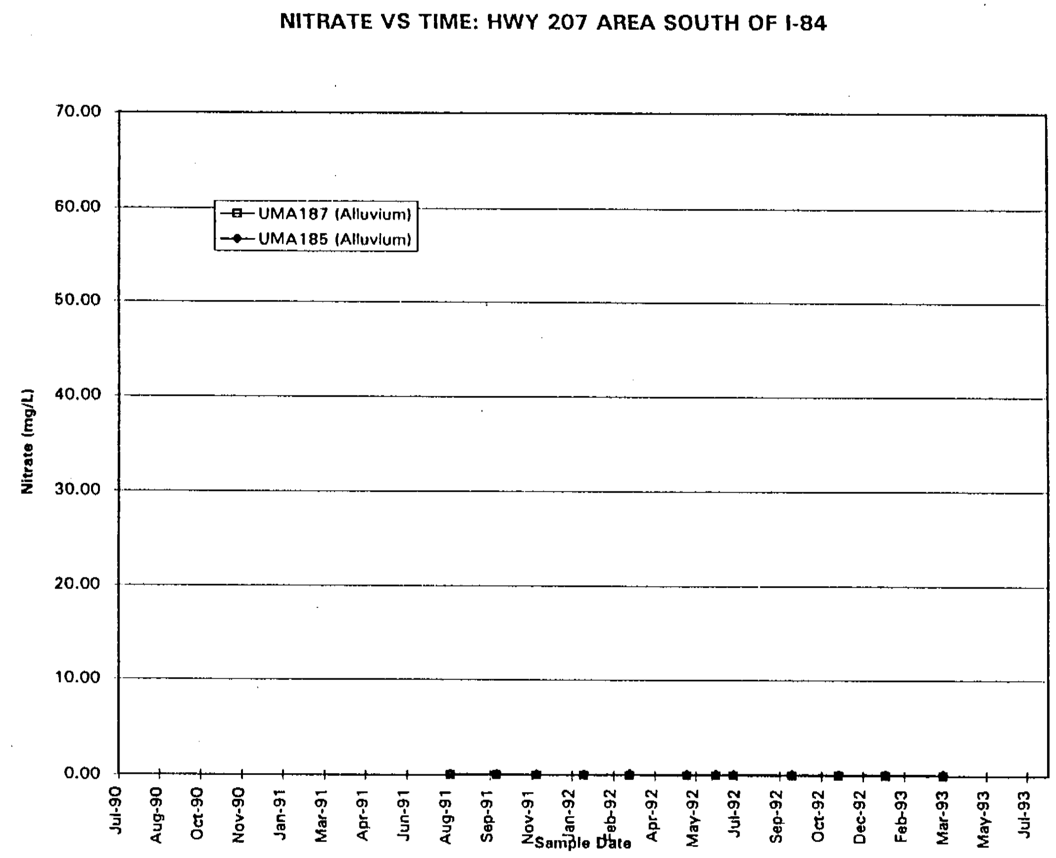


Figure 4.46 Nitrate+nitrite versus time in Butter Creek Highway area south of Interstate 84 alluvial groundwater at project bimonthly sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.25 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Butter Creek Highway area south of Interstate 84.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 185 (Alluvial)	U		S	U	U	U	U	
UMA 187 (Alluvial)	U	U	U	U	U	U	U	

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

This project used nitrate-nitrogen and groundwater elevation versus time graphs to review Lamb-Weston and Simplot groundwater data for their land application sites south of Interstate 84. Data related to sites west of Highway 207 had a sampling period too short for useful analyses. The time period was sufficient for data related to the Simplot site east of Highway 207.

All the nitrate versus time graphs related to the Simplot east site show increasing concentrations for the sampling period represented (1989 to 1992). Nitrate concentrations and groundwater elevations generally fluctuate seasonally at sites within or downgradient of the land application area, which indicates seasonal influences. The nitrate fluctuations appear to lag 9 to 12 months behind the groundwater elevation fluctuations. This time lag appears related to the time required for nitrate to locally travel from land surface to regional alluvial groundwater.

Figure 4.47 shows nitrate+nitrite-nitrogen concentrations versus time in Butter Creek-Umatilla River confluence area regional alluvial groundwater sampled by this project. Table 4.26 presents how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. Well UMA 122 is located south of the Umatilla River in the vicinity of crop agriculture, food processing wastewater land application, and a confined animal operation. Well UMA 058 is located at the Simplot food processing plant and wastewater land application site north of the Umatilla River. The nitrate data over time graphed somewhat similarly, and they compared somewhat similarly to other constituent versus time graphs. The similarities appear related to food processing water influences. The total phosphate and boron differences probably relates to additional influences in the UMA 122 vicinity.

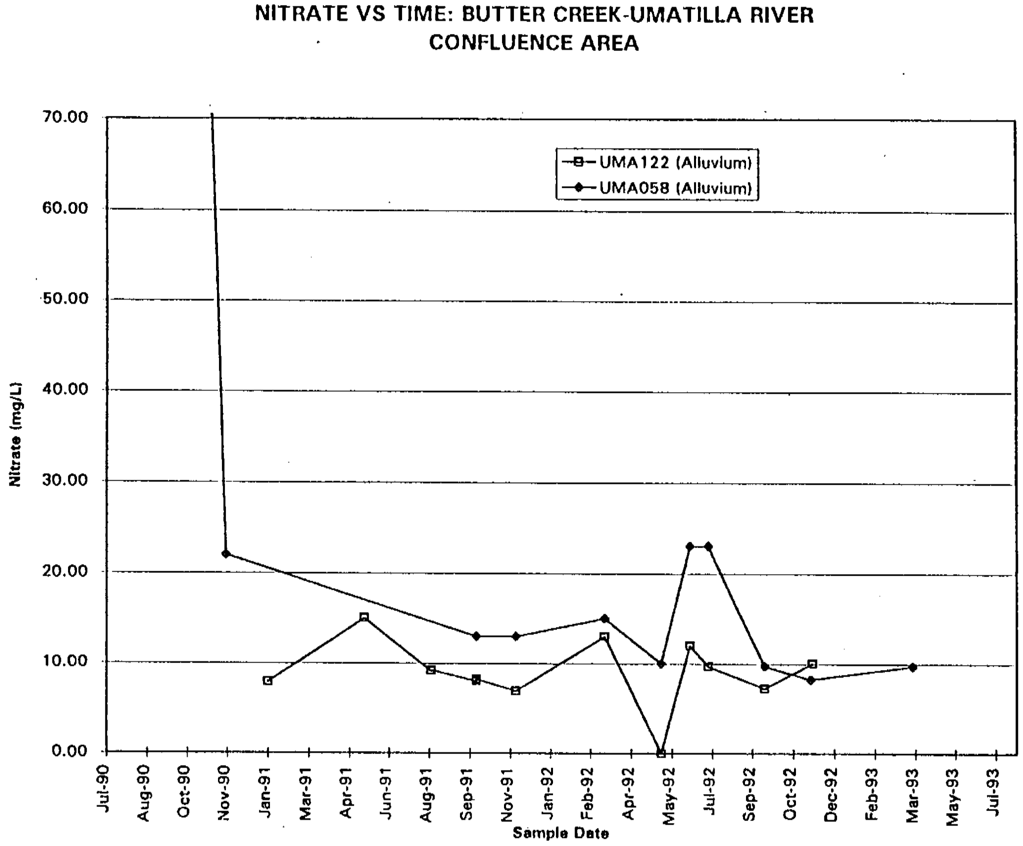


Figure 4.47 Nitrate+nitrite versus time in Butter Creek-Umatilla River confluence area alluvial groundwater at bimonthly sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.26 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Butter Creek - Umatilla River confluence area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 058 (Alluvial)	S	S	S	S	S	S	S	S
UMA 122 (Alluvial)	S	S	S	WS	S	S	I	I

Note: The comparisons were qualitative rather than quantitative

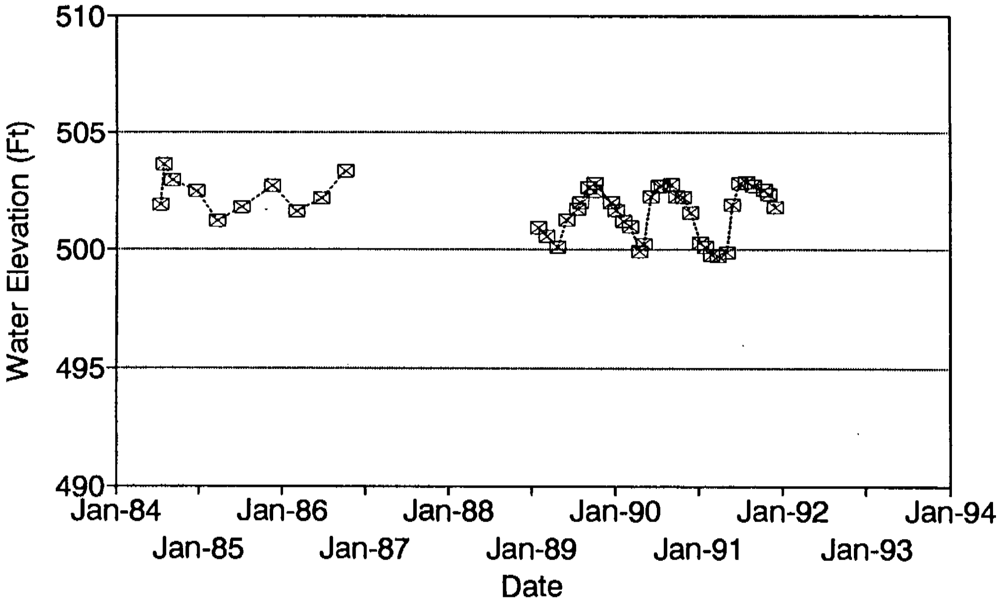
Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

This project reviewed the J.R. Simplot Company nitrate-nitrogen and groundwater elevation data for the plant and land application site north of the Umatilla River and east of Highway 207. The data represents shallow unconfined and regional alluvial groundwater. The data reviewed varied indicating different influences affecting groundwater at each site. Three influences affecting the shallow unconfined groundwater are presented here.

Figure 4.48 shows nitrate-nitrogen and groundwater elevation versus time at UMA 261 (Simplot MW-11S). The site is located adjacent to a land application circle on the terrace north of the Umatilla River. The data show similar seasonal fluctuations with an approximately 8 month time lag for the nitrate fluctuations. This indicates the time required for nitrate to locally travel from land surface to the shallow unconfined groundwater.

Figure 4.49 shows nitrate-nitrogen versus time at UMA 250 (Simplot MW-12). The graph illustrates how local groundwater nitrate concentrations can respond when water and nitrate loading is controlled. Well UMA 250 is located near a wastewater pond. Nitrate concentrations rising above the top of the graph correspond to a period when the pond was unlined. Lining the pond to control seepage caused the nitrate concentrations to decline rapidly.

Figure 4.50 shows nitrate-nitrogen versus time at UMA 248 (Simplot MW-17) located in the Simplot land application area within Umatilla River flood plain. The generally low concentrations over time probably reflect a Umatilla River influence. The isolated concentration peak was detected by sampling that occurred two weeks after a Umatilla River flood event (EMCON Northwest, Inc., 1992). The nitrate peak occurrence suggests a reservoir of nitrate may have been in the soil, and it was mobilized when the flood provided sufficient moisture.



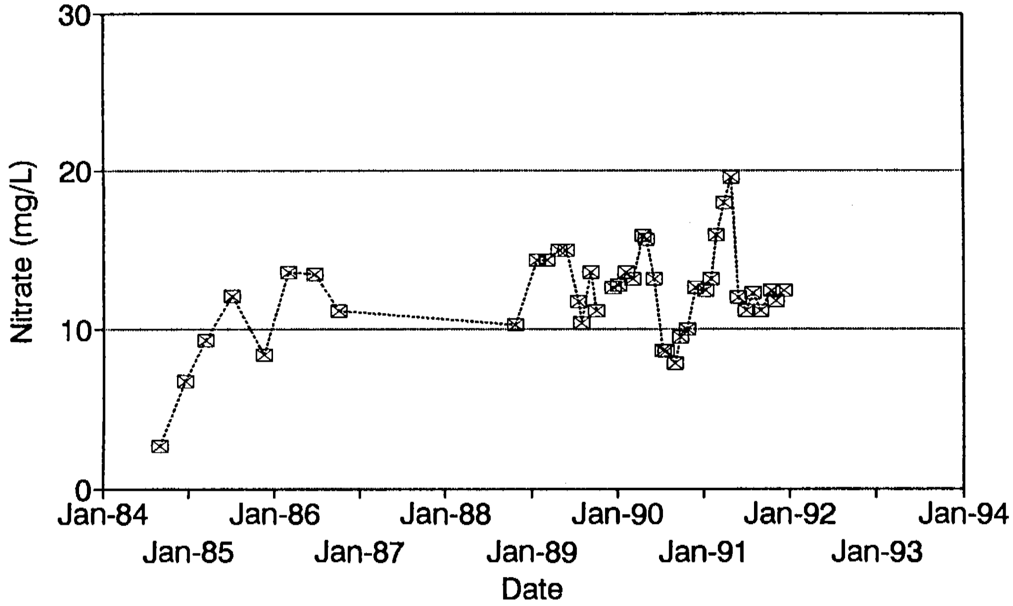


Figure 4.48 Nitrate-nitrogen and groundwater elevation versus time for shallow unconfined alluvial groundwater at UMA 261 (LUB 042, Simplot MW-11S).

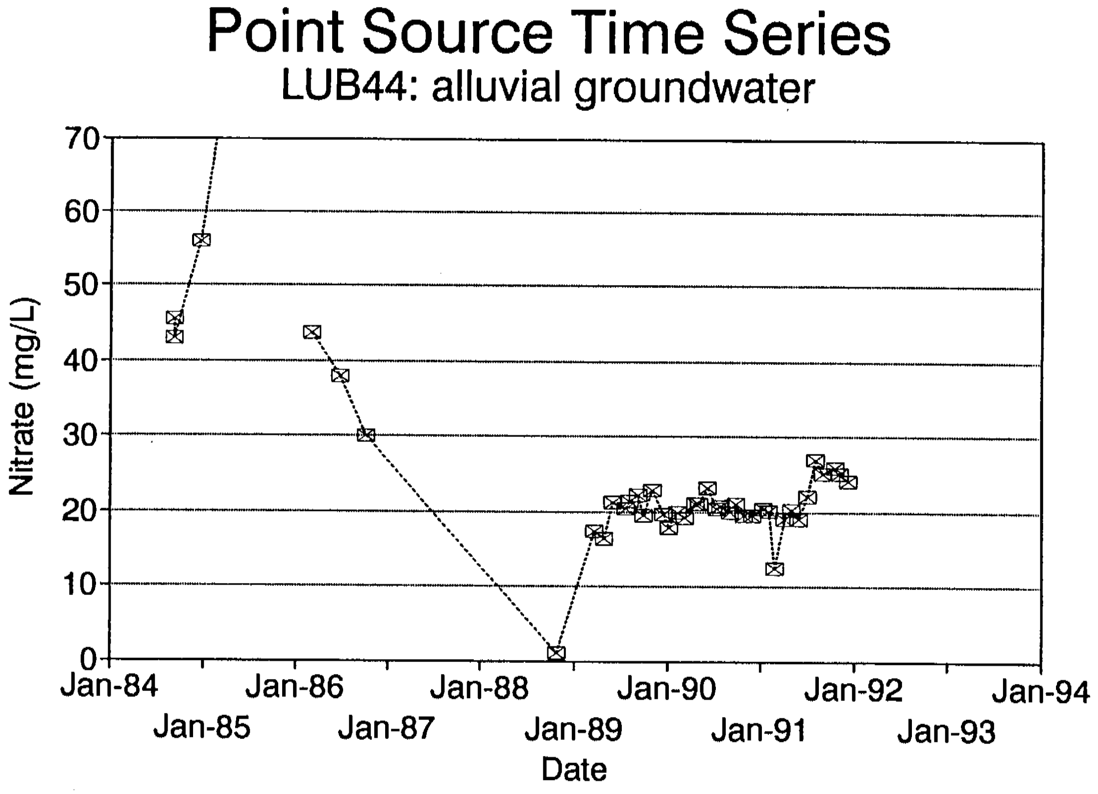


Figure 4.49 Nitrate-nitrogen versus time for shallow unconfined alluvial groundwater at UMA 250 (LUB 044, Simplot MW-12).

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

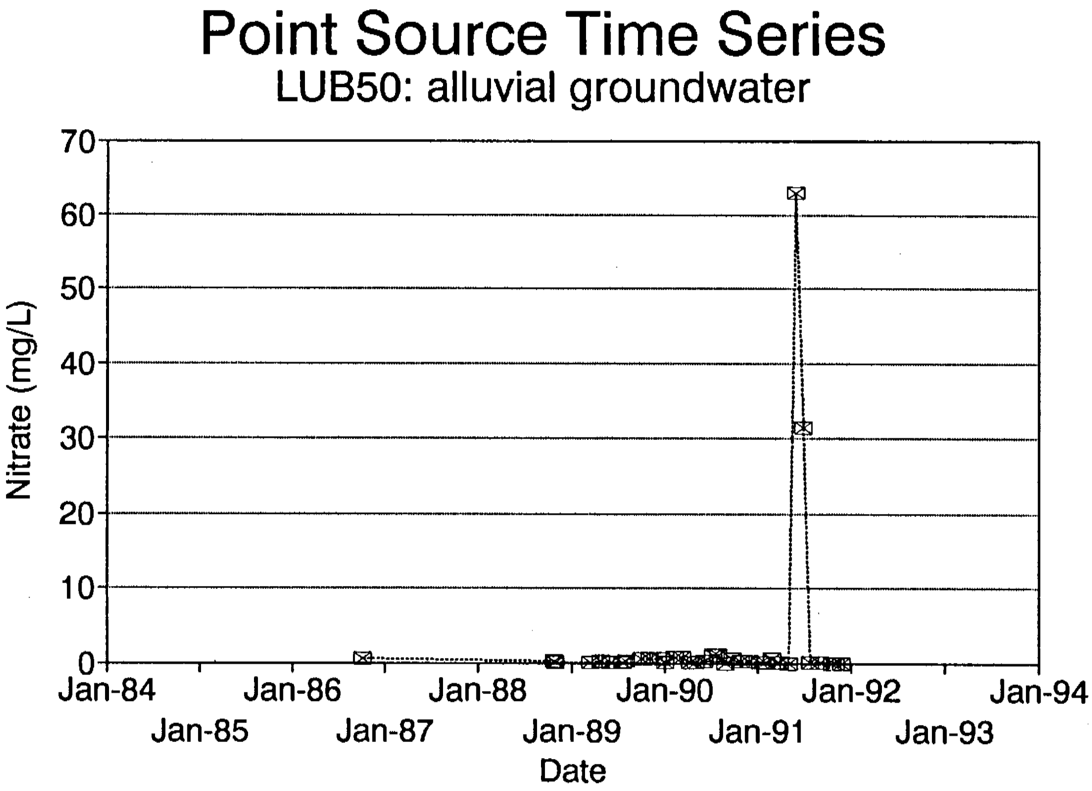


Figure 4.50 Nitrate-nitrogen versus time for shallow unconfined alluvial groundwater at UMA 248 (LUB 050, Simplot MW-17).

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Figure 4.51 shows nitrate+nitrite nitrogen concentrations versus time in alluvial groundwater sampled north of Interstate 84 and east of the Umatilla River by this project. Table 4.27 shows how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. UMA 084 and UMA 119 data show some similarities but differ from UMA 077.

Similar land use influences would account for the similarities between UMA 084 and UMA 119. Well UMA 084 is located within a rural residential area, less than 0.3 miles from C&B Livestock, and less than 300 feet from A Line Canal. Well UMA 119 is located among irrigated fields and downgradient of Maxwell Canal, A Line Canal, rural residential homes and C&B Livestock. C&B Livestock appears to influence groundwater at both sites with irrigated crop agriculture an additional influence at UMA 119. Different influences appear to occur at UMA 077. The site is located in west Hermiston where alluvial groundwater with low nitrate concentrations discharges from the Hermiston basin toward the Umatilla River.

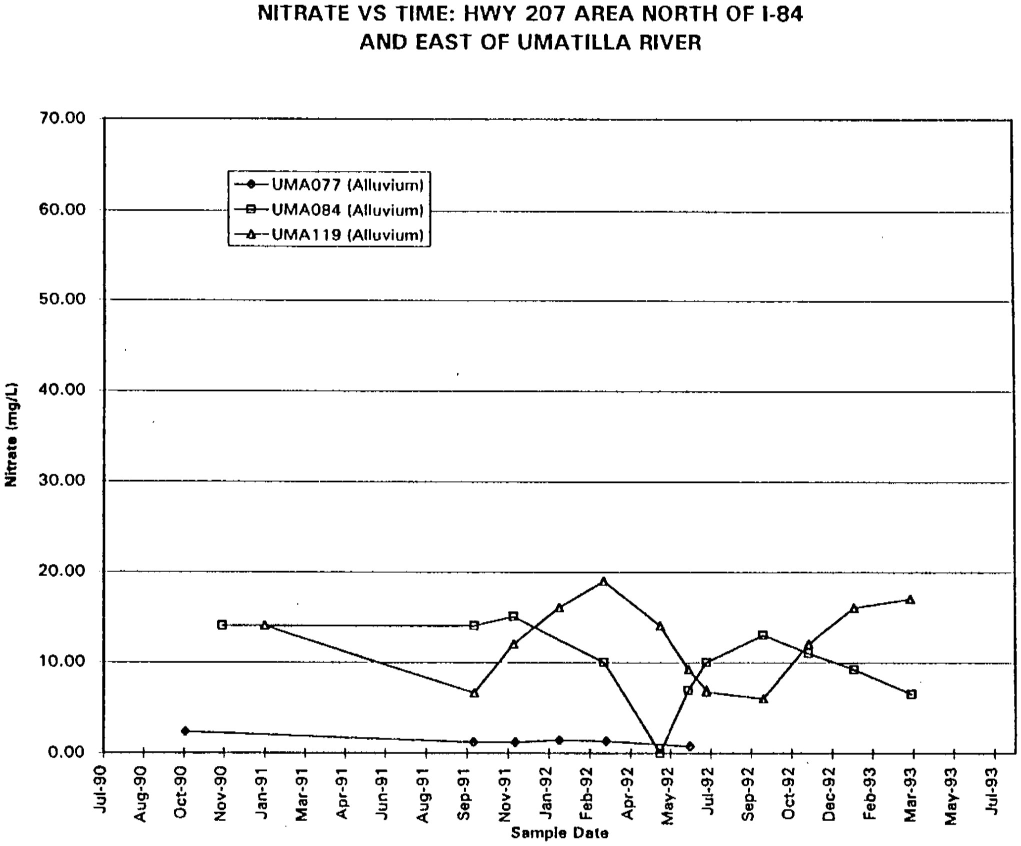


Figure 4.51 Nitrate+nitrite versus time in Butter Creek Highway north of Interstate 84 and east of the Umatilla River area alluvial groundwater at project bimonthly sampling sites.

Note: 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.27 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Butter Creek Highway area north of Interstate 84 and east of the Umatilla River.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 077 (Alluvial)	WS	S	WS	WS	S	S	I?	U
UMA 084 (Alluvial)	WS	I	S	WS	I	S	WS and I	NS
UMA 119 (Alluvial)	S	S	S	S	S	S	I	S and I

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Figure 4.52 shows nitrate+nitrite nitrogen concentrations versus time in alluvial groundwater sampled north of Interstate 84 and west of the Umatilla River by this project. Table 4.28 shows how each nitrate versus time graph compared to other constituent versus time graphs for each sampling site. Figure 4.52 and Table 4.28 show some similarity and differences between the sites.

Well UMA 198 is located within the Lamb-Weston wastewater land application area next to the U.S. Army Depot. Food processing wastewater is identified as the nitrate source in that area. The UMA 198 data shows some seasonal influence which is consistent with land application activity.

Wells UMA 094 and UMA 088 are located downgradient among rural residential homes and irrigated crop agriculture. Constituent versus constituent graphical analyses (Appendix 4H) and a nitrate concentration distribution comparison to local land uses indicates septic systems and/or irrigated crop agriculture influences groundwater at these sites. The UMA 094 and UMA 088 nitrate versus time graphs may be considered consistent with a septic system influence.

The comparison of UMA 088 nitrate versus time graph to other constituent versus time graphs differs from the UMA 094 and UMA 198 graphical comparisons (Table 4.28). This may relate to a possible Umatilla River influence. Well UMA 088 is located close to the river within a meander loop.

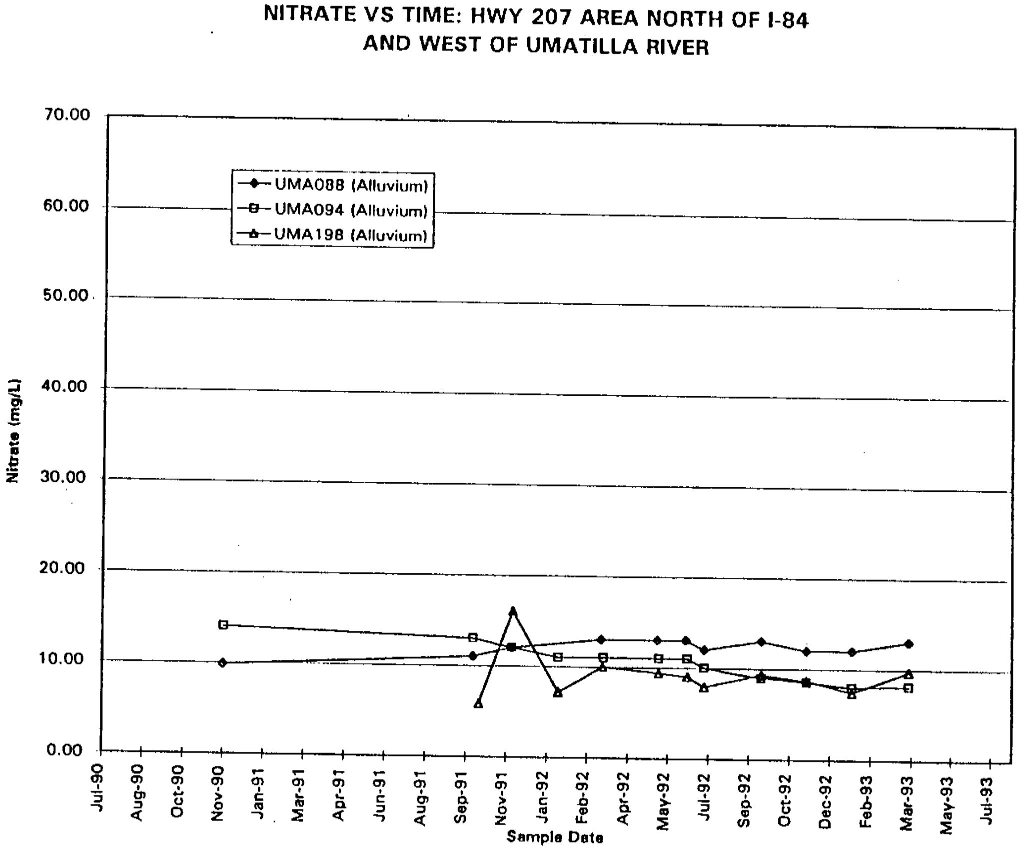


Figure 4.52 Nitrate+nitrite versus time in Butter Creek Highway north of Interstate 84 and west of the Umatilla River area alluvial groundwater at project bimonthly groundwater sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.28 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Butter Creek Highway area north of Interstate 84 and west of the Umatilla River.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 088 (Alluvial)	S	S	NS	S and I	S and I	S and I	S and I	U
UMA 094 (Alluvial)	S	S	S	S	S	S	I	NS
UMA 198 (Alluvial)	S	S	S	S	S	S	I	

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

This project reviewed Lamb-Weston, Incorporated alluvial groundwater data for the land application site adjacent to the U.S. Army Umatilla Depot Activity using nitrate-nitrogen and groundwater elevation versus time graphs. The nitrate-nitrogen versus time graphs generally show seasonal fluctuations. Some of those graphs correlate with a time lag to the groundwater elevation versus time graphs. Time lags ranging from less than 1 month to possibly 18 months were observed between unique groundwater elevation and nitrate concentration peaks. This time lag appears related to the time required for nitrate to travel to groundwater.

Figure 4.53 shows nitrate+nitrite-nitrogen concentrations versus time in City of Umatilla area alluvial groundwater sampled by this project. Table 4.29 presents how the nitrate versus time graph compared to the other constituent versus time graphs. The site is located in an unsewered residential and small agriculture area adjacent to the city. Constituent versus constituent graphical analysis (Appendix 4H) indicates a mixed septic system and animal waste influence. Animal activity does occur south of the city.

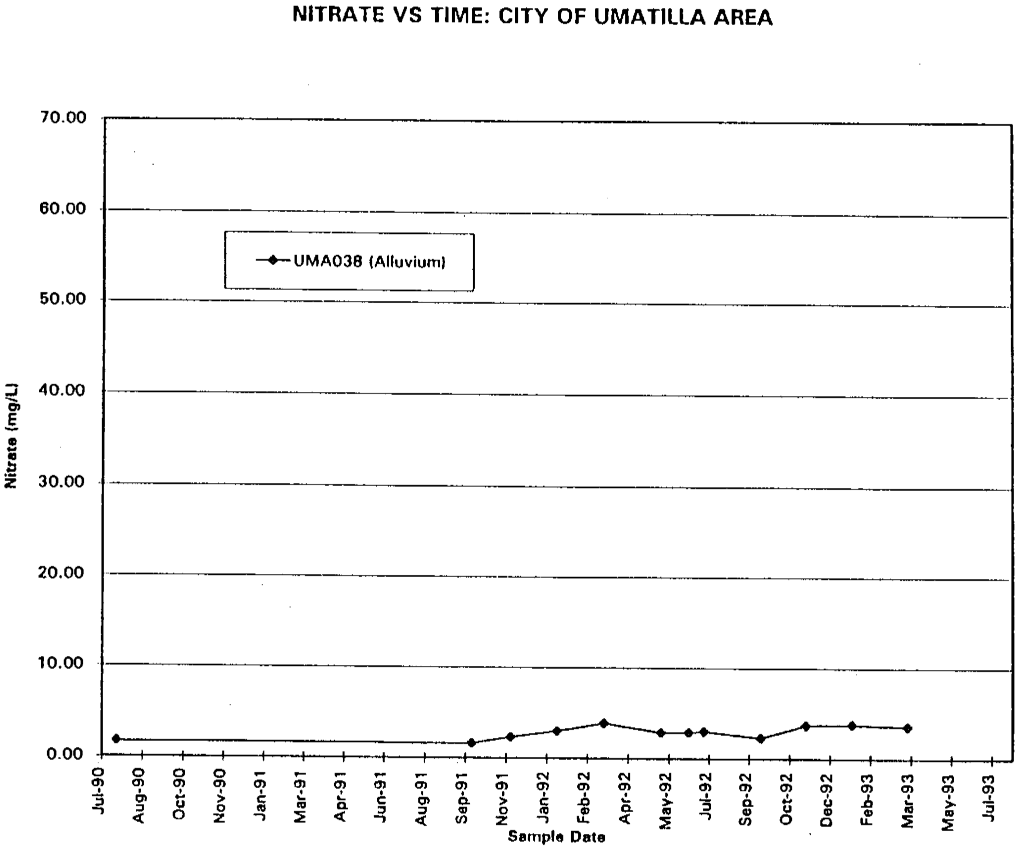


Figure 4.53 Nitrate+nitrite-nitrogen versus time in City of Umatilla area alluvial groundwater at the project bimonthly groundwater sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.29 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the City of Umatilla area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 038 (Alluvial)	WS	S	WS	S	WS	WS	I	NS

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Graphical Analyses: Piper Trilinear Graphs and Schoeller Diagrams.

Project bimonthly and synoptic groundwater sampling data related to the Butter Creek to the City of Umatilla area were plotted on Piper trilinear graphs and Schoeller diagrams. Both graphs proved useful for observing data variations or lack of variation. Variation characterized most of the data graphed. The trilinear graphs proved useful for classifying the groundwater chemistry and observing mixing relationships. Table 4.30 shows the groundwater chemistry classification observed by location and groundwater source.

Table 4.30 Observed Piper Trilinear water chemistry classification of alluvial and basalt groundwater sampled from the Butter Creek to Umatilla area.

Area	Groundwater Source	Groundwater Chemistries Observed
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Butter Creek Highway Area: South (south of Interstate 84 and west of Highway 207) (Project Sampling)	Alluvial (Shallow Unconfined)	mixed-cation/bicarbonate
Butter Creek Highway Area: South (south of Interstate 84 and east of Highway 207) (Project Sampling)	Alluvial	calcium/mixed-anion no dominant type
Butter Creek - Umatilla River Confluence Area (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Butter Creek - Umatilla River Confluence Area (Project Sampling)	Alluvial (Shallow Unconfined)	mixed-cation/bicarbonate
Butter Creek Highway Area: North (north of Interstate 84 and east of Umatilla River) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate sodium + potassium/bicarbonate
Butter Creek Highway Area: North (north of Interstate 84 and west of Umatilla River) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Lamb-Weston, Inc. Land Application Area (adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial	mixed-cation/bicarbonate sodium + potassium/bicarbonate
Lamb-Weston, Inc. Land Application Area (Adjacent to U.S. Army Depot's northeast corner) (Project Sampling)	Alluvial (Shallow Unconfined)	mixed-cation/bicarbonate
City of Umatilla Area (Project Sampling)	Alluvial	mixed-cation/bicarbonate

Note: Project bimonthly and synoptic groundwater sampling data was used for the groundwater chemistry classifications

Nitrate concentration variation or lack of variation over time correlates to water chemistry variation or lack of variation observed on the trilinear graphs and Schoeller diagrams. Nitrate and other constituents in regional alluvial groundwater at sites sampled in the southern portion of the Butter Creek area varied little over time as illustrated by UMA 187 data (Figures 4.54 and 4.55) Corresponding nitrate+nitrite-nitrogen concentrations range from non-detect to 0.02 mg/L. Most of the other data graphed varies over time. Figures 4.56 and 4.57 show variation over time related to alluvial groundwater at UMA 122 within the Butter Creek-Umatilla River confluence area as an example. The data is distributed along a mixing line on the trilinear graph. Corresponding nitrate concentrations range from 6.90 to 20 mg/L. The higher nitrate concentrations correlate with higher chloride and sulfate proportions on the trilinear graph.

Note in figure 4.56 that relative proportions of the major cations show little variation, while the anions, specifically the bicarbonate to chloride ration varies significantly. The Schoeller diagram (Figure 4.57) indicates a relative constant value for bicarbonate. Consequently, the bulk of the variations observed for UMA 122 in the trilinear diagram reflect variations in chloride, and to a lesser extent, sulfate concentrations.

Nearly all the Butter Creek to City of Umatilla area data vary by location. Figures 4.58, 4.59, and 4.60 show the variation in the Butter Creek Highway area north of Interstate 84 and west of the Umatilla River as an example. Analysis identified three mixing lines on the trilinear graph that correspond to three different conditions. Two mixing lines correspond to shallow unconfined (UMA 237 and UMA 238) and regional (UMA 198, 234, 235, 236, and 243) alluvial groundwater at the Lamb-Weston land application site next to the U.S. Army Depot. The third mixing line (UMA 063, 078, 088, 092, 094, 136, 181, and 207) corresponds to alluvial groundwater further downgradient primarily within a mixed irrigated crop agriculture and rural residential home area. The mixing line end members were not identified. However, higher chloride proportions correspond to higher nitrate concentrations for all three mixing lines. Higher calcium proportions correspond to higher nitrate concentrations also. However, the calcium proportions vary more in groundwater from the food processing land application area than from the downgradient area. This was observed in graphs of the Butter Creek-Umatilla River confluence area data also.

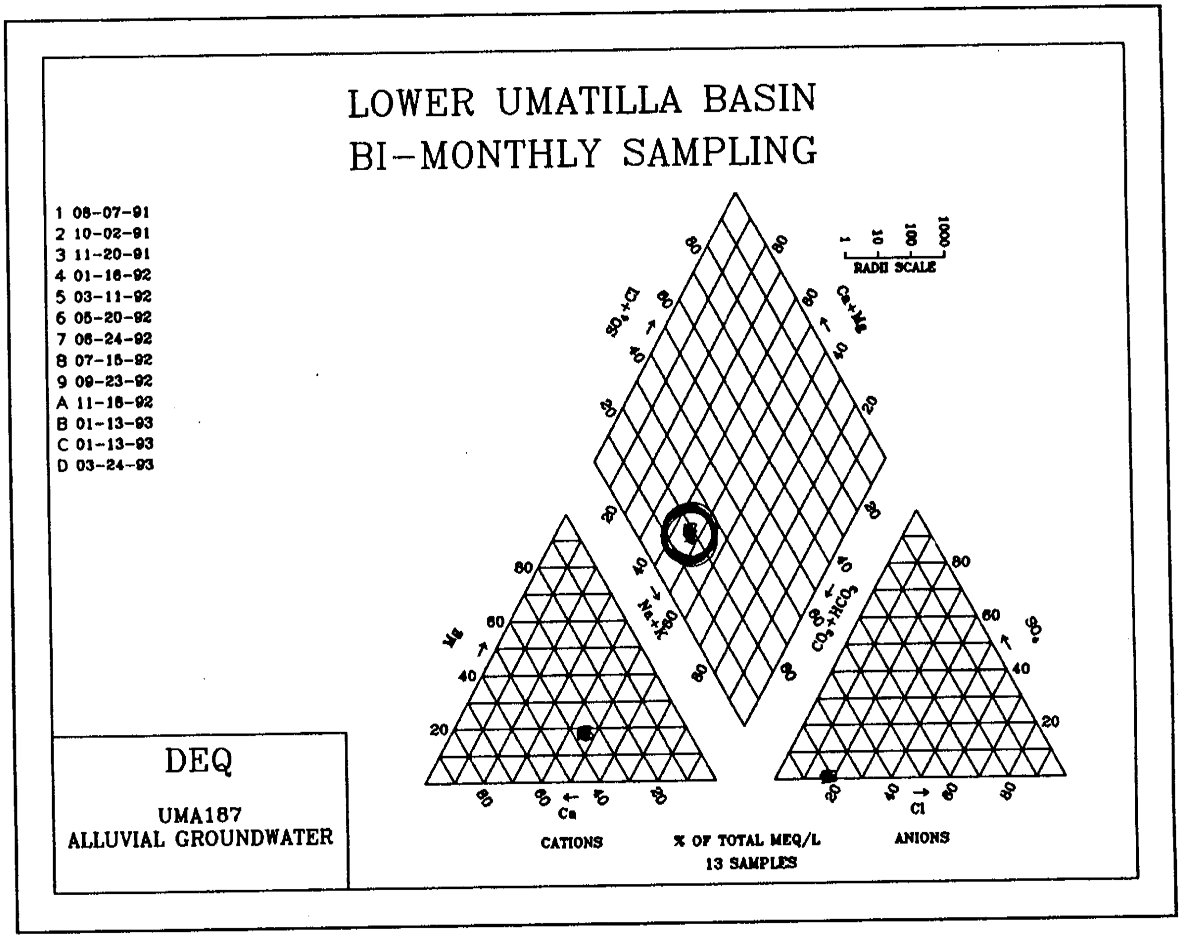


Figure 4.54 Piper Trilinear Graph of project bimonthly sampling data for alluvial groundwater collected at UMA 187 in the Butter Creek Highway area south of Interstate 84.

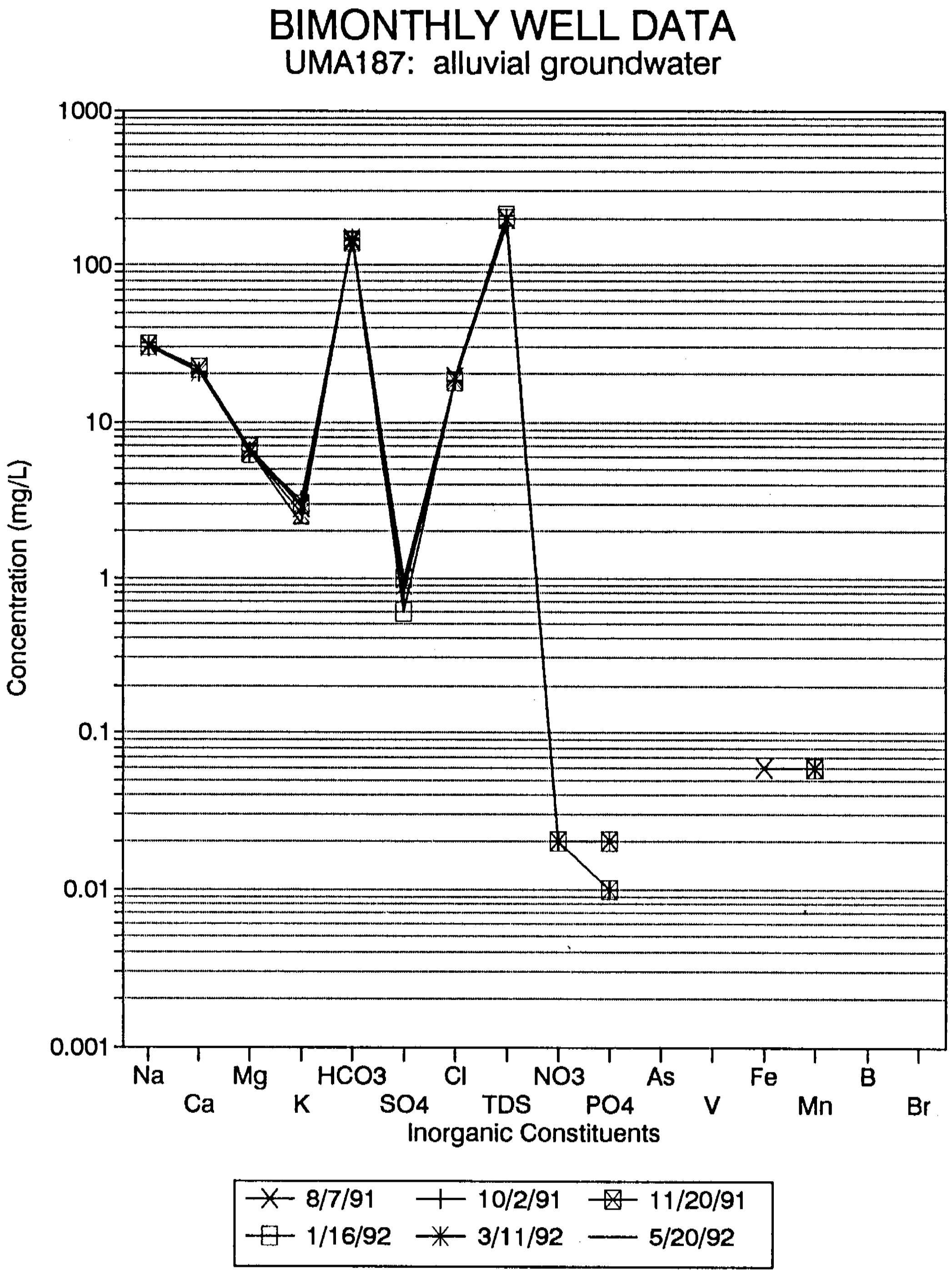


Figure 4.55 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 187 in the Butter Creek Highway area south of Interstate 84.

Note: The variation is small.

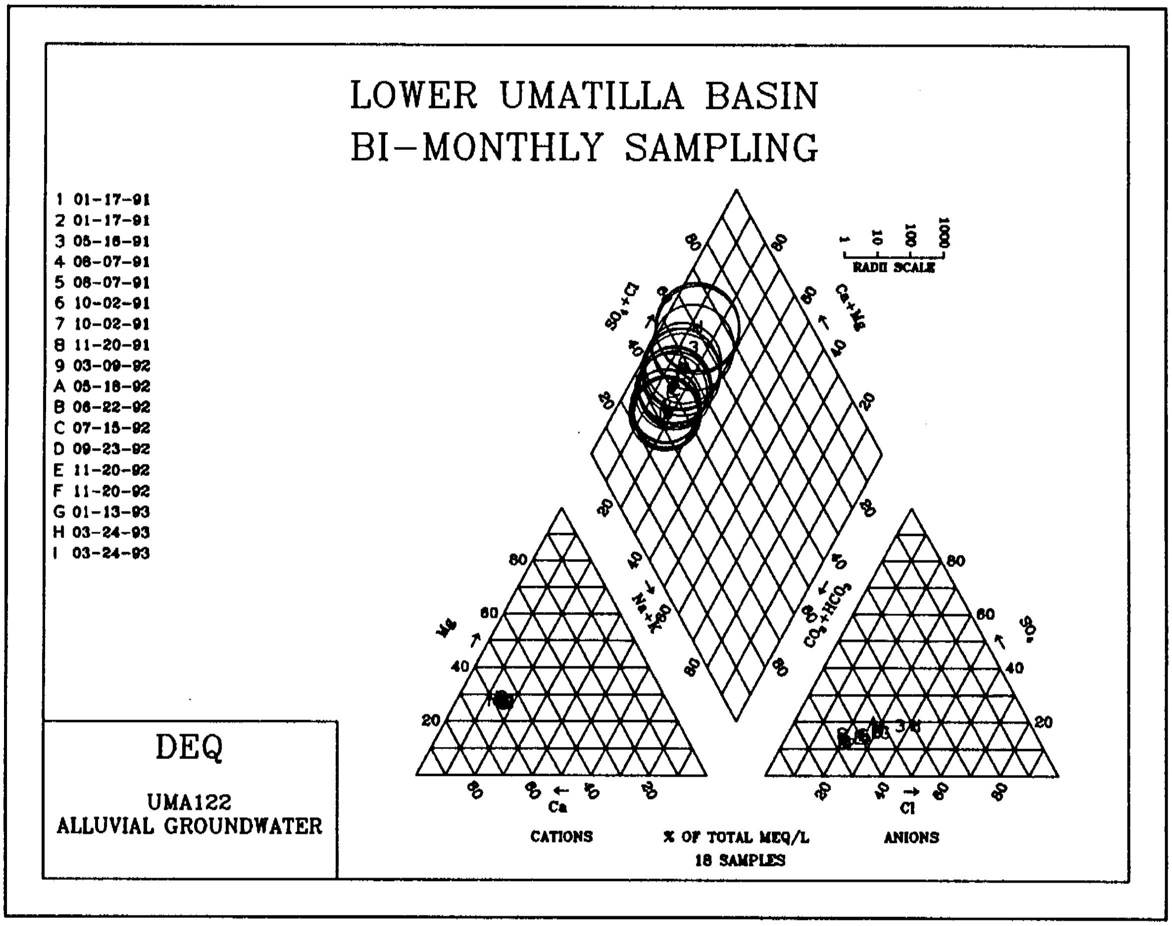


Figure 4.56 Piper Trilinear Graph of project bimonthly sampling data for alluvial groundwater collected at UMA 122 in the Butter Creek-Umatilla River confluence area.

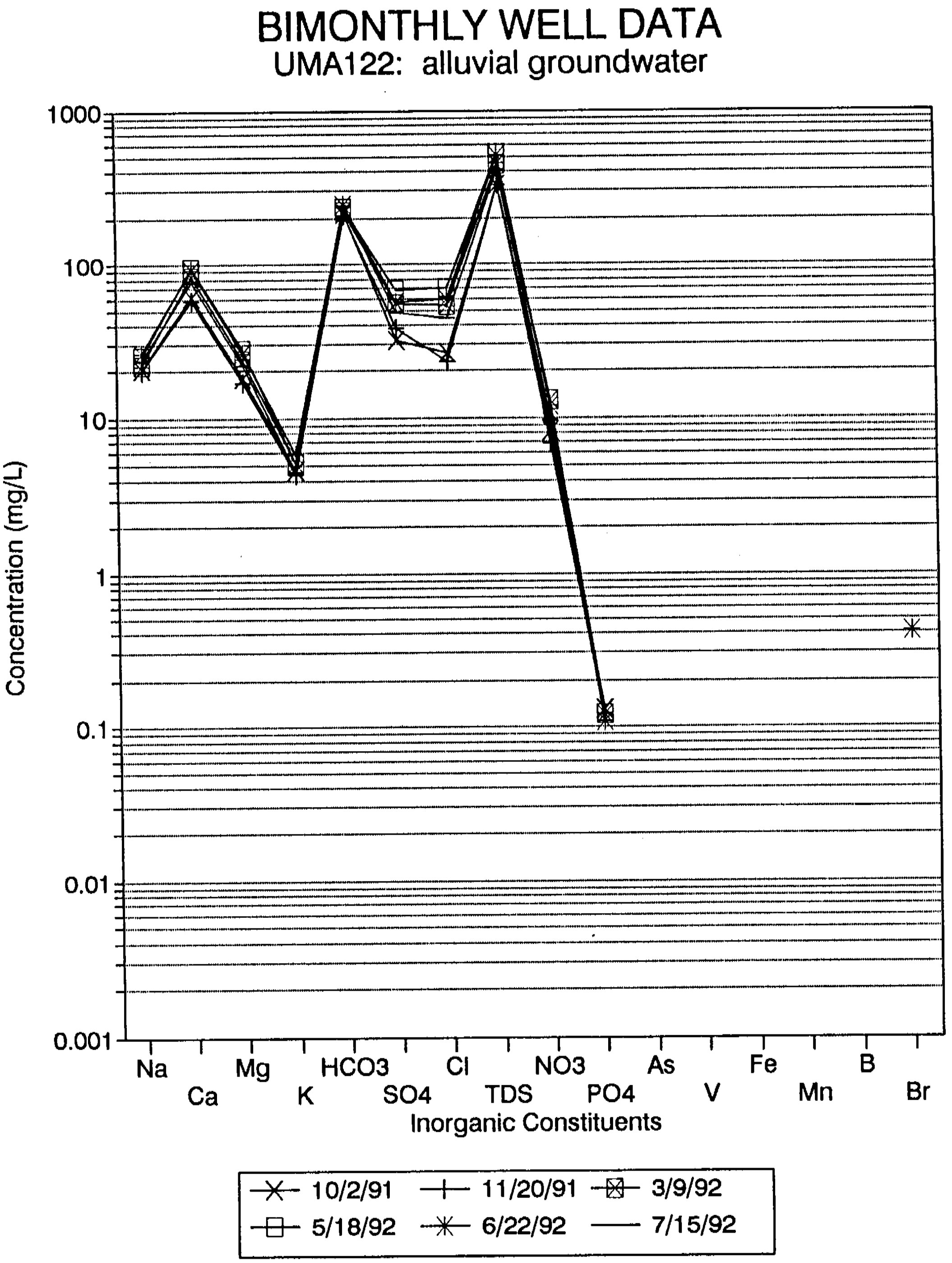


Figure 4.57 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 122 in the Butter Creek-Umatilla River confluence area.

Note: The variation is larger.

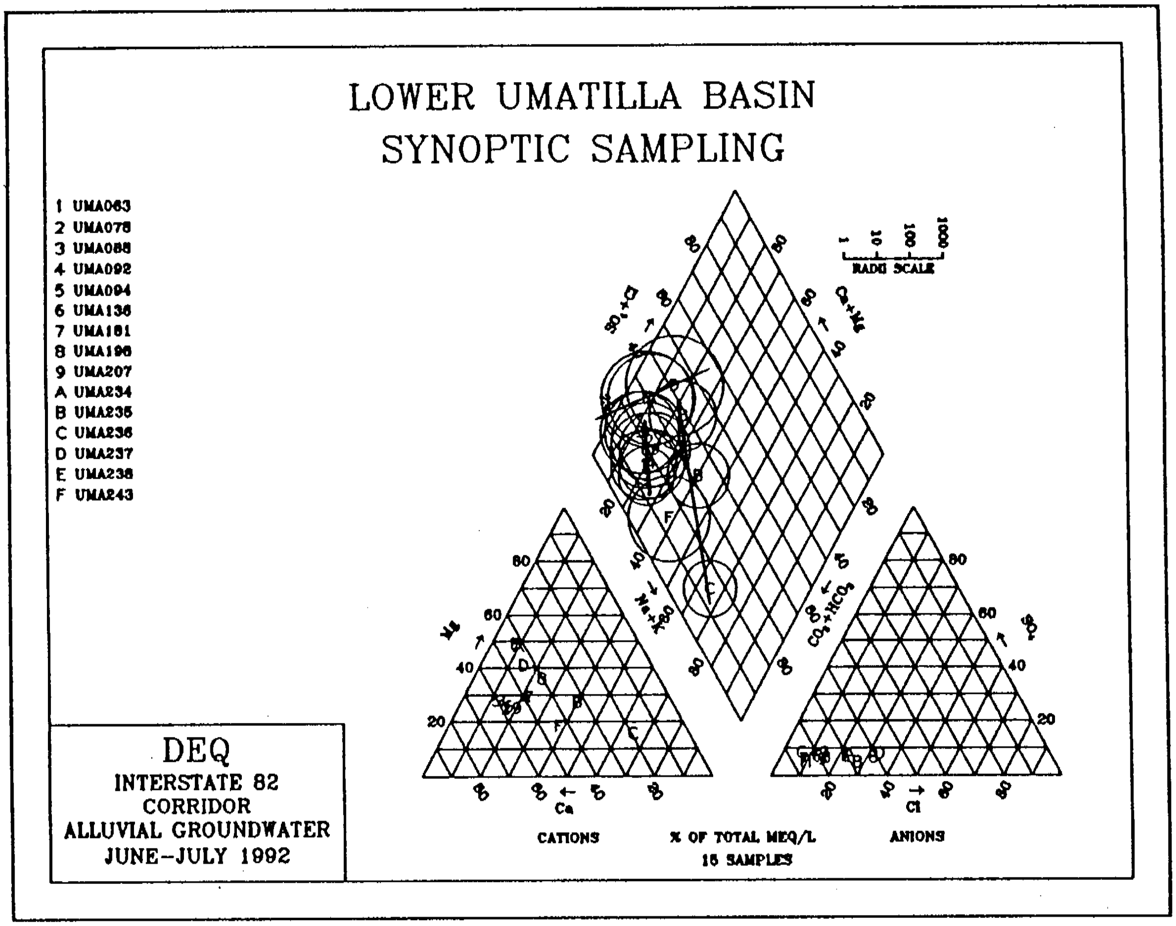


Figure 4.58 Piper Trilinear Graph of project synoptic sampling data for alluvial groundwater collected in the Butter Creek Highway area north of Interstate 84 and west of the Umatilla River, including the Lamb-Weston food processing wastewater land application area.

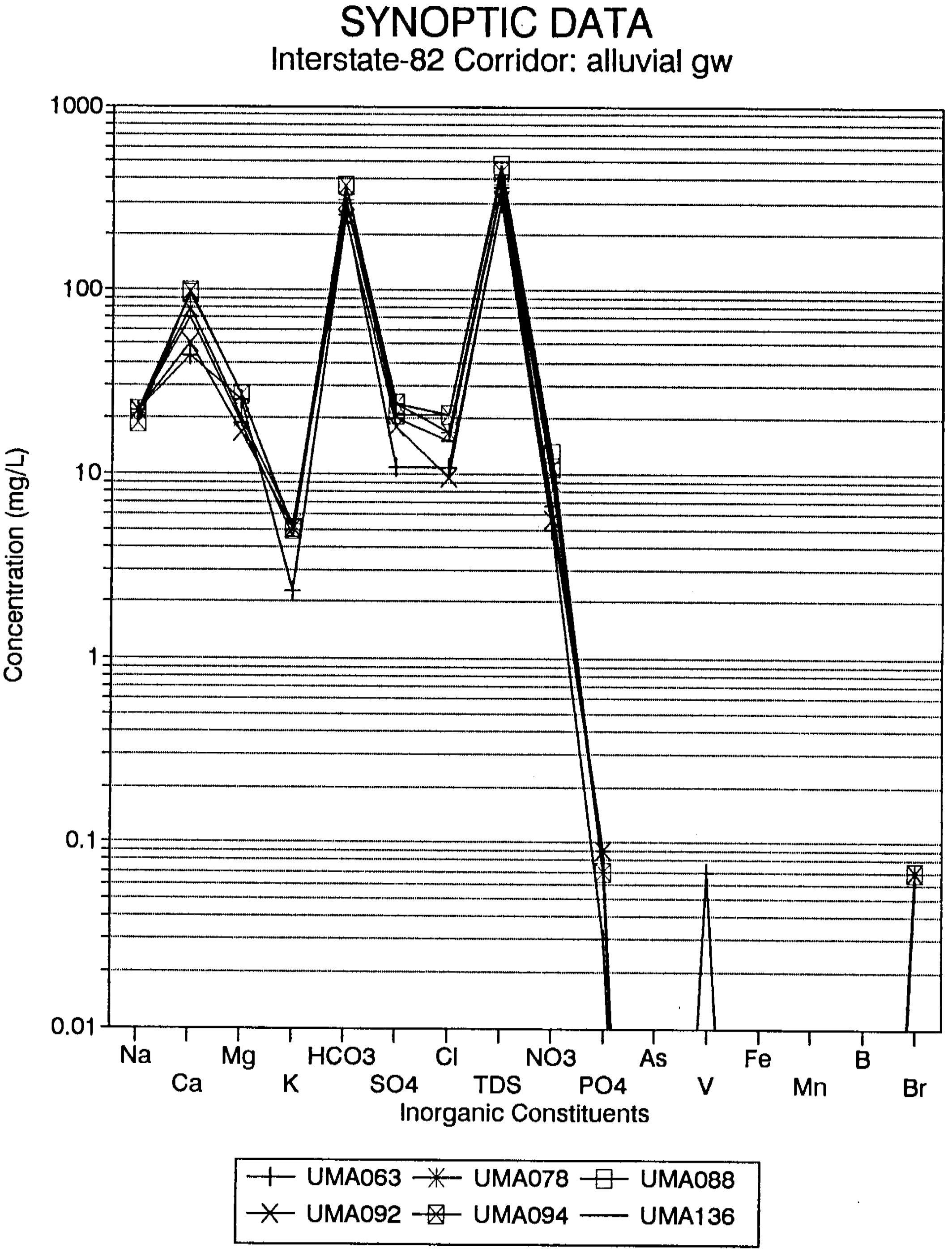


Figure 4.59 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected in the Butter Creek Highway area north of Interstate 84 and west of the Umatilla River area.

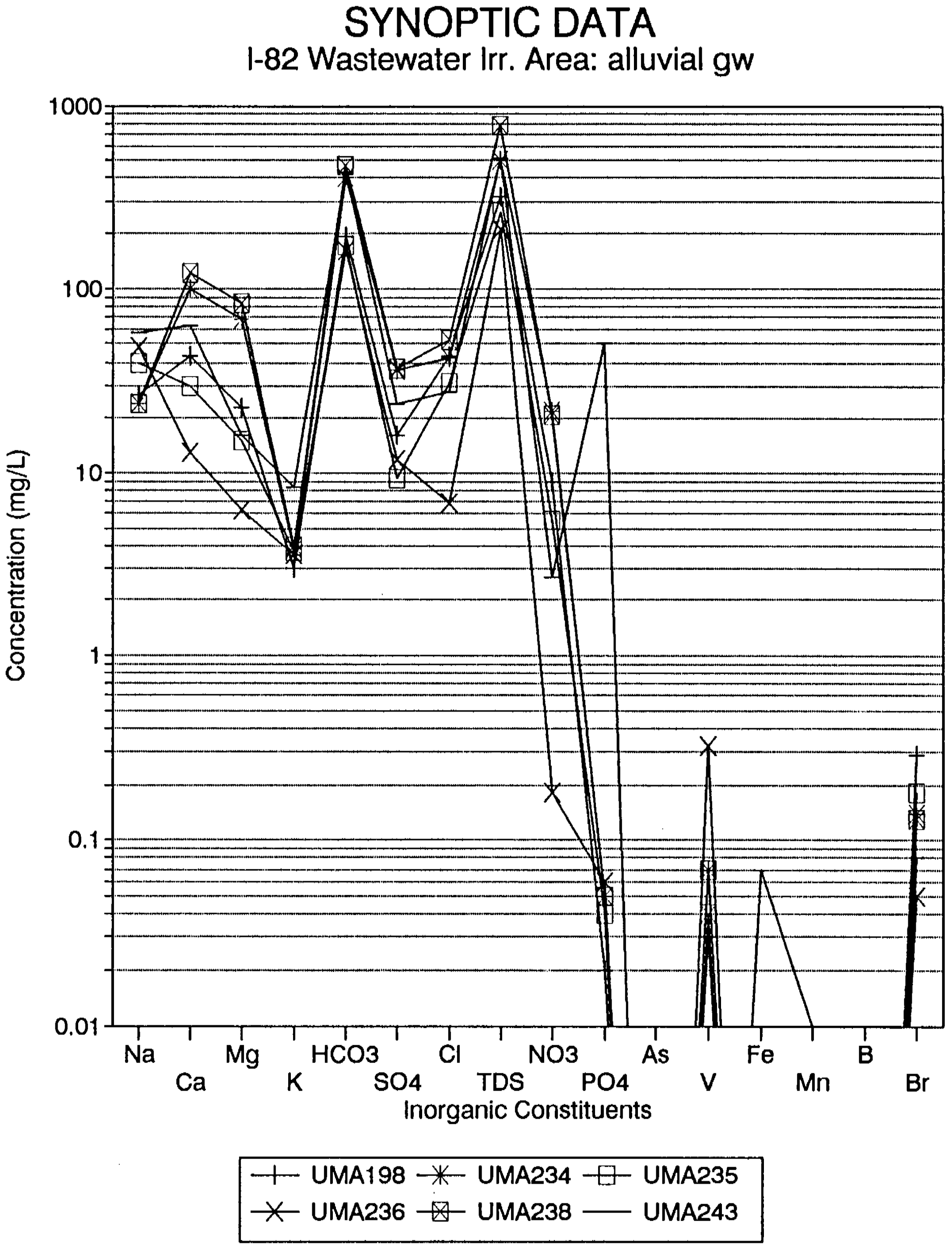


Figure 4.60 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected in the Lamb-Weston food processing wastewater land application area.

Graphical Analyses: Constituent Versus Constituent

Constituent versus constituent graphs were used to distinguish nitrate sources. The analysis primarily used project synoptic sampling data. Graphs reviewed included chloride versus potassium, bromide versus potassium, and chloride/bromide versus chloride. The analyses indicate a variety of land uses influence the groundwater chemistry in the Butter Creek to the City of Umatilla area (see Appendix 4H). Noteworthy results include the following:

- Irrigation by crop agriculture and/or by the food processing industry primarily influenced the groundwater chemistry in samples collected in the Butter Creek Highway area south of Interstate 84. Septic systems appear to be a possible secondary and local influence at some sites.

- The groundwater chemistry in the Butter Creek-Umatilla River confluence area reflects mixed influences. Irrigation by crop agriculture and/or by the food processing industry influences the groundwater chemistry in many samples. Animal waste and septic systems also appear to influence the groundwater chemistry at several sites.

- Animal waste appears to influence the groundwater chemistry in samples collected downgradient of C&B Livestock. The influence of irrigation and septic systems appears to increase further north.

- Septic systems appear to be an important influence upon the groundwater chemistry in the area north of Interstate 84 and west of the Umatilla River. However, irrigation by crop agriculture and/or the food processing industry appears the dominant influence at UMA 063.

- Food processing wastewater irrigation is the dominant influence upon groundwater at the Lamb-Weston wastewater land application area next to the U.S. Army Umatilla Depot Activity.

- Septic and animal waste influence alluvial groundwater in an unsewered area adjacent to the City of Umatilla. Animal activity occurs south of Umatilla.

Groundwater Flow Path Analysis

Project flow path analyses focused primarily upon the Butter Creek-Umatilla River drainage due to the complexity of the hydrogeolgy and land uses in the area. Some of the results apply to other areas in the Lower Umatilla Basin. The flow path analyzed extends from UMA 185 to UMA 077. A thorough discussion of the analysis is presented separately in a following section (Evaluating Chemical Trends with Flow Path Analysis: Butter Creek Example). The analysis found:

- Several influences affect the groundwater chemistry. Not all of the influences contribute nitrate.
- Nitrate and other constituent concentrations in alluvial groundwater peak in the Butter Creek-Umatilla River confluence area.
- The concentration peak fluctuates seasonally.
- The concentration peak appears not to move downgradient. That indicates a local influence(s) causes the peak.

Groundwater Chemistry Computer Modeling

This project used the NETPATH groundwater chemistry model to evaluate the influences responsible for a concentration peak in alluvial groundwater identified by flow path analysis. A thorough discussion of the analysis is presented separately in the following "Evaluating Chemical Trends with Flow Path Analysis: Butter Creek Example" section. The analysis found:

- Water mineral interactions contribute minor changes to the groundwater chemistry.
- Shallow unconfined alluvial groundwater in the Butter Creek-Umatilla River confluence area does impact the deeper regional alluvial groundwater.
- Infiltrating food processing wastewater is responsible for the nitrate peak in the alluvial groundwater in the Butter Creek-Umatilla River confluence vicinity.
- Cyclic evaporation-dissolution in the soil and unsaturated zone is an additional and important influence upon the groundwater chemistry.

- Significant mixing between Umatilla River water and groundwater appears to occur north of Interstate 84 and east of the Umatilla River. This mixing appears responsible for lower constituent concentrations detected downgradient of a concentration peak. The river water may come directly from river leakage or from canals conveying Umatilla River water.

Nitrogen Isotopic Analyses

Nitrogen isotopic laboratory analyses included a sample from shallow unconfined alluvial groundwater from UMA 258 within the Simplot plant site land application area. Isotopic data analysis indicates an organic waste influence.

Butter Creek to City of Umatilla Area Summary and Conclusions

This investigation used a variety of techniques to analyze the Butter Creek to City of Umatilla area groundwater chemistry data, which came from project sampling and local facilities. The data analyses led project investigators to the following observations and interpretations:

- Nitrate+nitrite-nitrogen concentrations detected in local project or facility groundwater samples ranged from non-detect to 74 mg/L in regional alluvial groundwater and non-detect to 100 mg/L in shallow unconfined alluvial groundwater.

- The time required for nitrate to locally travel from land surface to groundwater appears to vary from less than 1 month to 18 months which probably relates to available water.

- Food processing wastewater appears responsible for elevated nitrate concentrations detected in groundwater at established wastewater land application areas.

- Food processing wastewater appears primarily responsible for a stationary nitrate concentration peak in the Butter Creek-Umatilla River confluence vicinity.

- C&B Livestock appears responsible for elevated nitrate concentrations in alluvial groundwater sampled at nearby sites downgradient of the facility.

- Dacthal acid was detected in an alluvial groundwater sample collected at UMA 119 located northwest of C&B Livestock. That detection indicates an irrigated crop agriculture influence.

- Septic systems appear to be an important influence upon groundwater west of the Umatilla River and north of Interstate 84.

- Water-mineral interactions contribute minor changes to the groundwater chemistry in the area.

- Cyclic evaporation-dissolution in the soil and vadose (unsaturated) zone is an important influence upon the groundwater constituent chemistry.

- Significant mixing between Umatilla River water and groundwater appears to occur north of Interstate 84 and east of the Umatilla River.

- Total dissolved solids (TDS) concentrations greater than the 500 mg/L secondary (aesthetic) drinking water standard generally occurred east of Highway 207 and south of Minnehaha Road.

- The distribution of some lower TDS concentration areas suggest dilution from canal and/or surface water leakage.

- Arsenic greater than the 0.050 mg/L drinking water standard occurred in a sample collected from a site within the Lamb-Weston wastewater land application area next to the U.S. Army Depot.

- Sodium in area groundwater commonly exceeds the 20 mg/L limit recommended for persons on a physician-prescribed sodium restricted diet.

- The distribution of total phosphate concentrations in area groundwater is nearly divided. Lower concentrations were generally found in groundwater sampled north of Interstate 84 and west of the Umatilla River. Higher concentrations were generally found in samples collected along or near Highway 207, south of Hermiston.

City of Umatilla to Hat Rock to Echo Meadows Area

The City of Umatilla to Hat Rock to Echo Meadows Area includes the eastern half of Range 28 East, all of Range 29 East, and Townships 3, 4, and 5 North. Historic and current land uses in the area include:

- Cities of Umatilla, Hermiston, Stanfield, and Echo;
- Umatilla, Hermiston, Stanfield, and Echo sewage treatment facilities and land applications areas;
- Unsewered residential homes;
- Food processing plants, wastewater ponds, and land application sites;
- Animal operations;
- Irrigated agriculture.

Groundwater flow in the area varies. Alluvial groundwater in the Hermiston area generally flows west to southwest where it exits toward the Umatilla River through gaps between basalt buttes. Alluvial groundwater in the terrace between Hermiston and Stanfield generally divides and flows north to northwest toward Hermiston or south to southwest toward Umatilla and Echo Meadows. Alluvial groundwater in Umatilla and Echo Meadows area generally flows northwest where it exits through a basalt gap at the Butter Creek-Umatilla River confluence.

This section presents data analyses. The analyses relied primarily upon project reconnaissance, bimonthly and synoptic sampling data. The Hermiston Foods, Incorporated and A.E. Staley Manufacturing Company data obtained by this project was limited.

Map and Data Set Observations: Nitrate

Table 4.31 and Plates 4.2 and 4.3 show the nitrate+nitrite-nitrogen concentration range and distribution in the City of Umatilla to Hat Rock to Echo Meadows area. Table 4.31 shows local concentration ranges detected by this project or reported by local facilities. Plate 4.3 shows the distribution of maximum concentrations this project detected in alluvial and basalt groundwater samples. Plate 4.2 shows the June-July 1992 concentration distribution in regional alluvial groundwater based upon synoptic sampling. Nitrate+nitrite-nitrogen concentrations detected in shallow unconfined alluvial groundwater samples and basalt groundwater samples are printed next to each sampling location.

The shape and extent of each concentration range contoured on Plate 4.2 was derived by linear interpolation between data locations. Data control was sparse in the southern portions of the terrace between Hermiston and Stanfield. This needs to be considered to avoid misinterpreting the source and movement of nitrate in that area.

Table 4.31 Nitrate concentration ranges detected in alluvial and basalt groundwater sampled from different locations in the City of Umatilla to Hat Rock to Echo Meadows area.

Area	Groundwater Source	Dominant Land Uses (Historic and Current)	Nitrate-N (mg/L)	
			Maximum	Minimum
City of Umatilla Area (Project Sampling)	Alluvial	municipal sewage treatment facility	4.20	1.70
Hat Rock Area (Project Sampling)	Alluvial	irrigated crop agriculture rural residential	6.90	4.80
Hermiston Area: North Terrace (north of Punkin Center Road) (Project Sampling)	Alluvial	animal operations rural residential irrigated crop agriculture	9.90	<0.02
Hermiston Area: North Terrace (north of Punkin Center Road) (Project Sampling)	Uncertain	animal operations rural residential irrigated crop agriculture	31.00	0.72
Hermiston Area: Basin (south of Punkin Center Road) (Project Sampling)	Alluvial	municipal sewage treatment facility unsewered residential (high density)	3.80	<0.02
Hermiston Area: Basin (south of Punkin Center Road) (Project Sampling)	Uncertain	municipal sewage treatment facility unsewered residential (high density)	4.00	<0.02
Hermiston Area: General (Project Sampling)	Basalt	municipal with sewage treatment facility rural residential crop agriculture and animal operations	1.50	0.02
Stanfield-Hermiston Corridor (Highway 395) (Project sampling)	Alluvial (shallow and deep)	irrigated crop agriculture food processing wastewater land application	12.00	<0.02
Stanfield-Hermiston Corridor (Highway 395) (Hermiston Foods, Inc. Sampling)	Alluvial	food processing wastewater land application formerly irrigated crop agriculture	9.00	4.5

Stanfield-Hermiston Loop Road: North (Project Sampling)	Alluvial	irrigated crop agriculture rural residential	19.00	0.47
Stanfield-Hermiston Loop Road: North (Project sampling)	Basalt (shallow)	irrigated crop agriculture rural residential	29.00	17.00
Stanfield-Hermiston Loop Road: North (Project Sampling)	Uncertain	irrigated crop agriculture rural residential	20.00	4.30
Stanfield-Hermiston Loop Road: South (Project Sampling)	Alluvial	municipal with sewage treatment facility irrigated crop agriculture rural residential	7.30	1.20
Echo and Umatilla Meadows Area (Project Sampling)	Alluvial	municipal with sewage treatment facilities irrigated crop agriculture rural residential	8.60	0.44
Echo and Umatilla Meadows Area (A.E. Staley Manufacturing Company Sampling)	Alluvial	wastewater land application Stanfield sewage treatment facility	6.50	<0.50
Echo and Umatilla Meadows Area (Project sampling)	Alluvial (Shallow Unconfined)	wastewater land application Stanfield sewage treatment facility	4.50	0.60
Echo and Umatilla Meadows Area (A.E. Staley Manufacturing Company Sampling)	Alluvial (Shallow Unconfined)	wastewater land application Stanfield sewage treatment facility	10.00	<0.50
Echo and Umatilla Meadows Area (Project Sampling)	Basalt (shallow and deep)	municipal with sewage treatment facilities irrigated crop agriculture rural residential	2.70	<0.02

Note: Project sampling reports nitrate concentrations as nitrate+nitrite-nitrogen.
Note: Shallow refers to wells less than 300 feet deep.
Note: Deep refers to wells 300 feet or more deep.

Sources:
Project Sampling
DEQ Water Quality File 9584
DEQ Water Quality File 104738
Barlow and Scott, 1991a
Barlow, Scott, and Urban, 1992

Project sampling detected nitrate+nitrite-nitrogen exceeding the 10 mg/L drinking water standard in alluvial groundwater samples collected at UMA 153 and UMA 154 located on the terrace north of Hermiston. Concentrations measured 31 mg/L and 12 mg/L in samples from UMA 153 and UMA 154, respectively. Well UMA 153 is located at City Beef Feedlot and downgradient of crop agriculture where center pivot irrigation currently occurs. Well UMA 154 is located at a West Locust Road rural residential home among irrigated crop agriculture and some livestock. Chloride versus potassium graphical analysis indicates crop irrigation primarily influences groundwater at both sites (see Appendix 4H).

Nitrate+nitrite-nitrogen concentrations in alluvial groundwater sampled from other north terrace sites remained below 10 mg/L. Some sites had groundwater nitrate concentrations approaching 10 mg/L. Constituent versus constituent graphical analysis indicates different influences at each of those sites. For example, the analysis indicates a septic system influence at UMA 055 and UMA 057, an irrigation influence at UMA 158, and an animal waste influence at UMA 108. Additional analysis generally indicates a septic system influence at sites with groundwater nitrate concentrations below 5 mg/L.

Nitrate+nitrite-nitrogen concentrations remained below 5 mg/L in project samples collected in the Hermiston basin. Higher concentrations were anticipated in samples collected near Diagonal Road where numerous residential homes are located. Review of Plates 4.2 and 4.5 as well as a NETPATH computer groundwater chemistry model indicates dilution from canal leakage is primarily responsible for the lower concentrations in the alluvial groundwater.

Project sampling detected nitrate+nitrite-nitrogen exceeding the 10 mg/L drinking water standard in alluvial and basalt groundwater samples collected at sites on the terrace between Hermiston and Stanfield. Pesticides detected and constituent versus constituent graphical analysis indicates irrigation and septic systems influences. Pesticides detected in some samples strongly indicate an irrigated crop agriculture influence. Atrazine and ethylene dibromide were detected in alluvial samples collected from UMA 044 where groundwater nitrate concentrations ranged from 12 to 16 mg/L. Dacthal acid was detected in alluvial and basalt groundwater samples collected from UMA 156 and UMA 125, respectively. Nitrate concentrations ranged from 7.90 mg/L to 19 mg/L in UMA 156 samples and 17 to 29 mg/L in UMA 125 samples. Constituent versus constituent graphical analysis indicate septic systems influence groundwater at UMA 042, UMA 087 and UMA 152 where nitrate concentrations in project samples reached 13 mg/L, 20 mg/L and 12 mg/L, respectively (see Appendix 4H).

Nitrate+nitrite-nitrogen concentrations remained below 10 mg/L in project alluvial and basalt groundwater samples collected in the Echo and Umatilla Meadows area. However, nitrate-nitrogen reached 10 mg/L in a shallow unconfined alluvial groundwater sample collected by A.E. Staley Manufacturing. The sample came from a well located within the Staley wastewater land application area and near Stage Gulch. The gulch conveyed City of Stanfield treated sewage wastewater to the Umatilla River during the sampling period reported. Project TKN data related to the land application site indicates an organic nitrogen source. Constituent versus constituent graphical analysis of the project data indicates wastewater irrigation is the primary influence at the site.

Nitrate+nitrite-nitrogen concentrations in alluvial groundwater at UMA 193 reached 8.60 mg/L . The well is located in an Echo and Umatilla Meadows downgradient area. Constituent versus constituent graphical analysis indicate an irrigation related influence (see Appendix 4H).

Dilution from canal leakage may be responsible for nitrate concentrations remaining below 10 mg/L in the Echo and Umatilla Meadows area. Evidence of canal leakage influencing local groundwater chemistry came from sampling groundwater and ditch water at UMA 189 in August 1991. A major thunderstorm occurred in the area the day before project staff sampled at UMA 189. The storm caused river, canal and ditch sediment loads to increase. The UMA 189 well owner informed project staff that water from his well turned dirty shortly after the storm. This prompted project field staff to conduct field conductivity and alkalinity tests of nearby ditch water as well as for the groundwater sample. The field measurements for the two sources nearly matched indicating a likely surface water influence upon local groundwater.

Map and Data Set Observations: Total Dissolved Solids

Plates 4.4 and 4.5 show the total dissolved solids (TDS) concentration distribution in the City of Umatilla to Hat Rock to Echo Meadows area. Plate 4.5 shows the maximum concentration detected in alluvial and basalt groundwater samples. Plate 4.4 shows the June-July 1992 TDS concentration distribution in regional alluvial groundwater based upon project synoptic sampling. The shape and extent of each concentration range contoured was derived by linear interpolation between data locations. TDS concentrations detected in shallow unconfined alluvial groundwater samples and basalt groundwater samples are printed next to each sampling location.

The TDS concentration distribution is similar to the nitrate concentration distribution. Concentrations exceeded the 500 mg/L secondary (aesthetic) drinking water standard in project groundwater samples collected at some sites on the terraces north and south of Hermiston and at a Hat Rock site. Alluvial groundwater with lower TDS concentrations occurs within the Hermiston basin, the terrace south of Hermiston, and within Echo and Umatilla Meadows. Review of Plate 4.4 found the distribution of lower TDS concentrations in alluvial groundwater within the Hermiston basin and the terrace south of Hermiston coincided very well with surface water canals. This strongly indicates leaky canals locally influence alluvial groundwater chemistry.

Map and Data Set Observations: Other Constituents

Arsenic was detected in project samples collected primarily adjacent and north of Stanfield. Plate 4.6 shows the maximum concentration distribution. One sample contained arsenic above the drinking water standard of 0.050 mg/L. That sample came from UMA 260 located within the A.E. Staley wastewater land application area. The arsenic concentration measured 0.074 mg/L.

Plate 4.7 shows the maximum concentration distribution for sodium. Concentrations in project groundwater samples frequently exceeded the 20 mg/L limit currently recommended for persons on a physician prescribed sodium restricted diet. Groundwater samples with concentrations exceeding 50 mg/L came primarily from terrace sites.

Plate 4.8 shows the maximum concentration distribution for chloride. Concentrations in project groundwater samples remained within the 250 mg/L secondary (aesthetic) drinking water standard except for one UMA 125 sample. Project laboratory analysis reported the concentration as 490 mg/L. Chloride in other UMA 125 samples remained below 40 mg/L. The well is located on the north side of the south Hermiston terrace.

Plate 4.9 shows the maximum concentration distribution for total phosphate in groundwater sampled by this project. The concentration distribution appears nearly divided. Relatively higher concentrations were detected in samples from the terrace north of Hermiston, the eastern portion of the Hermiston basin, and the Echo and Umatilla Meadows area. The relatively lower concentrations were detected in groundwater sampled within the west Hermiston area and the terrace south of Hermiston.

Plate 4.10 shows the maximum concentration distribution for boron in project samples collected in the area. Groundwater samples with detected boron came from the City of Umatilla, Hat Rock, the terrace north of Hermiston, west Hermiston, along Diagonal Road, the northern portion of the terrace south of Hermiston, and the eastern portion of Umatilla and Echo Meadows areas. The highest boron concentrations detected for the area came from samples collected within the City of Echo vicinity.

Project sampling detected bromide in groundwater sampled from most of the area (see Plate 4.11). Bromide was not detected in groundwater from the central and southeastern portion of Umatilla and Echo Meadows area nor the northeastern portion of the terrace south of Hermiston. The greatest bromide concentrations detected area groundwater came from the central portion of the terrace south of Hermiston.

Plate 4.12 shows the maximum concentration distribution for vanadium for project samples collected in the area. Groundwater samples with detected boron came primarily from the Stanfield area and sites east of Highway 395 and southeast of Diagonal Road. Area samples with relatively higher vanadium concentrations came from the Stanfield vicinity.

Table 4.32 and Plate 4.13 show local sites where project sampling detected volatile organic compounds (VOC) and/or pesticides. Appendix 4G provides a complete listing. In addition to project sampling, the City of Hermiston reported detecting tetrachloroethene, 1,1,1-TCA, toluene, and total xylenes in alluvial groundwater as well as dacthal and picloram in basalt groundwater within the Hermiston area (Loeb, 1992, Bidleman, 1993). These detections strongly indicate a human activity influence upon groundwater.

Table 4.32 Volatile organic compounds and pesticides detected in the City of Umatilla to Hat Rock to Echo Meadows area.

Site	Groundwater Source	Location	Constituent	Concentration	Nitrate+Nitrite-Nitrogen Concentration (mg/L)
UMA 044	Alluvial	South Edwards Road north of Stanfield-Hermiston Loop Road	Ethylene Dibromide	0.0015 - 0.0026 mg/L	12.00 - 16.00
UMA 044	Alluvial	South Edwards Road north of Stanfield-Hermiston Loop Road	Atrazine	1.30 ug/L	12.00 - 16.00
UMA 067	Uncertain	Stanfield Junction area (Highway 395 - Interstate 84)	Atrazine	2.30 ug/L	3.40
UMA 068	Alluvial	Northwest Hermiston	Atrazine	0.60 ug/L	0.03 - 0.04
UMA 101	Alluvial	Hermiston-Stanfield Corridor	Chloroform	0.0028 mg/L	4.50 - 4.60
UMA 116	Alluvial	East Punkin Center Road	Tetrachloro-ethylene	0.0011 mg/L	3.00 - 3.60
UMA 125	Alluvial	north Stanfield-Hermiston Loop Road area	Dacthal acid	0.60 - 20.00 ppb	17.00 - 29.00
UMA 156	Alluvial	north Stanfield-Hermiston Loop Road area	Dacthal acid	0.10 - 11.00 ppb	7.90 - 19.00
UMA 191	Alluvial	City of Echo sewage lagoons site	Atrazine	non detect - 0.60 ug/L	0.44 - 1.20

Note: Data from Lower Umatilla Basin project sampling.

Note: Laboratory methods can occasionally cause chloroform detections at low concentrations

Graphical Analyses: Nitrate versus Time

Graphical analysis of City of Umatilla to Hat Rock to Echo Meadows area groundwater data included reviewing nitrate versus time graphs. Data analyzed came from project bimonthly sampling. The analysis included comparing the nitrate versus time graphs to other constituent versus time graphs.

Figure 4.61 shows nitrate+nitrite-nitrogen versus time in alluvial groundwater sampled in the City of Umatilla and the Hat Rock areas. Table 4.33 presents how the nitrate versus time graphs compared to the other constituent versus time graphs for each sampling site. The areas are geographically and hydrogeologically separated from each other.

Well UMA 038 is located in an unsewered residential and small agriculture area adjacent to the City of Umatilla. Constituent versus constituent graphical analysis (Appendix 4H) indicates a mixed septic system and animal waste influence. Animal activity does occur south of the city.

Well UMA 066 is located at Hat Rock within a mobile home park near irrigated crop agriculture. The nitrate concentration versus time is consistent with a constant nitrate source such as a septic system. However, constituent versus constituent graphical analysis indicates a mixed septic system, animal waste, and possible irrigation influence (see Appendix 4H). Project investigators are not aware of any animal operation or animal waste use in the area.

Figure 4.62 shows nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater sampled from the terrace north of Hermiston. Table 4.34 presents how the nitrate versus time graphs compared to the other constituent versus time graphs for each sampling site. The nitrate concentrations remain below 5 mg/L. Constituent versus constituent graphical analysis indicates a predominantly septic system influence at these particular sites.

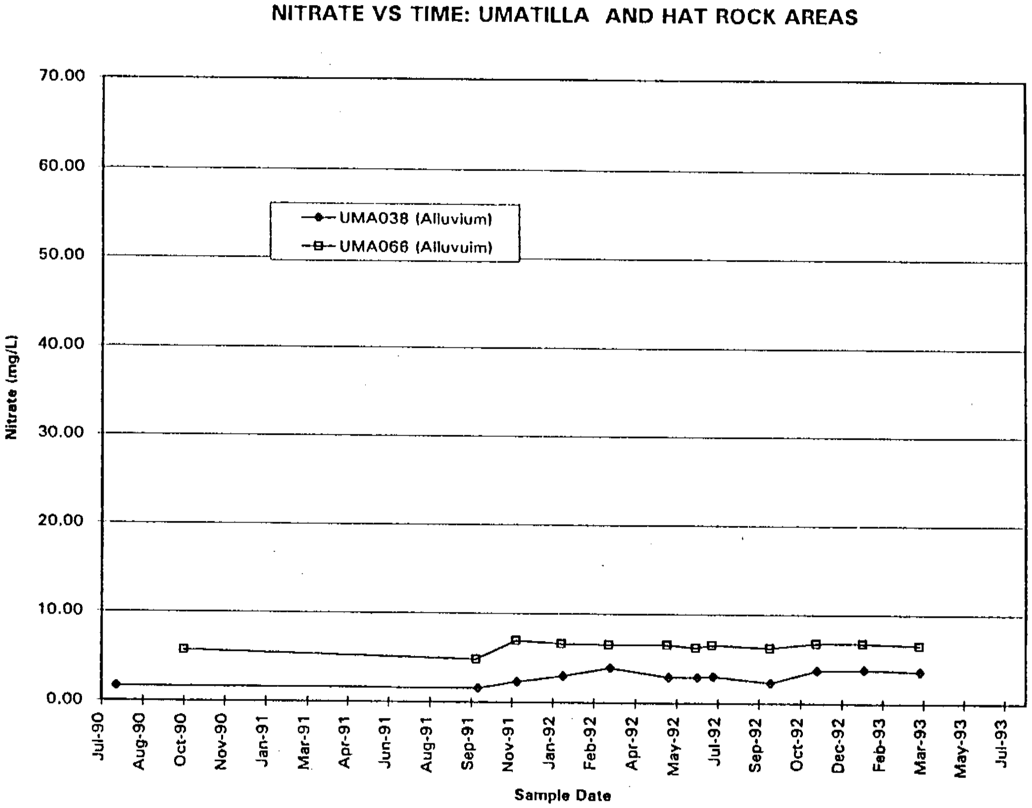


Figure 4.61 Nitrate+nitrite-nitrogen versus time in City of Umatilla and Hat Rock area alluvial groundwater at project bimonthly groundwater sampling sites.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.33 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the City of Umatilla and Hat Rock areas.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 038 (Alluvial)	WS	S	WS	S	WS	WS	I	NS
UMA 066 (Alluvial)	NS	NS	S	NS	WS	S and I	WS	WS

Note: The comparisons were qualitative versus quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

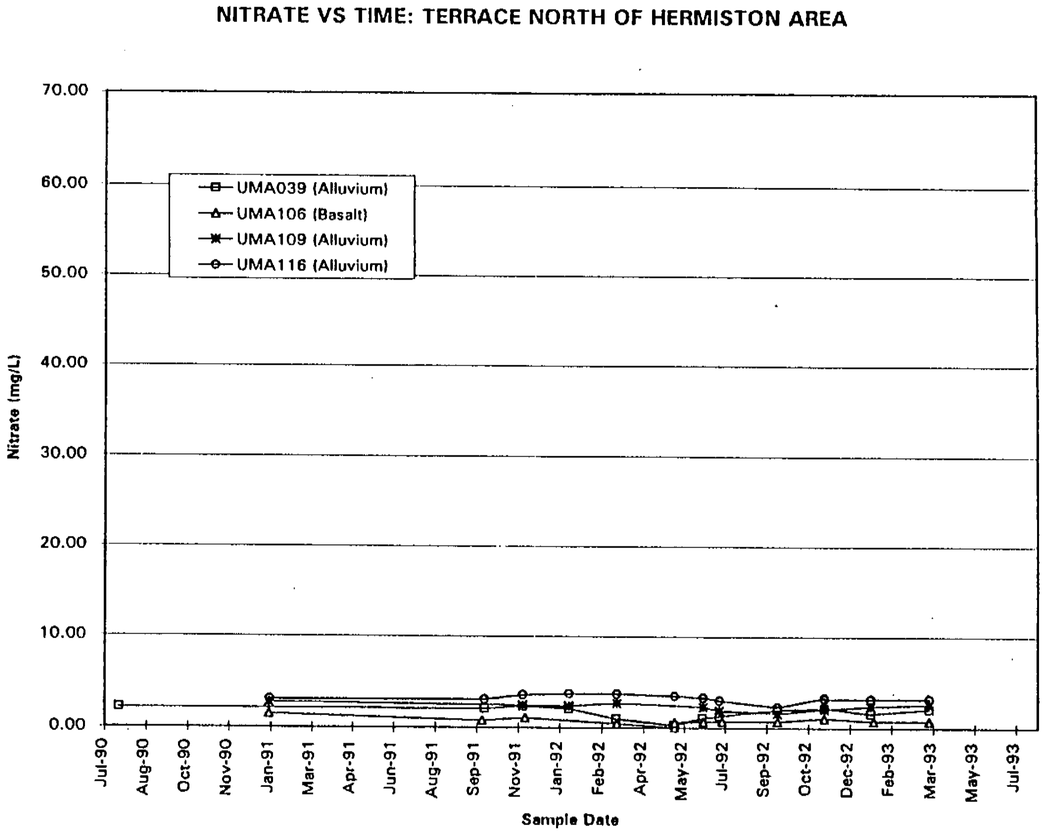


Figure 4.62 Nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater from project bimonthly groundwater sampling sites in the Hermiston area north terrace.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.34 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the Hermiston area north terrace.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 039 (Alluvial)	WS	S	S	S	S	S	I	NS
UMA 106 (Basalt)	WS	S	S	WS	WS	WS	I	WS
UMA 109 (Alluvial)	WS	S	I	WS	S and I	WS	I	S
UMA 116 (Alluvial)	S	S	S	S	S and I	WS	WS	WS

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Figure 4.63 shows nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater sampled from the terrace south of Hermiston. Table 4.35 presents how the nitrate versus time graphs compared to the other constituent versus time graphs for each sampling site. All the sites are located within an irrigated crop agriculture area with some rural residential homes.

The nitrate concentration at UMA 046 remains below 5 mg/L with little to no variability. The site is located near the upgradient margin of local irrigated agriculture and close to a canal. The canal appears responsible for lower nitrate and TDS concentrations observed in the area.

Canals nearly surround UMA 056 which is located adjacent to a former hog operation and downgradient of irrigated crop agriculture. The nitrate versus time graph for the site shows small seasonal fluctuations. Constituent versus constituent graphical analysis of UMA 056 data (Appendix 4H) suggests an irrigation related influence, which could include canal leakage.

The nitrate versus time graphs for UMA 110, UMA 125, and UMA 156 show notable fluctuation. Each site is located among irrigated crops. The seasonal fluctuations as well as pesticide detections in UMA 125 and UMA 156 samples strongly indicate an irrigated crop agriculture influence. Constituent versus constituent graphical analysis suggests an additional influence from septic systems (see Appendix 4H).

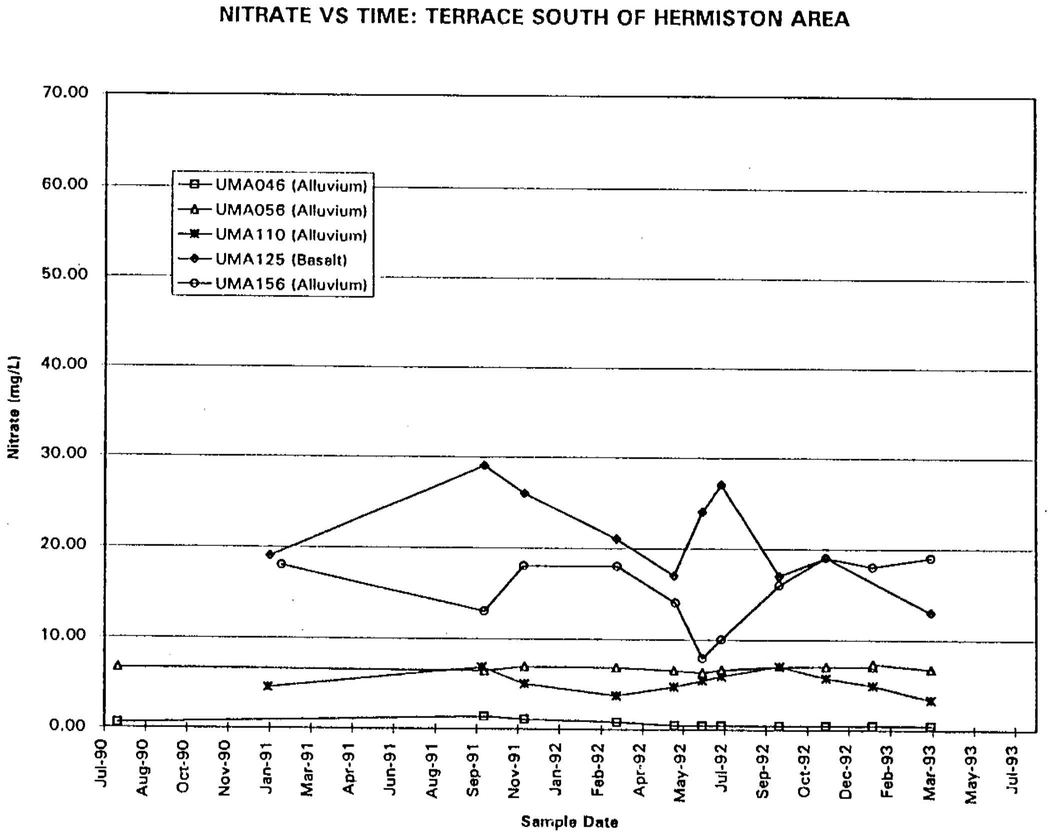


Figure 4.63 Nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater from project bimonthly groundwater sampling sites in the north Stanfield-Hermiston Loop Road area.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.35 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the north Stanfield-Hermiston Loop Road area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 046 (Alluvial)	S and NS	S	S	S and NS	S	S	U	
UMA 056 (Alluvial)	WS	I	WS	U	S	S	S	S
UMA 110 (Alluvial)	S	S	S	S	S and I	S	S	WS
UMA 125 (Basalt)	S	S	S	S	S	S	NS	S
UMA 156 (Alluvial)	S	S	S	I	S	S and I	S	S and I

Note: The comparisons were qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Figure 4.64 shows nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater sampled from the City of Stanfield vicinity. Table 4.36 presents how the nitrate versus time graphs compared to the other constituent versus time graphs for each sampling site. Nitrate concentrations in the project samples remained below 5 mg/L. Dilution could account for the lower nitrate concentrations since both sites are located near a canal.

Constituent versus constituent graphical analysis indicates an irrigation related influence at both sites and perhaps a septic system influence too (see Appendix 4H). Well UMA 047 is located within a unsewered area near an irrigated field. Well UMA 048 is located within a sewered area some distance downgradient of irrigated crop activity.

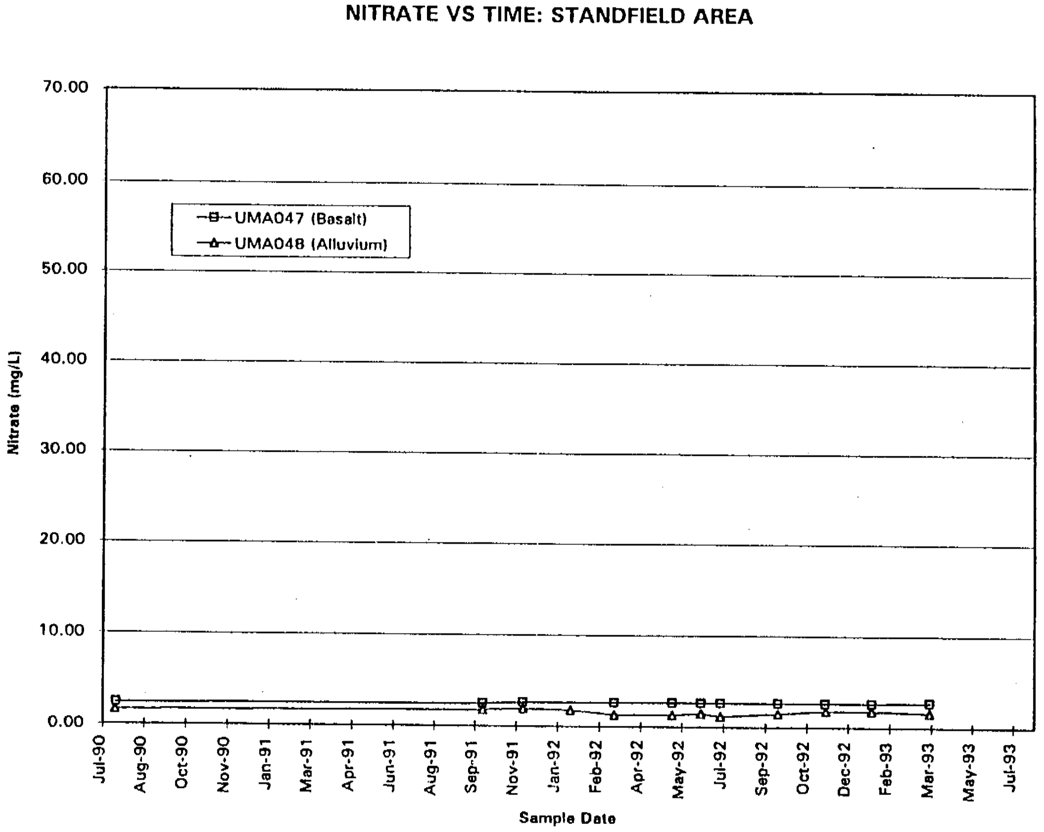


Figure 4.64 Nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater from project bimonthly groundwater sampling sites in the Stanfield area.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.36 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the City of Stanfield area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 047 (Basalt)	S	WS	WS	U	NS	NS	S	U
UMA 048 (Alluvial)	S	I	I	WS	S	S	I	NS

Note: The comparisons were qualitative rather than quantitative.

Note: S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Figure 4.65 shows nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater sampled from the City of Echo area. Table 4.37 presents how the nitrate versus time graphs compared to the other constituent versus time graphs for each sampling site. Nitrate concentrations in the project samples remained below 5 mg/L. Dilution could account for the lower nitrate concentrations since both sites are located near canals.

Constituent versus constituent graphical analysis indicates an irrigation related influence at both sites (see Appendix 4H). Well UMA 190 is located in the Umatilla River flood plain near irrigated crop agriculture. Well UMA 191 is located in the flood plain adjacent to the City of Echo municipal wastewater lagoons and near field crops and irrigated pasture. The municipal lagoons are lined to control leakage. Atrazine was repeatedly detected in UMA 191 samples which strongly indicates an agricultural influence.

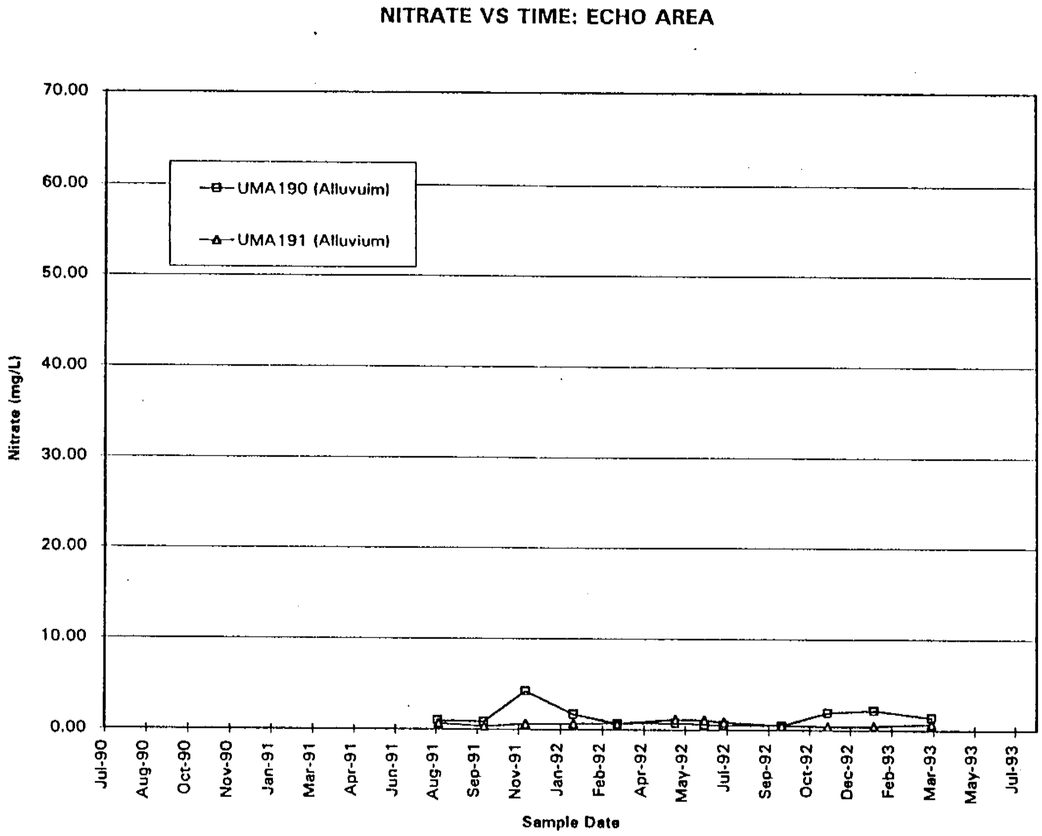


Figure 4.65 Nitrate+nitrite-nitrogen versus time in alluvial and basalt groundwater from project bimonthly groundwater sampling sites in the City of Echo area.

Note: A 0 to 70 mg/L concentration range is used to facilitate graphical comparisons.

Table 4.37 Results of comparing nitrate+nitrite-nitrogen versus time graphs to other constituent versus time graphs for data related to project bimonthly groundwater sampling sites in the City of Echo area.

Site	Other Constituent versus Time Graphs Compared to Nitrate+Nitrite versus Time							
	Total Dissolved Solids	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Total Phosphate	Boron
UMA 190 (Alluvial)	S	S	S	S	S	S	I	S
UMA 191 (Alluvial)	S	S	S	S	S and I	WS	U	U

Note: The comparisons are qualitative rather than quantitative.

Note:
S = graphs similar to the nitrate+nitrite-nitrogen versus time graph
WS = graphs weakly similar to the nitrate+nitrite-nitrogen versus time graph
NS = graphs not similar to the nitrate+nitrite-nitrogen versus time graph
I = graphs inverse to the nitrate+nitrite-nitrogen versus time graph
U = unable to determine a similar, inverse, or no similarity relationship

Graphical Analyses: Piper Trilinear Graphs and Schoeller Diagrams

Project bimonthly and synoptic groundwater sampling data related to the City of Umatilla to Hat Rock to Echo Meadows area were plotted on Piper trilinear and Schoeller diagrams. Both graphs proved useful for observing data variation over time or location. The trilinear graphs were also used to classify the groundwater chemistry and observe any mixing relationships. Table 4.38 shows the groundwater chemistry classifications observed by general location and groundwater source.

The groundwater chemistry data related to smaller areas within the City of Umatilla to Hat Rock to Echo Meadows area graphed differently. The groundwater chemistry variability or lack of variability by location and/or time differed. Variability among cation proportions versus anion proportions also differed. However, for nearly all areas, the chemical variability correlated to nitrate variability. The following discussion presents observations for the terrace north of Hermiston, the Hermiston basin, the terrace south of Hermiston, and Echo-Stanfield areas.

Project data indicates that the composition of alluvial groundwater in the terrace north of Hermiston varies by location (Figures 4.66 and 4.67). Cation proportions vary little. The increasing sulfate and chloride proportions (in Figure 4.67) correspond to higher nitrate concentrations, and they graph in a manner indicative of a mixing relationship. Conversely, project bimonthly nitrate and other chemistry data for north terrace alluvial groundwater varied little over time (Figures 4.68 and 4.69). The lack of variation over time in project data does not eliminate the possibility of groundwater chemistry time variation at other north terrace sites.

Table 4.38 Observed Piper Trilinear water chemistry classification of alluvial and basalt groundwater sampled from the City of Umatilla to Hat Rock to Echo Meadows area.

Area	Groundwater Source	Groundwater Chemistries Observed
Hat Rock Area (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Hermiston Area: North Terrace (north of Punkin Center Road) (Project Sampling)	Alluvial	calcium/bicarbonate
Hermiston Area: Basin (south of Punkin Center Road) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Hermiston Area: General (Project Sampling)	Basalt (shallow and deep)	mixed-cation/bicarbonate sodium + potassium/bicarbonate
Stanfield-Hermiston Corridor (Highway 395) (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate sodium + potassium/bicarbonate no dominant type
Stanfield-Hermiston Loop Road: North (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate no dominant type
Stanfield-Hermiston Loop Road: North (Project Sampling)	Basalt (shallow)	mixed-cation/bicarbonate
Stanfield-Hermiston Loop Road: South (Project Sampling)	Alluvial	mixed-cation/bicarbonate no dominant type
Echo and Umatilla Meadows Area (Project Sampling)	Alluvial	mixed-cation/bicarbonate calcium/bicarbonate
Echo and Umatilla Meadows Area (Project Sampling)	Alluvial (Shallow Unconfined)	mixed-cation/bicarbonate calcium/bicarbonate sodium + potassium/bicarbonate
Echo and Umatilla Meadows Area (Project Sampling)	Basalt (shallow and deep)	mixed-cation/bicarbonate sodium + potassium/bicarbonate

Note: Project bimonthly and synoptic groundwater sampling data was used for the groundwater chemistry classifications
Note: Shallow refers to wells less than 300 feet deep.
Note: Deep refers to wells 300 feet or more deep.

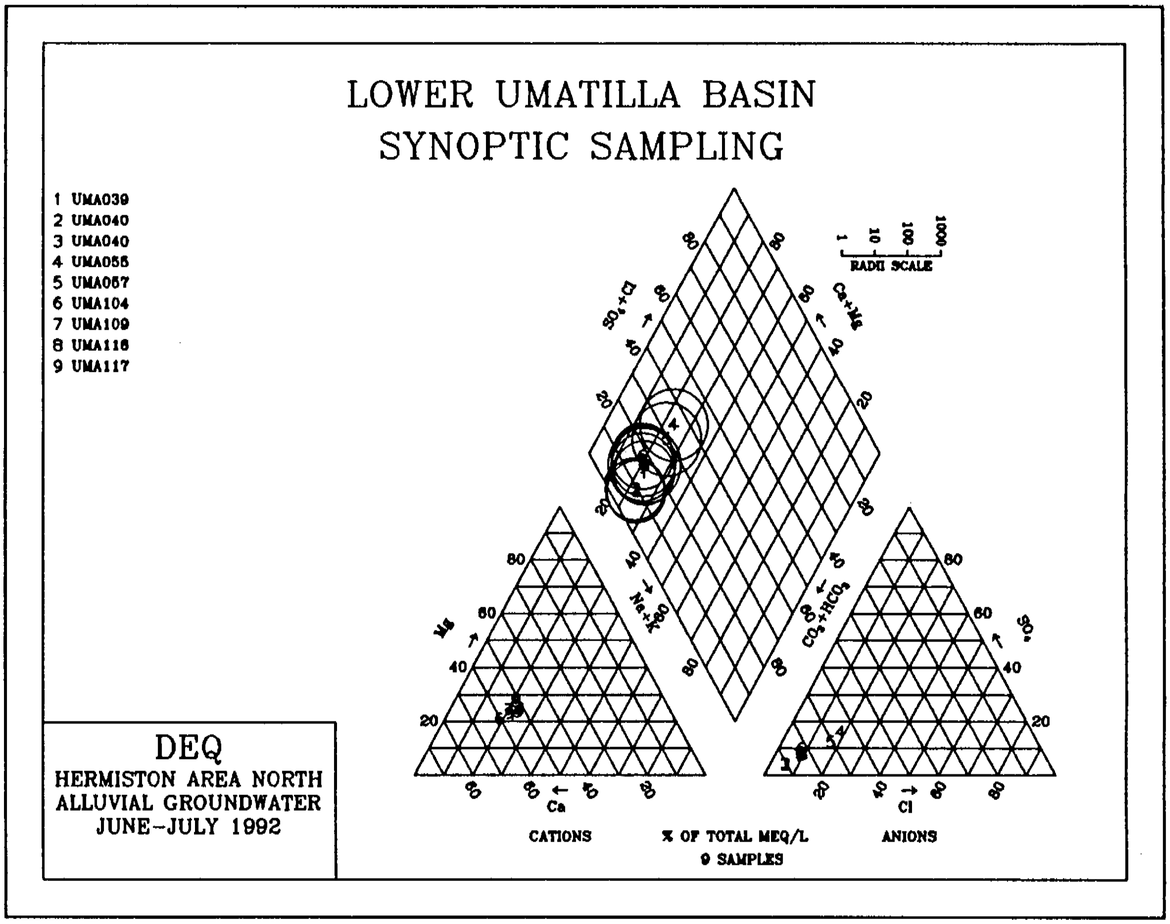


Figure 4.66 Piper Trilinear graph of project synoptic sampling data for alluvial groundwater collected from the terrace north of Hermiston.

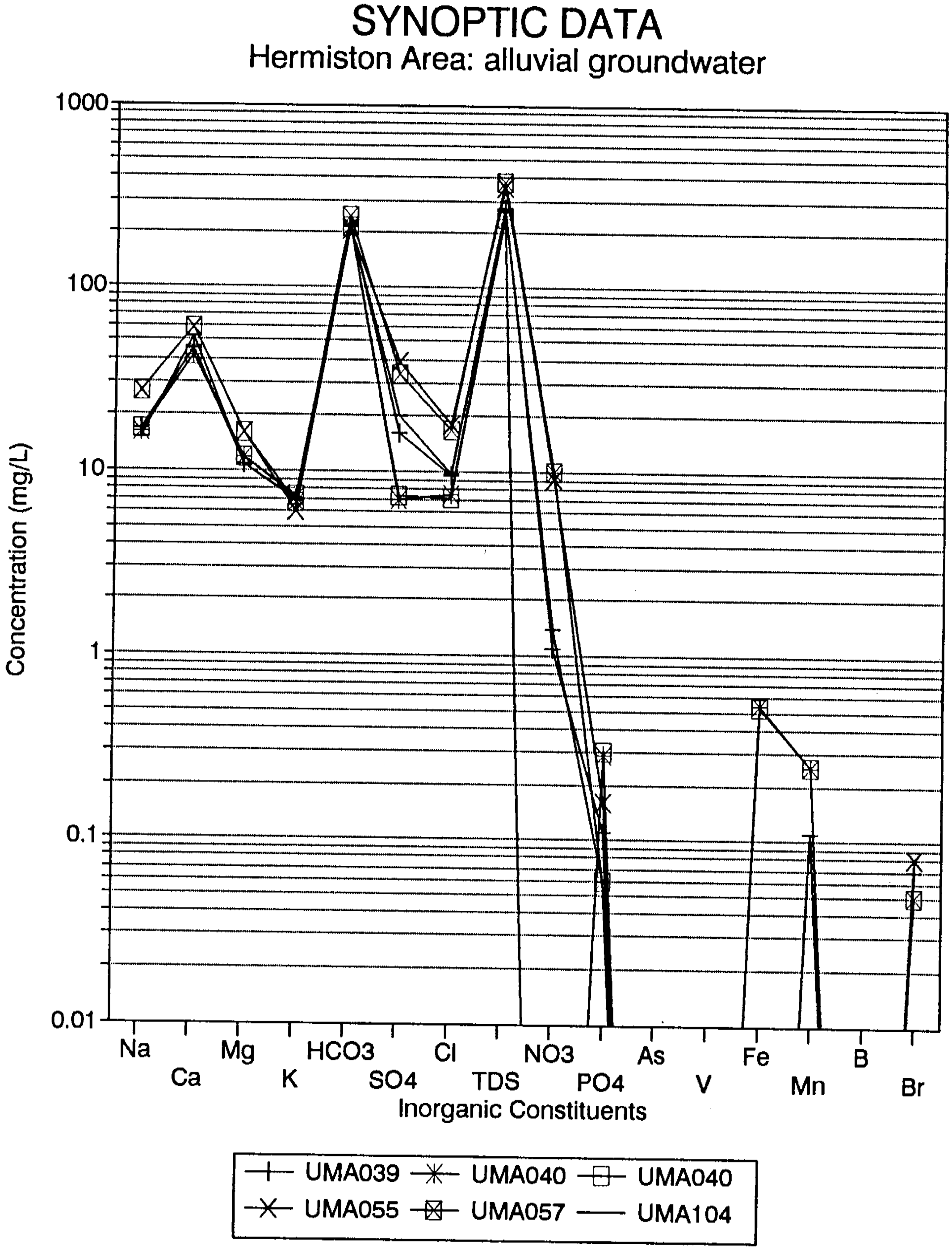


Figure 4.67 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected from the terrace north of Hermiston.

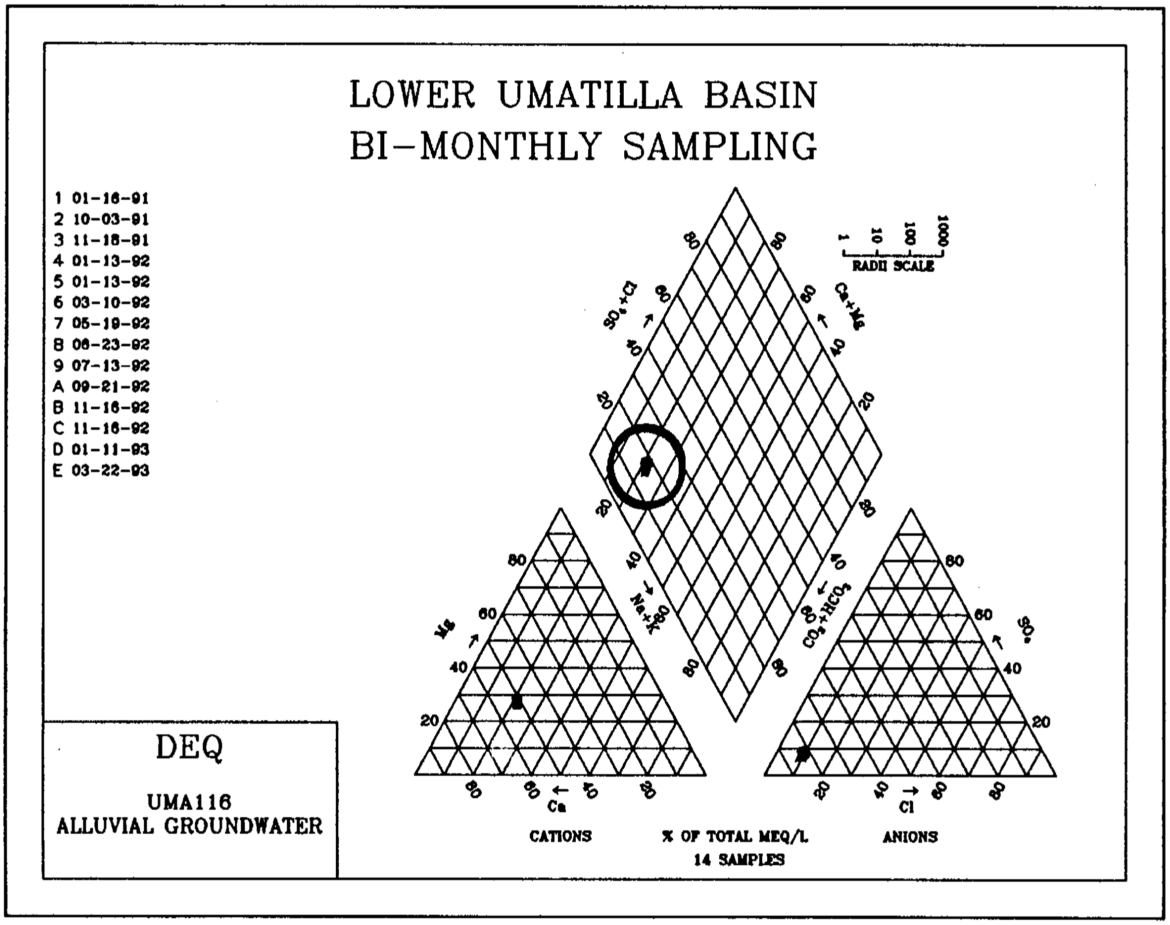


Figure 4.68. Piper Trilinear graph of project bimonthly sampling data for alluvial groundwater collected at UMA 116 located on the terrace north of Hermiston.

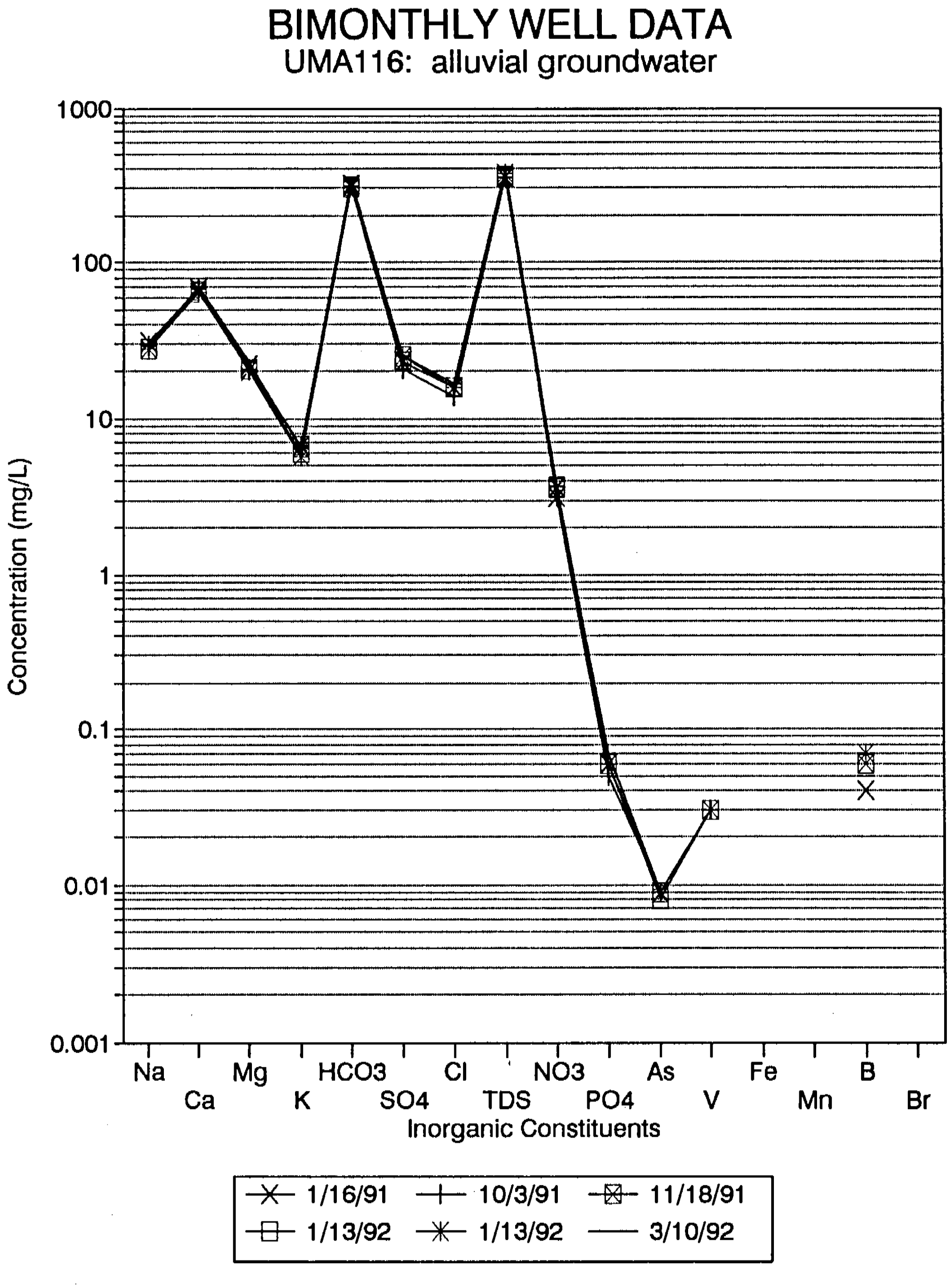


Figure 4.69 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 116 located on the terrace north of Hermiston.

Project data shows small variation in alluvial groundwater chemistry in the Hermiston basin by location and over time. Similarly, the nitrate concentrations vary little. Nitrate remained below 5 mg/L in Hermiston basin alluvial groundwater samples.

Project data indicates alluvial groundwater in the terrace south of Hermiston chemically varies by location and varies over time at most sites. Figures 4.70 and 4.71 show the variability by location. Both cation and anion proportions vary. Higher chloride and magnesium proportions correspond to higher nitrate concentrations for the two mixing lines apparent on Figure 4.71. The end members and processes responsible for the mixing lines were not identified. Figures 4.72 and 4.73 show the chemical variability over time in alluvial groundwater at UMA 156. Generally, higher chloride proportions corresponded to higher nitrate concentrations over time in project bimonthly samples from this area. The cation proportions relationship to nitrate concentration over time was not as consistent. For some sites, higher calcium and magnesium proportions corresponded to higher nitrate concentrations over time. They did not correspond at other sites.

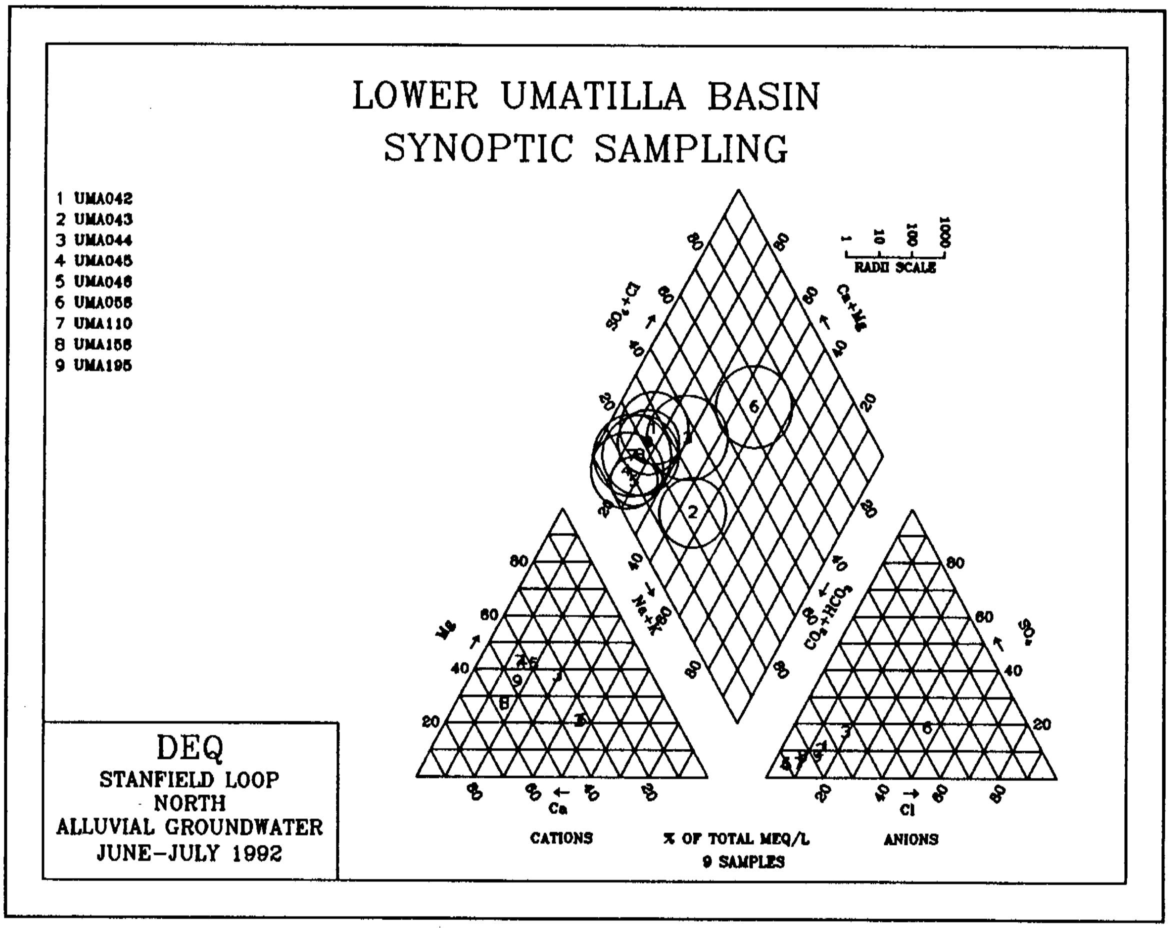


Figure 4.70 Piper Trilinear graph of project synoptic sampling data for alluvial groundwater collected from the terrace south of Hermiston.

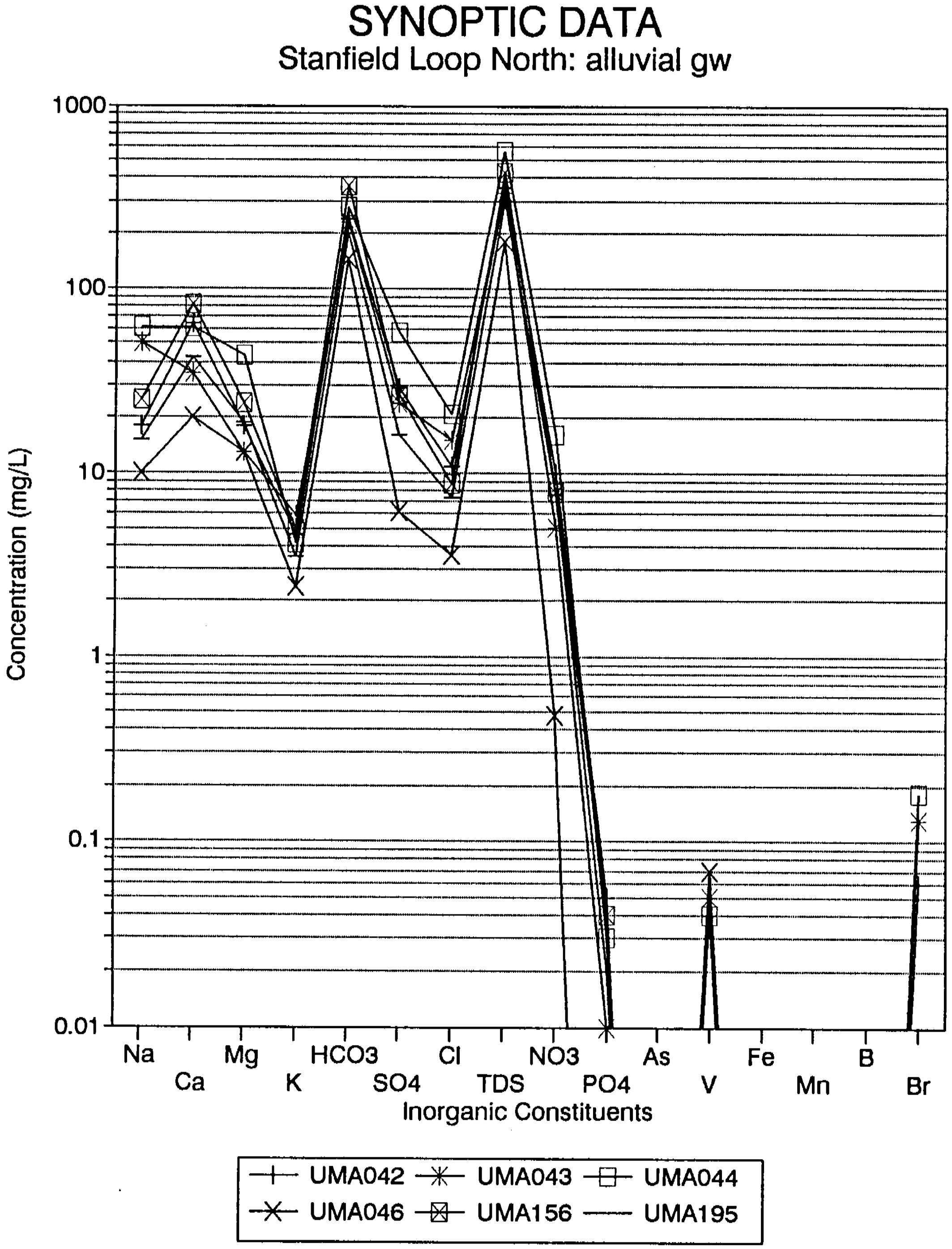


Figure 4.71 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected from the terrace south of Hermiston.

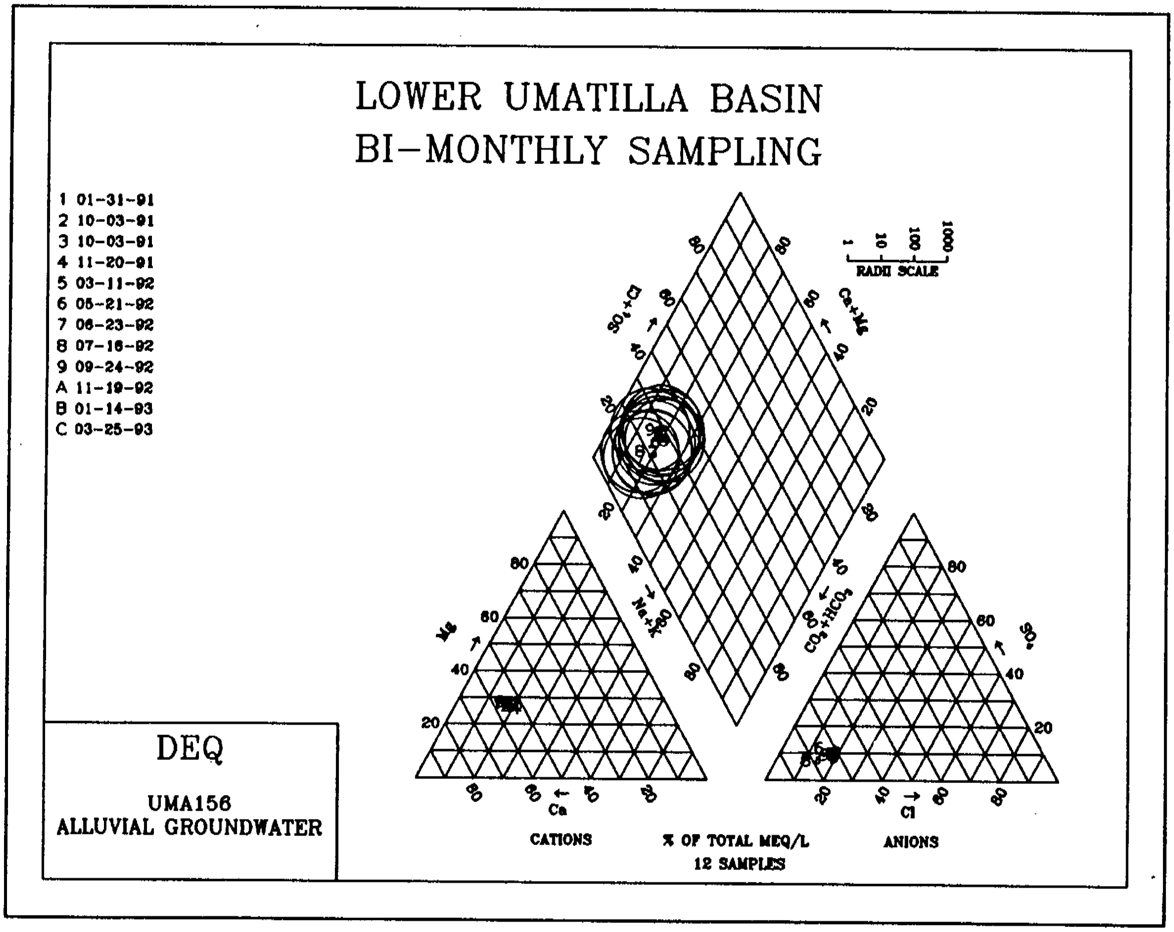


Figure 4.72 Piper Trilinear graph of project bimonthly sampling data for alluvial groundwater collected at UMA 156 located on the terrace south of Hermiston.

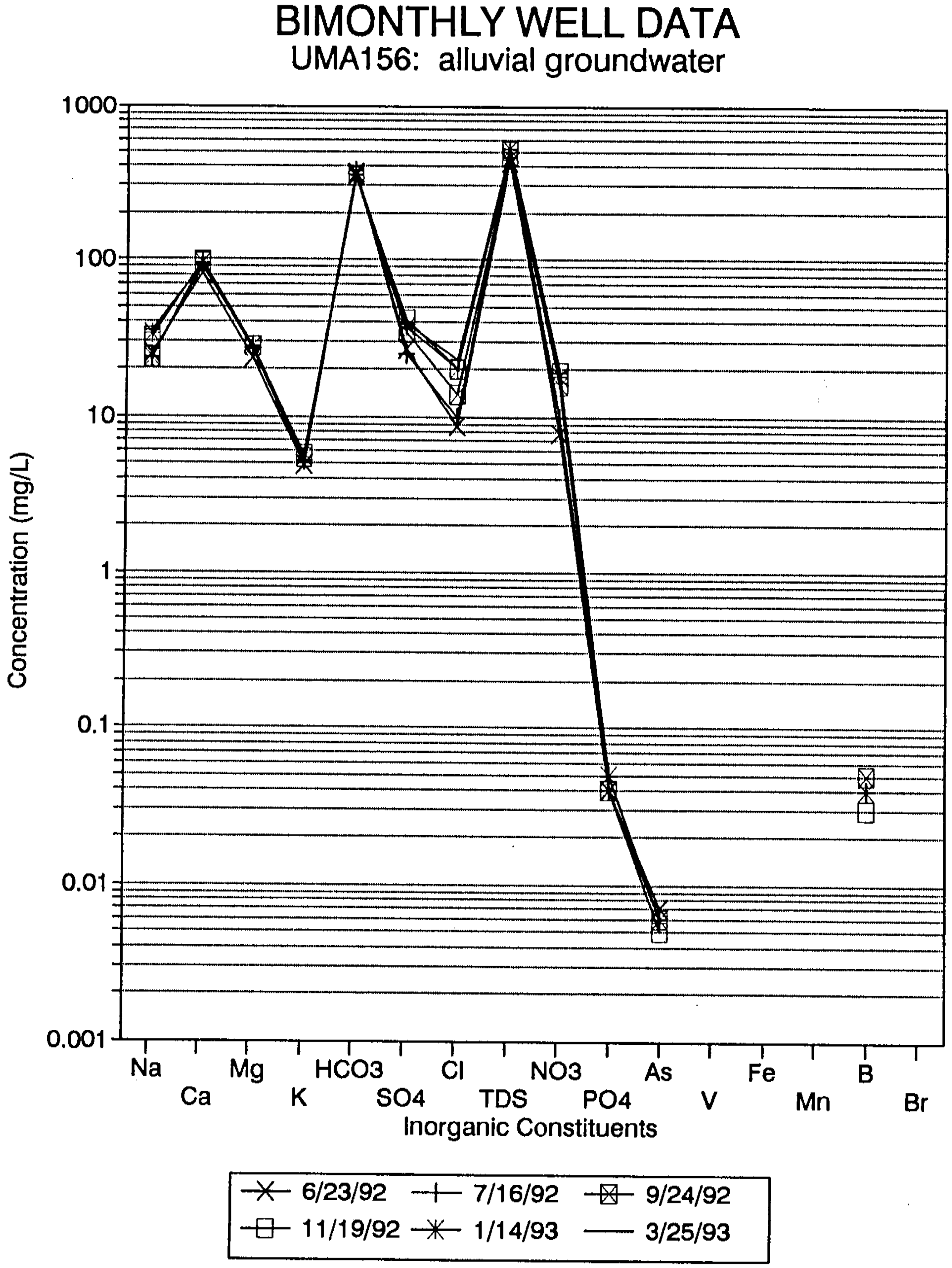


Figure 4.73 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 156 located on the terrace south of Hermiston.

Project data indicates alluvial groundwater in the Echo-Stanfield area chemically varies by location and over time at most sites. Figures 4.74 and 4.75 show the chemical variability in local alluvial groundwater by location. Cation proportions (primarily calcium versus sodium) vary the most. The usual nitrate concentration to ion ratio relationship was not observed. Figures 4.76 and 4.77 are an example of chemical variability in groundwater over time at UMA 190. The data varies along a mixing line Figure 4.77. Anion proportions vary the most and they relate in the usual manner to nitrate concentrations.

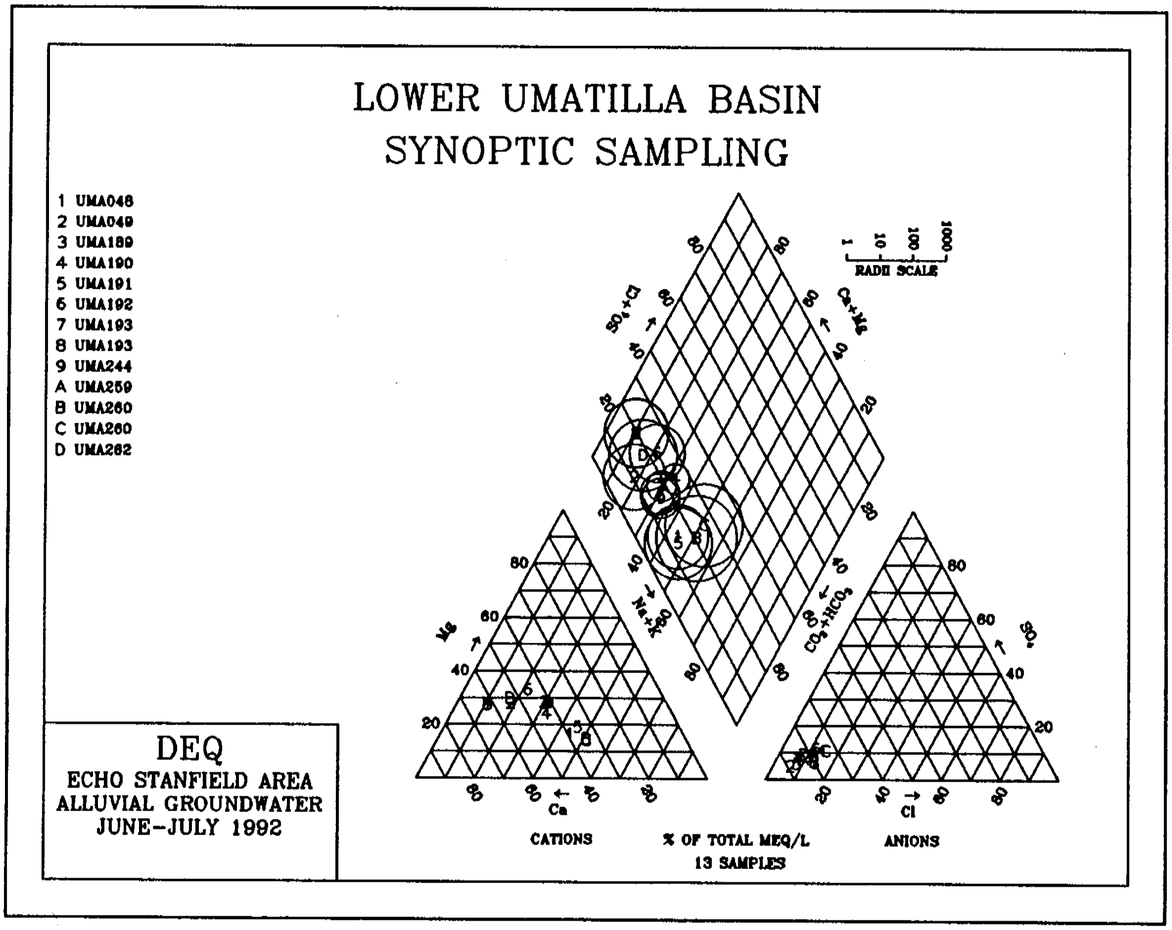


Figure 4.74 Piper Trilinear graph of project synoptic sampling data for alluvial groundwater collected in the Echo-Stanfield area.

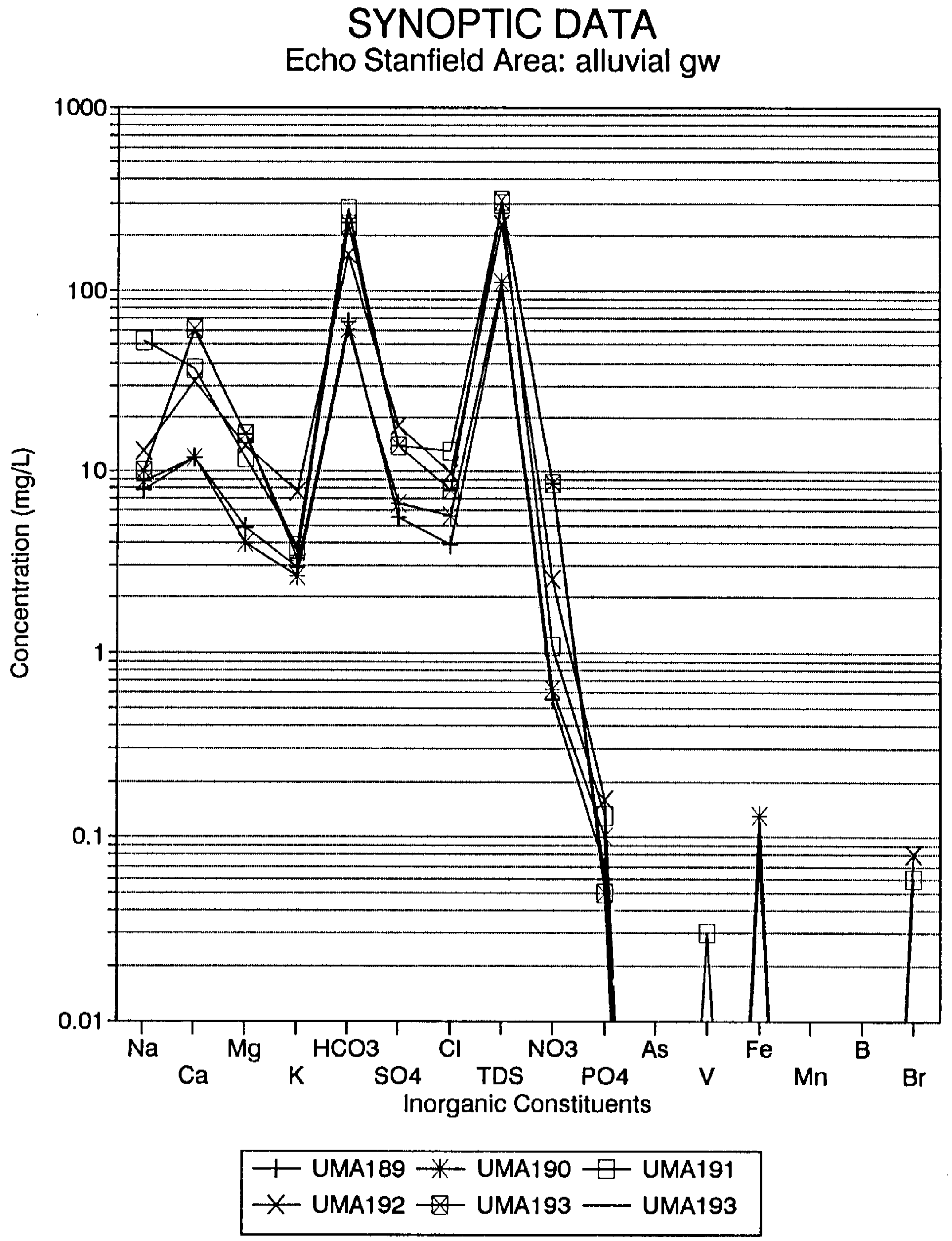


Figure 4.75 Schoeller Diagram of project synoptic sampling data for alluvial groundwater collected in the Echo-Stanfield area.

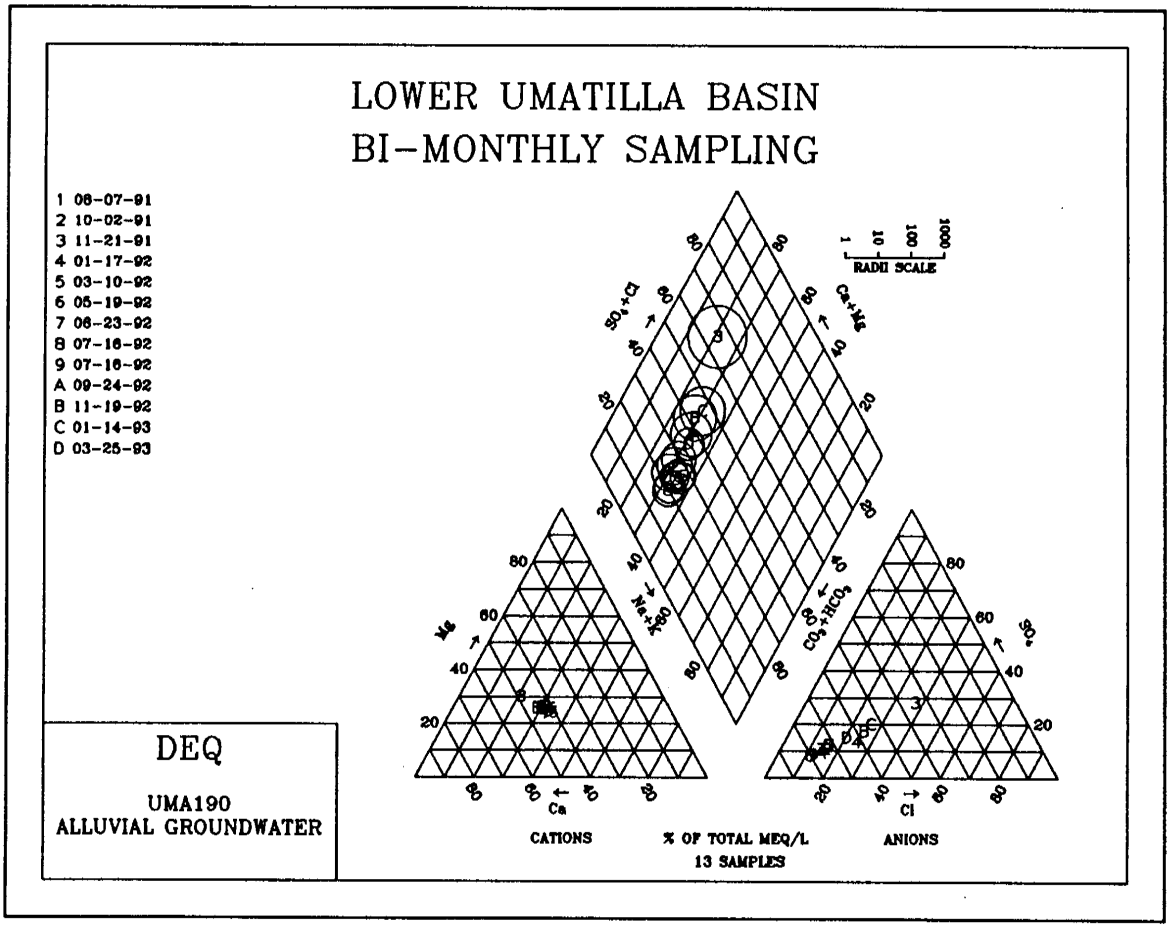


Figure 4.76 Piper Trilinear graph of project bimonthly sampling data for alluvial groundwater collected at UMA 190 located south of Echo.

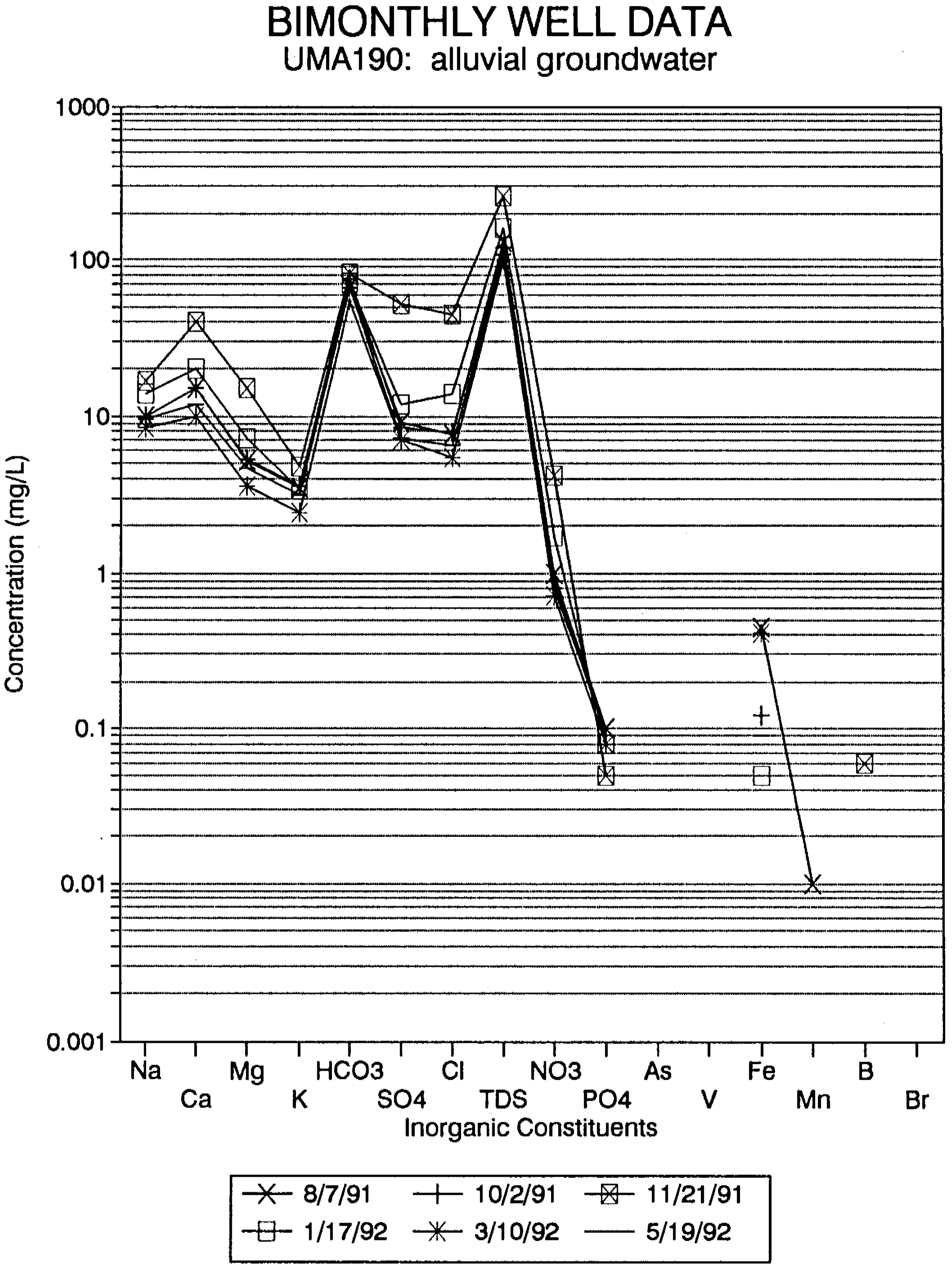


Figure 4.77 Schoeller Diagram of project bimonthly sampling data for alluvial groundwater collected at UMA 190 located south of Echo.

Graphical Analyses: Constituent Versus Constituent

Constituent versus constituent graphs were used to distinguish human influences on local groundwater chemistry (see Appendix 4H). The analysis primarily used project synoptic sampling data. Graphs reviewed included chloride versus potassium, bromide versus potassium, and chloride/bromide versus chloride. Analysis indicate the following:

- Influences affecting Hat Rock alluvial groundwater appears mixed. Analysis indicates a septic system, animal waste, and possibly irrigation influence. Project investigators are not aware of any animal operation or animal waste use in the area.

- Septic and animal waste appear to influence alluvial groundwater in an unsewered area adjacent to the City of Umatilla. Animal activity occurs south of Umatilla.

- Septic systems, local irrigation, and local animal waste appear to influence alluvial groundwater in the terrace north of Hermiston. Samples with higher nitrate concentrations generally corresponded to analysis indicating an irrigation or animal waste influence. For example, analysis indicates irrigation influences groundwater at sites UMA 153 and UMA 154. Nitrate+nitrite-nitrogen concentrations measured 31 mg/L and 12 mg/L in samples from those sites, respectively.

- Septic systems appear to be the most common influence at sites sampled in the Hermiston basin. Irrigation appears to be an additional influence at some sites.

- Irrigation related activity appears to be the most common influence at sites sampled on the terrace south of Hermiston. Septic systems appear to be an additional influence at some sites.

- Irrigation related activity appears to be the most common influence at sites sampled in the Stanfield and Echo-Umatilla Meadows area. Septic systems appear to be an additional influence at some sites.

Groundwater Flow Path Analysis

Project data analyses did not include flow path analysis for the City of Umatilla to Hat Rock to Echo Meadows area.

Groundwater Chemistry Computer Modeling

Nitrate concentrations in alluvial groundwater decrease markedly between upgradient sites located along the terrace south of Hermiston and downgradient sites in the Hermiston basin. Several canals convey water between the sites. Project analysis used the NETPATH groundwater chemistry computer model to evaluate the influence of canal leakage upon nitrate concentrations in groundwater flowing from the upgradient sites into the Hermiston basin.

Canal influences were evaluated by using alluvial groundwater data for UMA 043 and UMA 041. Well UMA 041 is located in the Hermiston basin downgradient of UMA 043 which is located on the terrace south of Hermiston. Maxwell and A Line Canals are located between the two well sites. Groundwater constituent concentrations at UMA 041 are lower than at UMA 043. For example, total dissolved solids and nitrate+nitrite-nitrogen concentrations measured 230 mg/L and 1 mg/L, respectively, in the down gradient UMA 041 sample and 330 mg/L and 5.1 mg/L, respectively, in the upgradient UMA 043 sample.

The model scenario allowed upgradient groundwater to mix with canal water while undergoing water-mineral reactions. The water chemistry at Cold Springs Reservoir was used to represent the canal water chemistry, because the reservoir is the canal water source. The scenario also utilized carbon dioxide, because water seeps through canal sediments containing organic matter. The model solutions indicate that canal water significantly affects the groundwater chemistry as it moves from UMA 043 downgradient to UMA 041. In fact, the groundwater chemistry at UMA 041 closely resembles the canal leakage water chemistry. Examples of the potential solutions for the model runs include:

UMA041 = [99.99% Cold Springs Reservoir] + [0.01% UMA043]
+ [0.44 Calcite] + [1.0 CO_2] + [0.14 dolomite]
+ [0.82 basalt glass]
- [0.06 exchange (Calcium and Magnesium exchange for Sodium)]

UMA041 = [99.99% Cold Springs Reservoir] + [0.01% UMA043]
+ [0.51 calcite] + [0.882 CO_2] + [0.165 dolomite]
+ [0.132 K-smectite]

The modeling results suggest that the canals do significantly impact groundwater in this area. The model runs indicate that mixing is limited between groundwater and infiltrating canal water locally. This suggests that canal leakage results in the lower salinity canal water displacing the higher salinity groundwater, limiting the mixing between groundwater and canal leakage. Some shallow wells may draw primarily from the low salinity water during periods of canal flow. Presumably, the low salinity water mixes with ambient groundwater over time and/or distance downgradient.

Nitrogen Isotopic Analyses

The Lower Umatilla Basin groundwater investigation did not include nitrogen isotope sampling and analyses for the City of Umatilla to Hat Rock to Echo Meadows area.

City of Umatilla to Hat Rock to Echo Meadows Area Summary and Conclusions

Multiple techniques were used to analyze the City of Umatilla to Hat Rock to Echo Meadows area groundwater chemistry data. The data analyzed came primarily from project sampling. The analysis led project investigators to the following observations and interpretations:

- Nitrate+nitrite-nitrogen concentrations in samples collected from the area ranged from non detect to 31 mg/L.

- Total dissolved solids concentration exceeded the 500 mg/L secondary (aesthetic) drinking water standard in some samples from Hat Rock, and the terraces north and south of Hermiston.

- Arsenic detections occurred primarily in samples from the Stanfield vicinity. One shallow unconfined alluvial groundwater sample from the A.E. Staley Manufacturing Company wastewater land application site contained arsenic greater than the 0.050 mg/L drinking water standard.

- Area groundwater samples commonly had sodium concentrations greater than the 20 mg/L limit recommended for persons on a physician prescribed sodium restricted diet. Some groundwater samples from the terraces north and south of Hermiston contained sodium greater than 50 mg/L.

- Project and City of Hermiston sampling detected pesticides and volatile organic compounds in alluvial and basalt groundwater. Project sampling detected these constituents in samples from the Hermiston basin, the terrace south of Hermiston, Stanfield, and City of Echo sewage treatment facility areas.

- Analyses indicate dilution from canal leakage influences groundwater within the Hermiston basin and part of the terrace south of Hermiston.

- Nitrate+nitrite-nitrogen remained below 10 mg/L in project groundwater samples collected in the City of Hermiston and Hat Rock areas. Analyses indicate mixed influences.

- Nitrate+nitrite-nitrogen concentrations in most project samples from the terrace north of Hermiston generally measured less than 10 mg/L. However, samples from two sites had concentrations of 12 and 31 mg/L. Analyses indicate a variety of influences. Septic systems appear to influence groundwater at sites where measured nitrate concentrations are low. Septic systems, irrigation, and animal waste appear to independently influence groundwater at different sites where concentrations approach 10 mg/L. Irrigation appears responsible for concentrations exceeding 10 mg/L in groundwater at the two sites mentioned despite the proximity of a feedlot at one of those sites.

- Nitrate+nitrite-nitrogen concentrations measured less than 5 mg/L in project groundwater samples from the Hermiston basin despite the presence of numerous unsewered homes in some areas. Graphical analysis indicates septic systems do influence the local alluvial groundwater chemistry. However, analyses also indicate a significant dilution influence from canal leakage.

- Nitrate+nitrite-nitrogen concentrations exceeded the 10 mg/L drinking water standard in groundwater sampled from several sites on the terrace south of Hermiston. The detection of pesticides in some of these samples and analyses indicate an irrigated crop agriculture influence. Analyses also indicate a septic system influence at some sites.

- Nitrate+nitrite-nitrogen concentrations generally remained below 10 mg/L in project groundwater sampled from the Echo and Umatilla Meadows area. Analyses indicate wastewater influences groundwater at the A.E. Staley Manufacturing Company land application site. Irrigation related activity and canal leakage appear to influence groundwater at other locations.

Evaluating Chemical Trends with Flow Path Analysis: Butter Creek Example

Introduction

Many different chemical and physical processes contribute to natural variations in groundwater chemistry in the Lower Umatilla Basin. Two techniques can be used to identify these various processes and evaluate regional trends in the groundwater chemistry. First, data from individual sample results can be graphed and analyzed for relationships. Second, the chemical changes affecting the water quality along groundwater flow paths can be investigated. The Lower Umatilla Basin investigation did conduct flow path analyses. Despite interconnections, the analysis considered groundwater within the alluvial sediments separately from groundwater in basalt, because they generally occur in different hydrogeologic units.

Nitrate Versus Other Constituent Relationships Basin Wide Show Need for Flow Path Analysis

A basin wide positive correlation exists between nitrate+nitrite-nitrogen and conductivity in Lower Umatilla Basin alluvial groundwater shown in Figure 4.78. This correlation is important, because it indicates that elevated nitrate is associated with higher levels of conductivity which is related to the total dissolved solids (TDS) in the water. The data indicates that the process(es) or activity(ies) that provide nitrate also contribute to higher TDS concentrations. It is possible that the TDS could be acquired independently as water passes from land surface through the vadose (unsaturated) zone to groundwater. However, that would not explain why nitrate correlates so well with TDS.

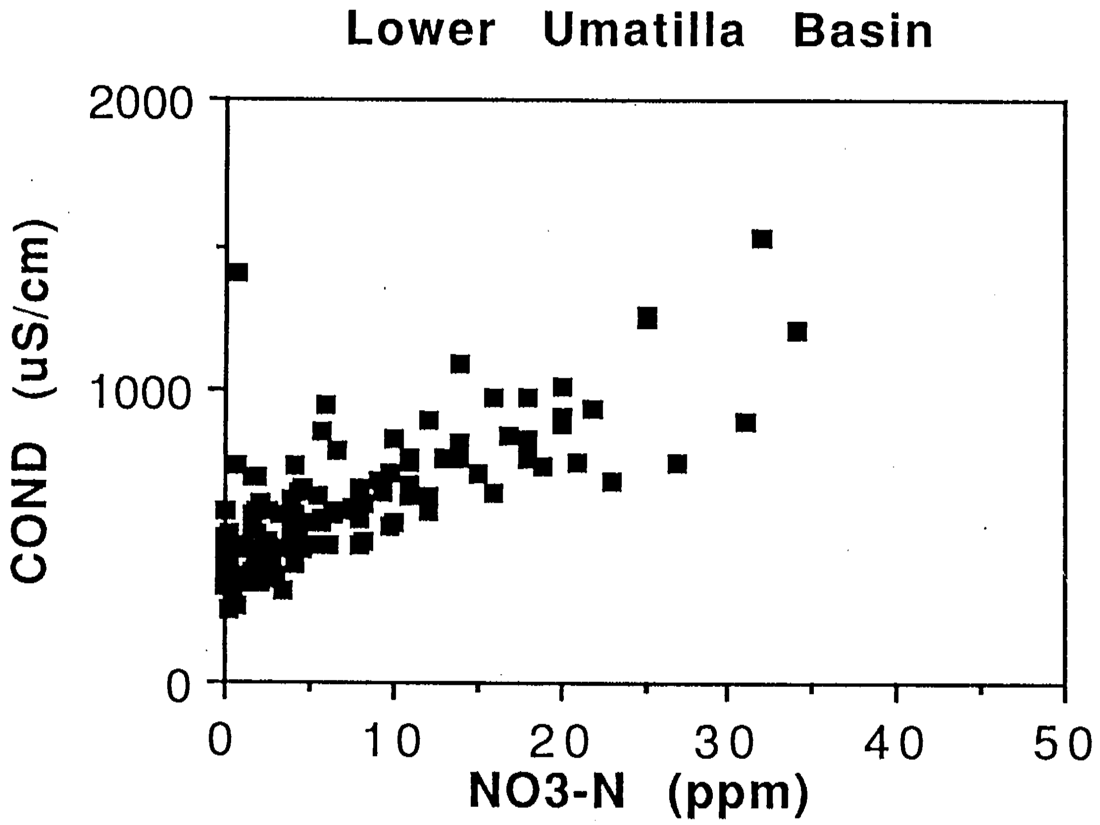


Figure 4.78 Nitrate+nitrite-nitrogen versus electrical conductivity for all project wells sampled in the Lower Umatilla Basin.

Note: The positive correlation.

The basin wide relationship between nitrate and other constituents is not as good as the correlation between nitrate and conductivity . For example, graphs of nitrate versus calcium shows considerable scatter (see Figure 4.79). Graphs of nitrate versus other constituents show even poorer correlations. The poor basin wide correlations indicate that groundwater of significantly different evolutionary histories are being displayed on the same diagram.

The good correlation with nitrate+nitrite-nitrogen exists because electrical conductivity and TDS in groundwater depend less upon the ionic species present than the total ionic concentration. Different groundwater histories can vary the constituents that accompany nitrate in groundwater. However, different chemistry histories can yield similar electrical conductivity values and TDS concentrations.

Nitrate versus other constituent relationships in the basin improves and becomes more understandable along identified groundwater flow paths. For example, Figure 4.80 shows nitrate+nitrite-nitrogen versus calcium for data related to the Butter Creek flow path analyzed. Some scatter is evident. However, the correlation for the Butter Creek flow path data is clearly better than basin wide data. A review of this figure indicates calcium is being added as nitrate is being added to groundwater moving along the Butter Creek flow path.

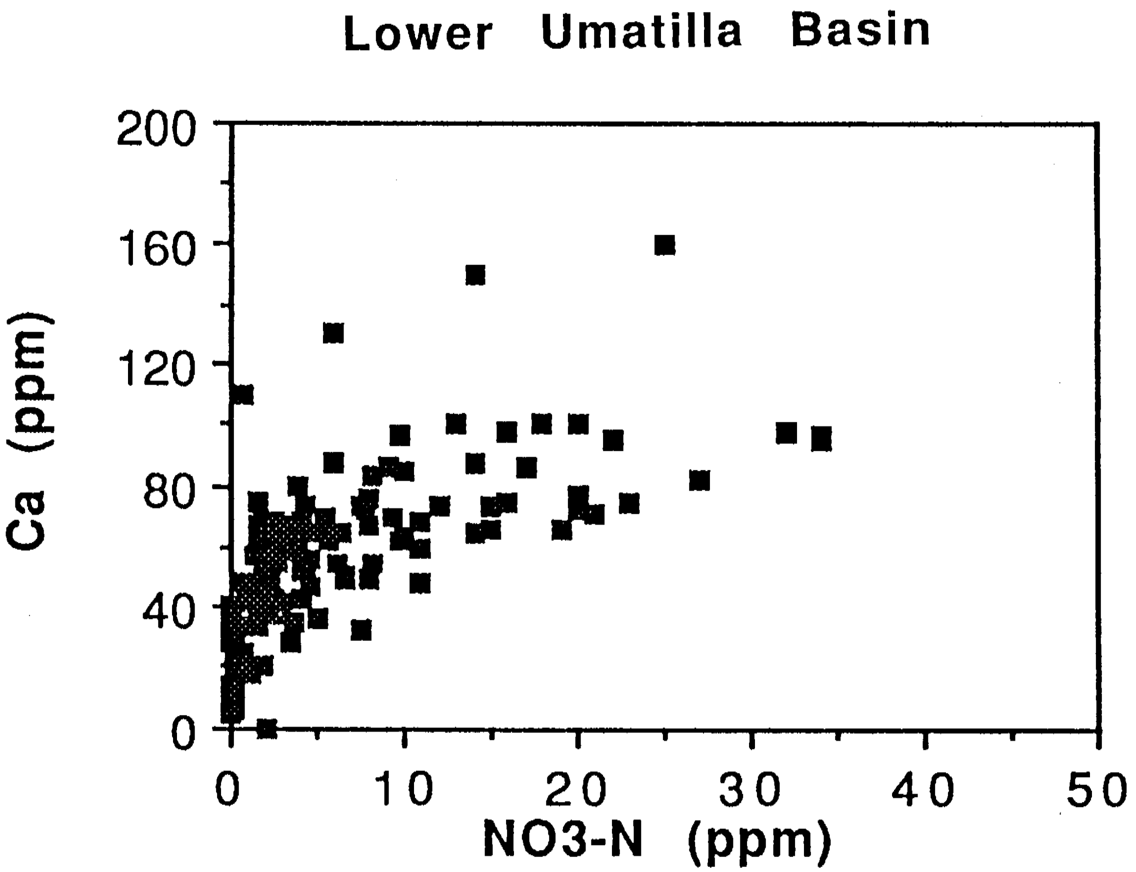


Figure 4.79 Nitrate+nitrite-nitrogen versus calcium for all project groundwater samples.

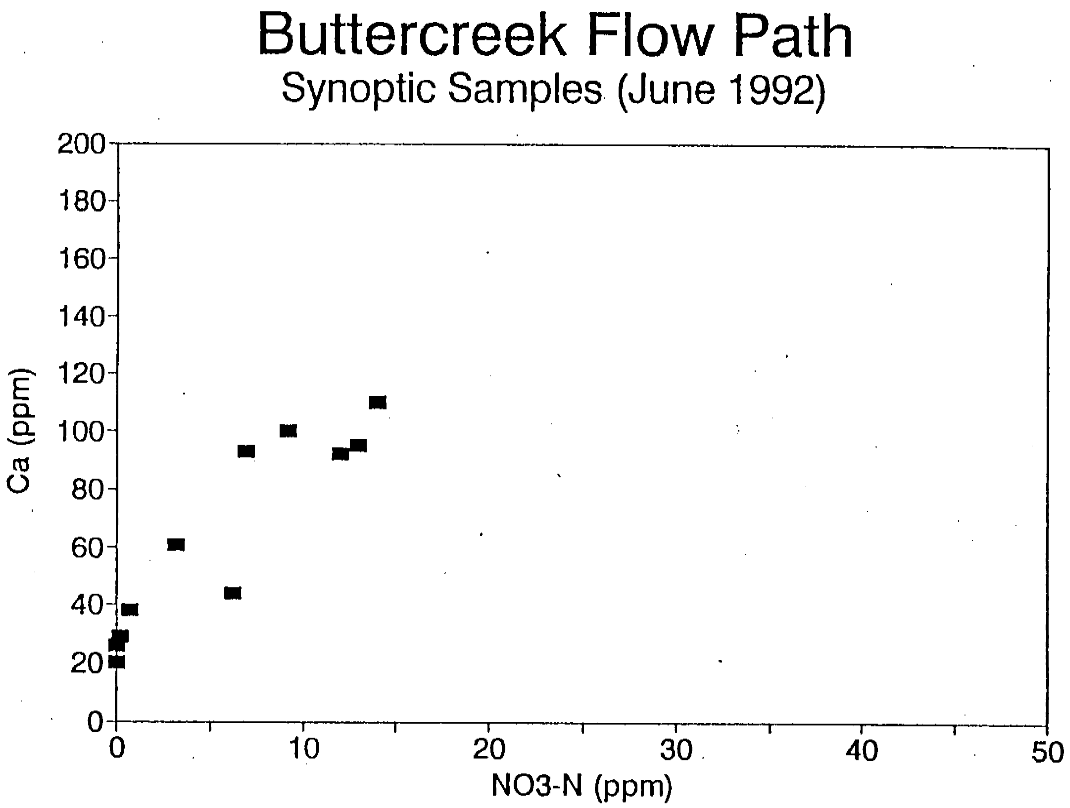


Figure 4.80 Nitrate+nitrite-nitrogen versus calcium for along the Butter Creek Flow path.

Flow Path Analyses in General

Interpreting the evolutionary processes affecting groundwater can best be accomplished by "following" a given mass of water as it migrates through the aquifer, recording the chemical changes that occur in the water, and relating the change to specific processes. "Following" a specific mass of groundwater through the aquifer is clearly not practical. However, the same result can be achieved by identifying an individual flow path and analyzing groundwater from wells along that flow path.

Figure 4.81 illustrates the flow path analysis concept. Recharge water enters the aquifer in an upgradient area where it begins to migrate downgradient. As the water moves along the flow path, it chemically evolves due to various processes and influences. Simultaneously sampling groundwater from wells along the flow path will provide a view of how the groundwater chemistry evolves along the flow path as long as no significant changes in the processes affecting the groundwater chemistry has occurred.

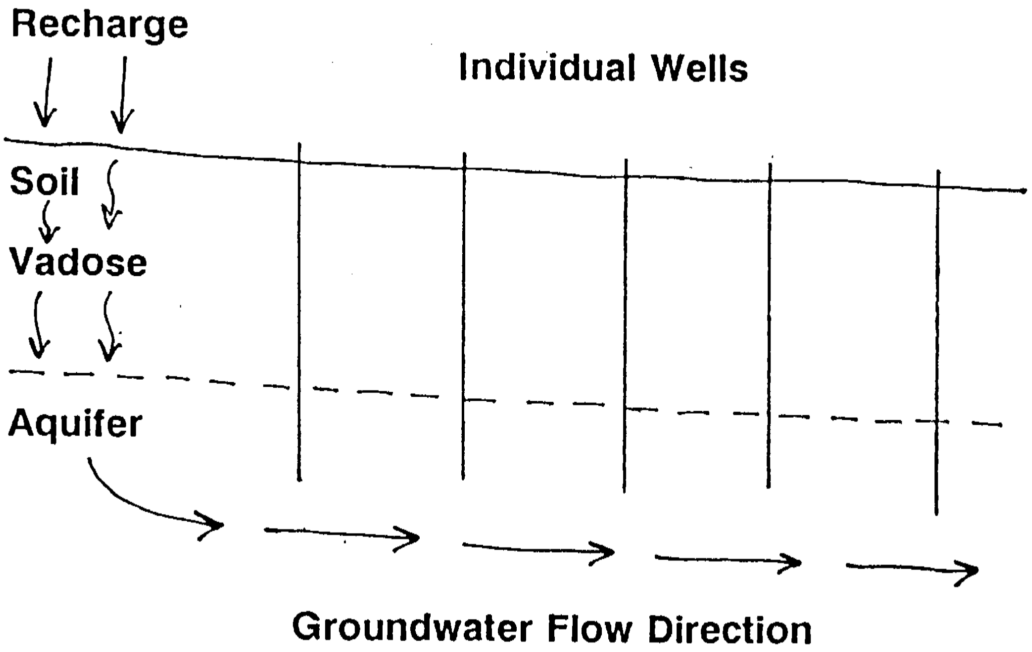


Figure 4.81 Diagrammatic representation of wells located along a groundwater flow path and obtaining water from the same aquifer.

Butter Creek Flow Path

The Butter Creek area was selected for a flow path analysis. Project hydrogeologic investigation results were used to identify groundwater flow paths within the drainage. The analysis used project sampling data related to wells located along a flow path of interest which obtain groundwater from the sediments only. This data selection constraint was necessary to obtain a view of the apparent chemical variations occurring in alluvial groundwater along a single flow path. This view would then provide a basis for determining the mechanism(s) by which chemical change was occurring and perhaps contributing to nitrate loading. Similar methods could be used for other geographic areas in the Lower Umatilla Basin.

Alluvial Aquifer Along the Butter Creek Flow Path

Data related to wells completed in the alluvial sediments only along the Butter Creek flow path of interest were selected for analysis. The path of interest passes among wells UMA 185, 120, 122, 081, 084, 073, 088, 119, 070, and 077. The well site locations are shown in Figure 4.82.

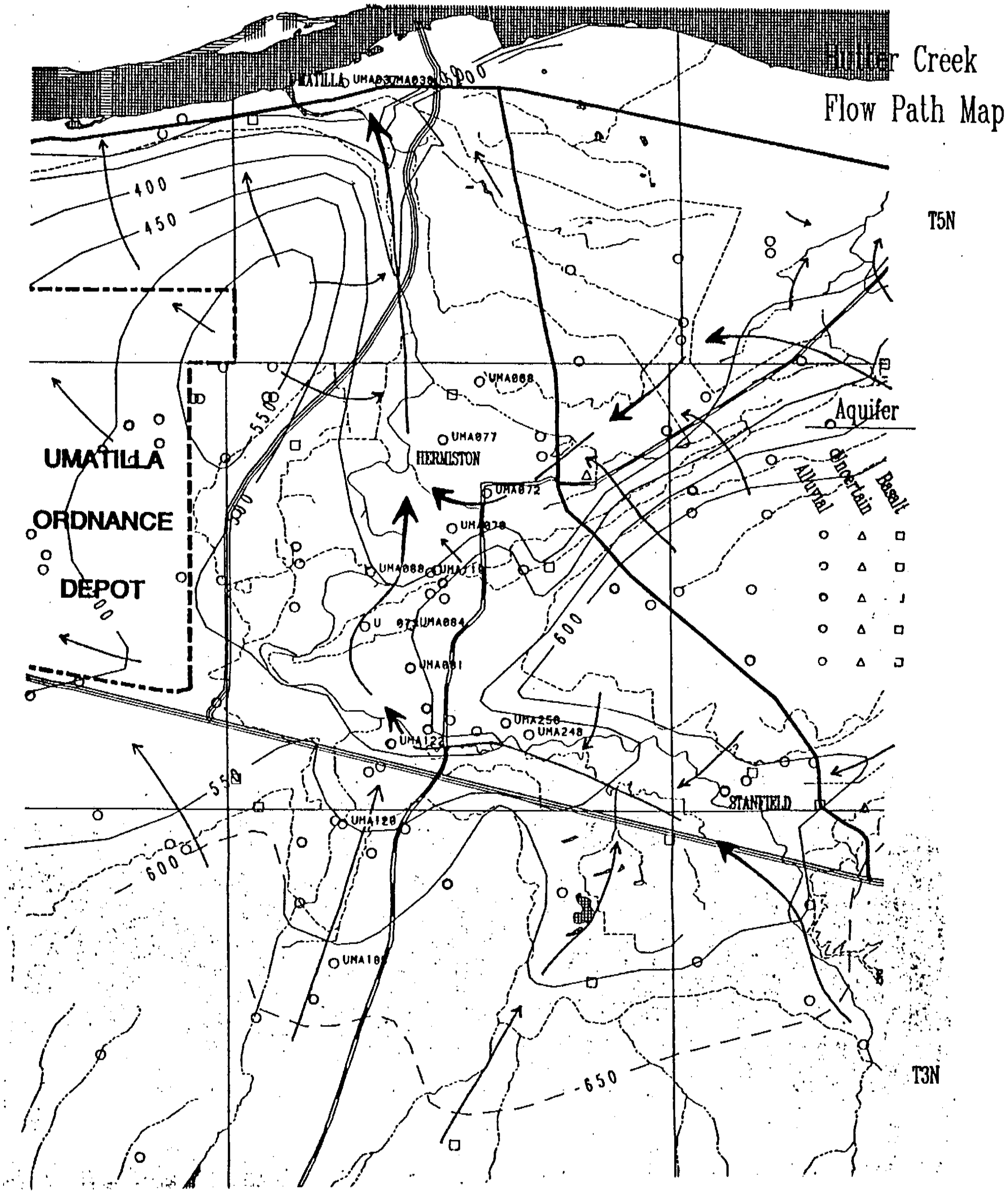


Figure 4.82 Butter Creek flow path map.

Note: Contours represent the potentiometric surface.

Note: Arrows indicate groundwater flow directions.

Mineralogy

The alluvial aquifer hosting the Butter Creek flow path is glaciofluvial in origin and consists largely of basaltic fragments varying in size from small boulders to sand. The primary mineralogy of the basalt fragments probably consists of plagioclase, clinopyroxene and volcanic glass. Allen and Strope (1983) indicate that volcanic glass may comprise from approximately 7 to over 30 percent of typical basalt.

Wright and others (1994) performed an extensive study of the mineralogy of similar sediments from the middle Ringold Formation at the Hanford site northwest of Richland Washington. Their analyses indicated a widely variable mineralogy including rock fragments (trace to 89%), quartz (4 to 84%), feldspar (1 to 29%) and clay (trace to 14%). The clay minerals were dominated by smectite and illite, with lesser chlorite and kaolinite. Hearn and others (1985) evaluated the secondary alteration products of Columbia River Basalt aquifers using drill cores and outcrops. They found smectite ($Si_{3.67}Al_{0.76}Fe_{1.11}Mg_{0.71}Ca_{0.15}Na_{0.07}K_{0.09}O_{10}(OH)_2$) and the zeolite clinoptilite ($Si_{14.34}Al_{3.66}Fe_{0.20}Mg_{0.10}Ca_{0.48}Na_{0.88}K_{0.94}O_{36}$), iron oxide and various forms of silica. In an arid environment like the Lower Umatilla Basin, additional secondary minerals may form in the unsaturated zone such as dolomite ($CaMg(CO_3)_2$), gypsum ($CaSO_4 \cdot 2H_2O$) and perhaps halite (NaCl). An assessment of the groundwater chemistry indicates mirabilite ($Na_2SO_4 \cdot 10H_2O$) may be the secondary mineral in some cases.

Groundwater Chemistry

Whether or not a given mineral will precipitate or dissolve from a specific water depends on the water's chemical state. For example, when a mineral such as calcite ($CaCO_3$) is placed in water undersaturated with respect to that mineral, calcite will begin to dissolve, contributing calcium [Ca^{2+}] and carbonate [CO_3^{2-}] to the solution. How much calcite dissolves depends on the solubility product of the mineral and the pH, temperature and dissolved load of the solution. When the product of their concentrations, or more precisely the activities, of calcium and carbonate reach a level equivalent to the solubility product, calcite will dissolve no further and the solution is saturated. The state of saturation can be expressed as the saturation index (SI), which for calcite is a ratio of the calcium and carbonate in solution to the solubility product. A SI index of 1 indicates saturation, greater than 1 indicates oversaturation, and less than 1 indicates undersaturation. The SI may change as water moves along a flow path owing to changes in the chemical state of the solution.

The groundwater chemistry computer model program NETPATH was used to evaluate the chemical relationship between groundwater and the aquifer material along the Butter Creek flow path. The program uses a modified version of WATEQF (Plummer and others, 1976) to calculate the identity and concentrations of dissolved species in a solution, and determine the saturation indices for a range of potential minerals for the water in question. The model input is a chemical analysis of the water.

The primary minerals in the alluvial aquifer include plagioclase and pyroxene. These primary minerals have very low solubilities and probably play a minor role in influencing the overall groundwater chemistry along a flow path. However, basaltic glass (Allen and Strope, 1983) may be an important influence on the chemical evolution of groundwater in the Lower Umatilla Basin area (Hearn and others, 1985, Hinkle, 1994) since basalt detritus makes up an important part of the alluvial sediments. The modeling effort used the composition of entablature glass as reported by Allen and Strope:

$$Si_{8.804}Ti_{0.1.69}Al_{2.272}Fe_{0.198}Mg_{0.105}Ca_{0.558}Na_{1.254}K_{0.466}P_{0.083}O_{24}$$

An additional concern are the secondary minerals that may occur in the alluvial sediments such as calcite, clay minerals, e.g smectite and clinoptilite are common (Hearn and others, 1985, Wright and others, 1994). Gypsum (or mirabilite), dolomite and halite may occur in small quantities.

Figure 4.83 shows the SI values for calcite, dolomite ($CaMg[CO_3]_2$) and gypsum ($CaSO_4.2H_2O$) along the flow path. Gypsum remains undersaturated (SI less than 1) in the groundwater along the entire flow path, while calcite and dolomite vary from undersaturated to oversaturated (SI greater than 1). These calculations indicate that none of the groundwater recognized along the flow path will precipitate gypsum (or mirabilite); calcite and dolomite can either precipitate or dissolve, depending where in the flow path the water is travelling. Other aspects of the water chemistry seen in Figure 4.84 indicates that the Butter Creek groundwater is in equilibrium with smectite. This clay mineral group is a common alteration product of basalt (e.g. Hearn and others, 1985, and Wright and others, 1994).

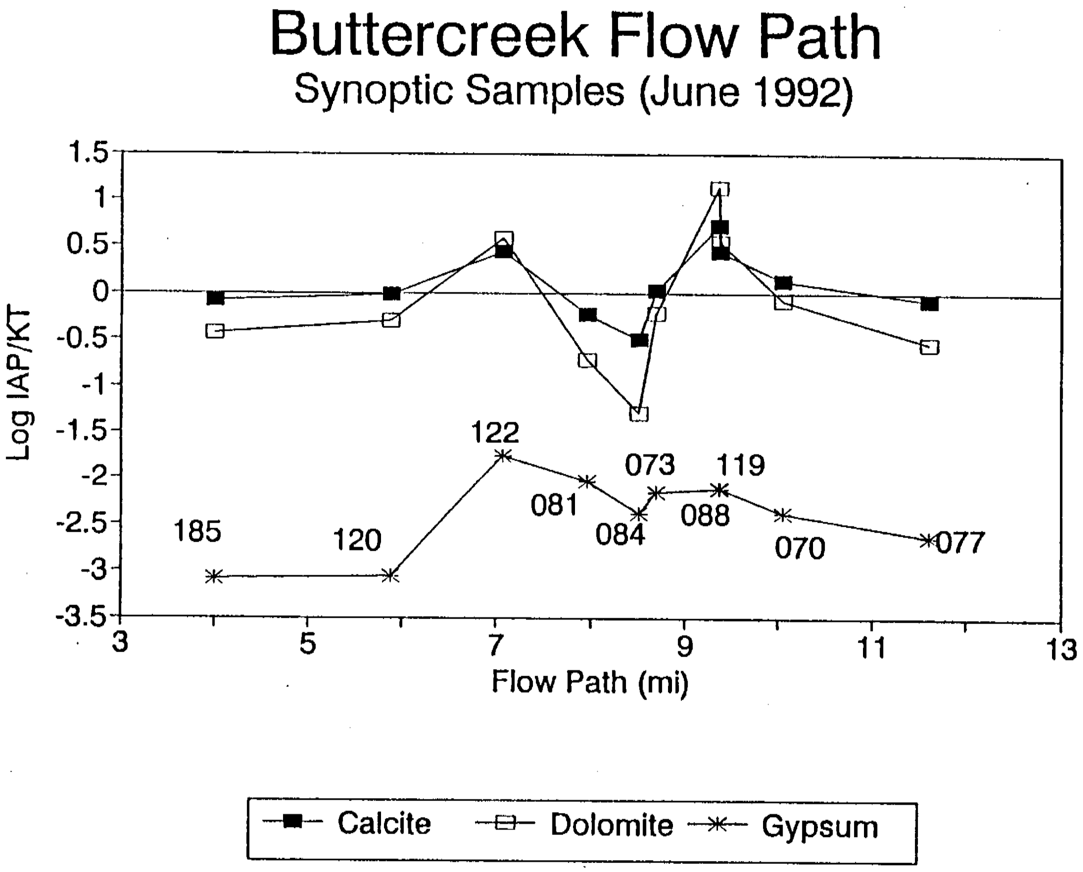


Figure 4.83 Saturation indices for calcite, dolomite, and gypsum along the Butter Creek flow path.

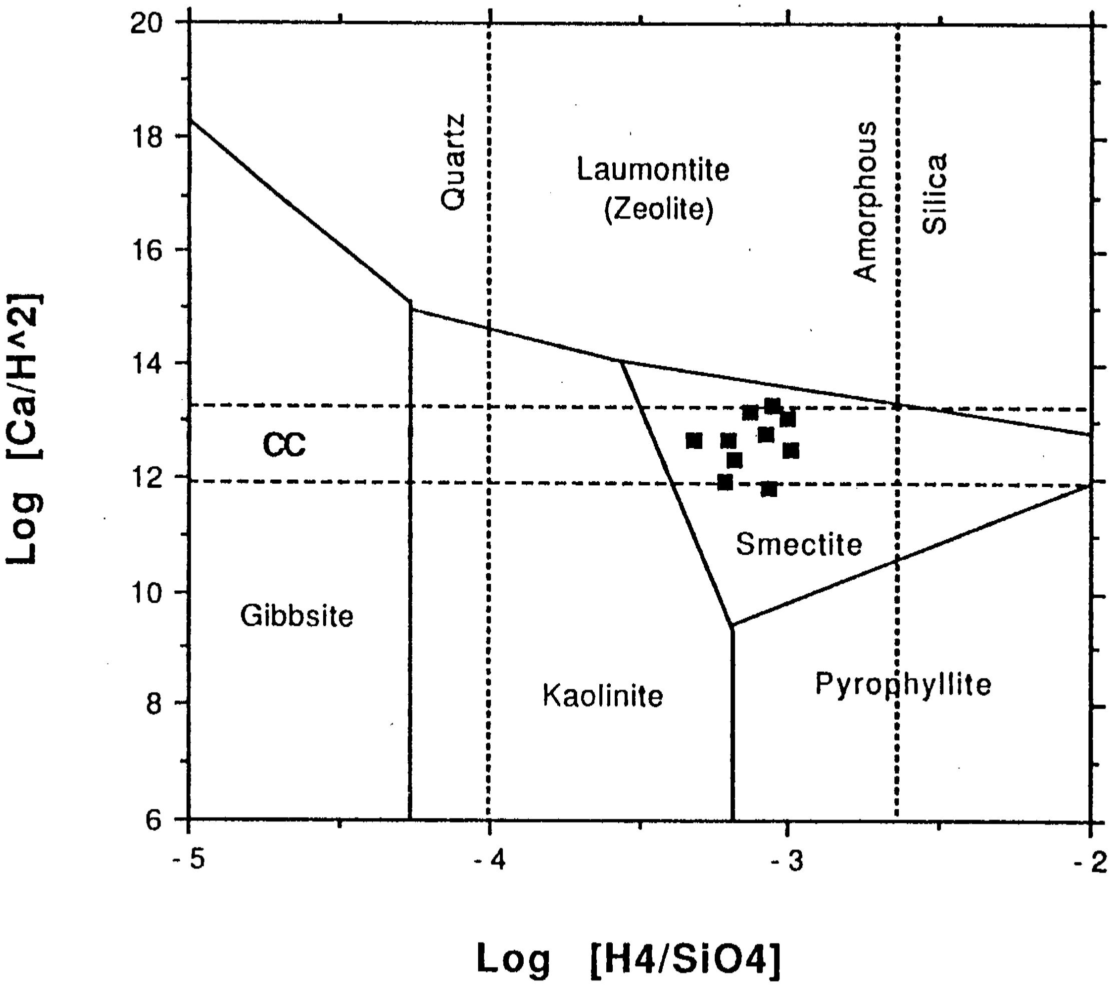


Figure 4.84 Ion activity graph.

Butter Creek Flow Path Analysis

Trends and Anomalies Observed Along the Flow Path

Analysis of the Butter Creek flow path data indicated several trends and anomalies. Figure 4.85 shows the variation of calcium, chloride, and nitrate+nitrite-nitrogen from the synoptic sampling along the flow path from an upgradient well, UMA 185, to downgradient wells such as UMA 077. It is apparent that the trends for all constituents are not characterized by progressive increases downgradient as might be expected if calcium and chloride resulted solely from progressive water-rock reactions or if NO_3-N resulting solely from nonpoint source loading. Instead, a concentration high is seen in the 7 to 9.5 mile range of the flow path. Several potential explanations exist to account for the compositional anomaly.

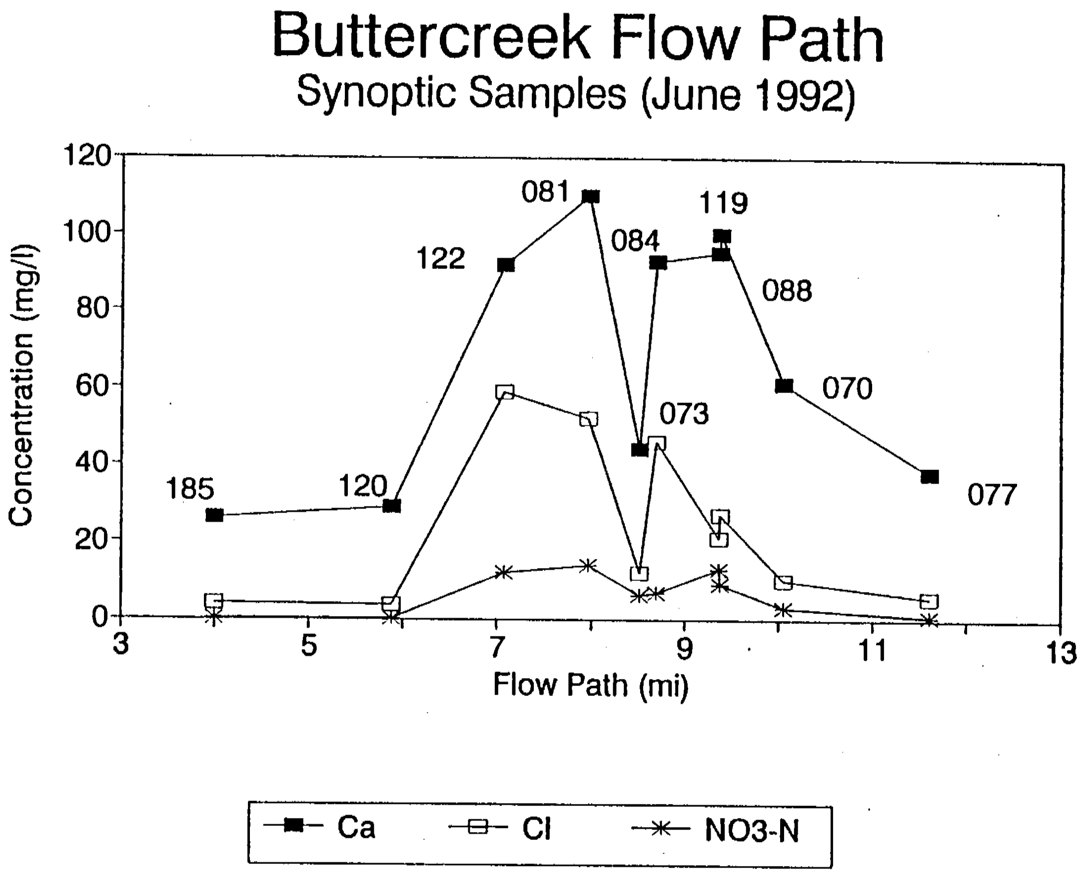


Figure 4.85 Variation of calcium, chloride, and nitrate+nitrite-nitrogen along the Butter Creek flow path for project synoptic sampling data.

One potential explanation for the concentration high is that the TDS compositions represent wells completed within the fine-grained sediments of the alluvial aquifer while the lower concentrations represent samples from the coarse-grained sediments. The rationale here is that water within the fine-grained sediments would experience a longer residence time owing to the lower hydraulic conductivity of those sediments.

As part of this hydrogeologic assessment, individual well logs were evaluated and the producing aquifer identified. Within the Butter Creek flow path, all wells except UMA 185, UMA 120, and UMA 122 are completed in the coarse-grained sediments. The other three wells are producing from the fine-grained sediments. It is evident from Figure 4.85 that the high (and low) concentrations occur in both sediments. Therefore, it is unlikely that residence time is the origin of all the chemical variation observed along the Butter Creek flow path.

A second potential explanation for the concentration high is that it represents a "snapshot" of a high TDS/nitrate pulse moving through the aquifer from some undetermined upgradient source. To evaluate this hypothesis, a representative set of Butter Creek wells were selected for bimonthly sampling. Figure 4.86 shows the nitrate+nitrite-nitrogen concentrations in groundwater along the Butter Creek flow path using data from the reconnaissance sampling phase (composite) and several of the bimonthly sampling events. The reconnaissance samples were collected over 14 months. The bimonthly samples were collected concurrently. The stationary peak implies that there is no tendency for concentrations to shift in the downgradient direction with time. The data suggests that the source of the dissolved constituents and elevated nitrate is local and, with some seasonal variations, is continuous. Concentrations in samples from a single well do vary over a short time period. For example, well UMA 119 samples varied in nitrate content from approximately 4 mg/L in October, 1991 to more than 15 mg/L in January 1992.

Nitrate Relationship to Other Constituents Along the Flow Path

A review of Figure 4.85 indicates calcium and chloride concentrations correlate well with nitrate. Correlations between nitrate and other constituents is less clear. For example sodium and sulfate reach elevated concentrations within the 7 to 9.5 mile flow path window (Figure 4.87). However, they vary independently from each other and from calcium, chloride, and nitrate. This indicates several influences affect the groundwater chemistry along the Butter Creek flow path, but not all of the influences contribute nitrate.

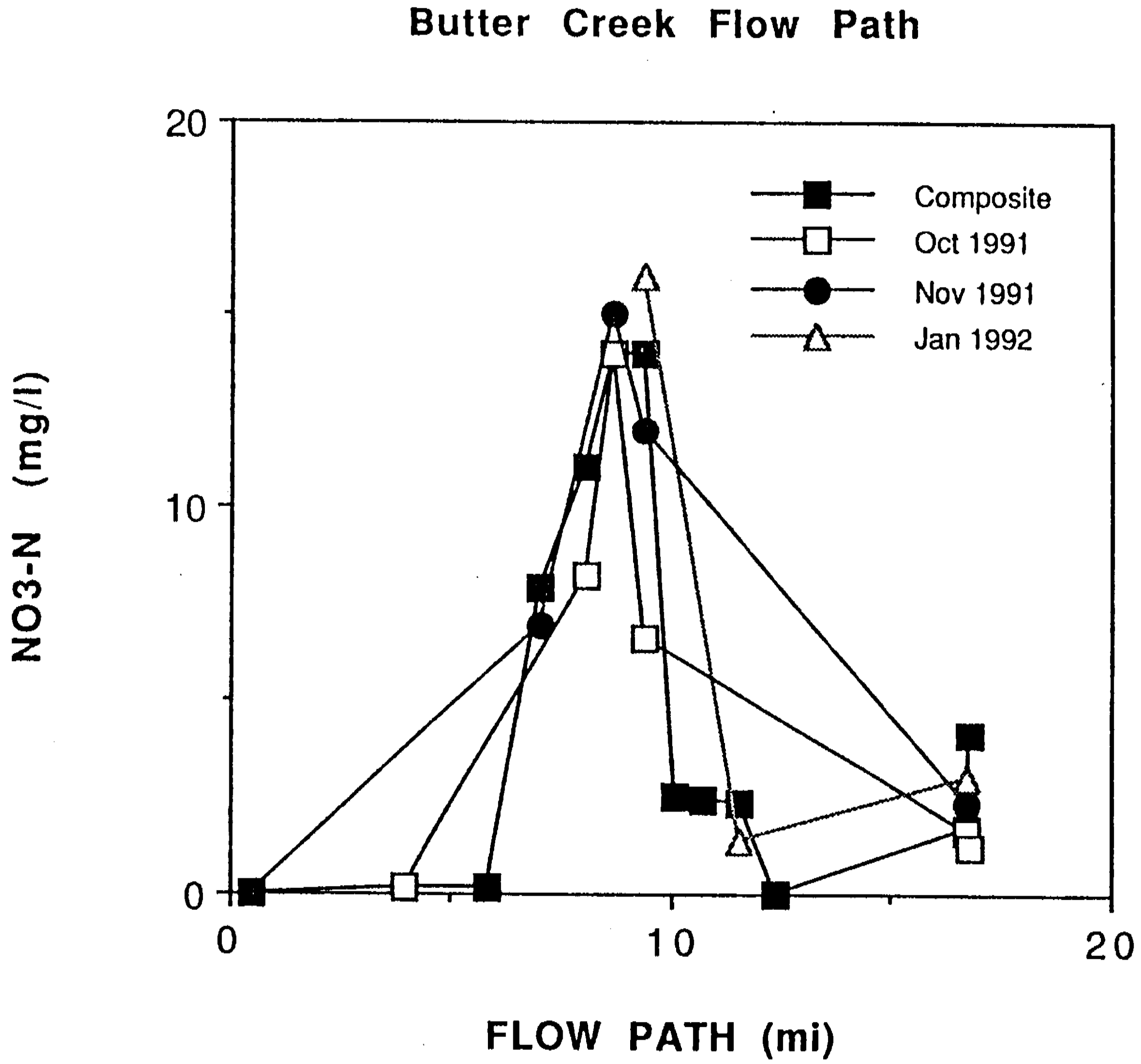


Figure 4.86 Nitrate+nitrite-nitrogen concentrations along the Butter Creek flow path at different sampling times.

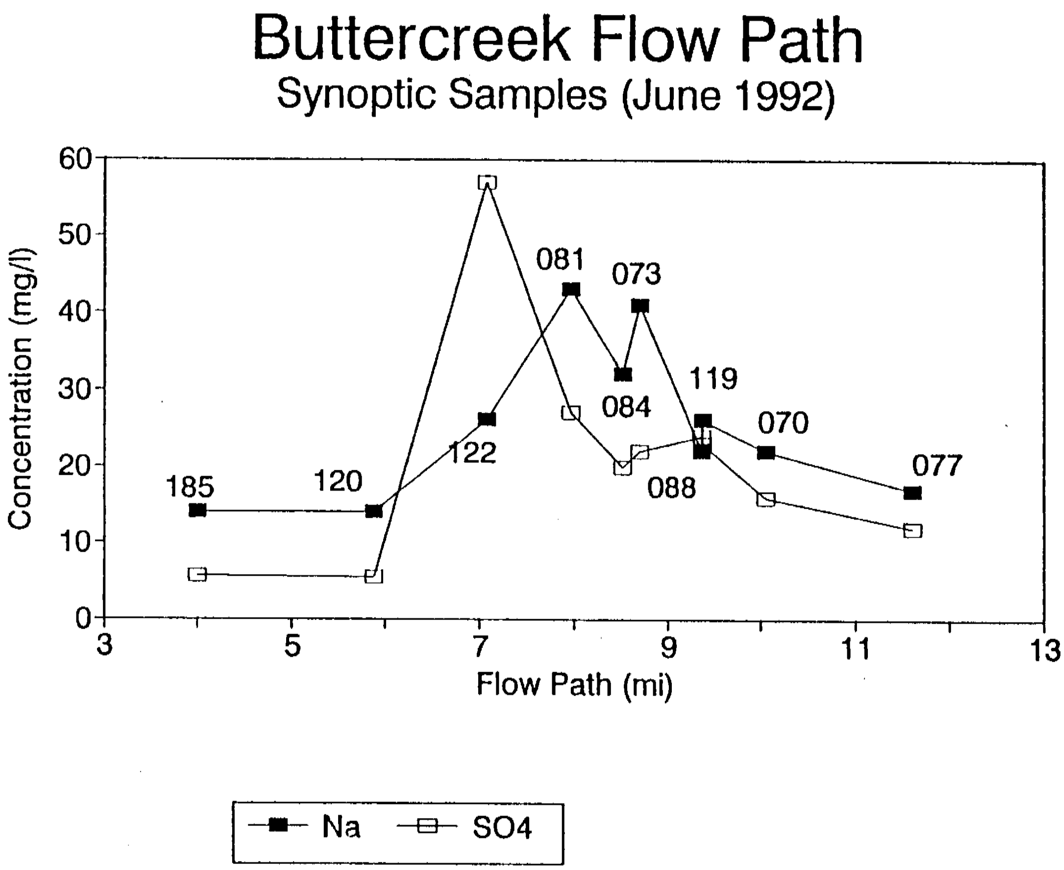


Figure 4.87 Sodium and sulfate concentrations along the Butter Creek flow path.

Similar arguments can be made for a "flow path" through the U.S. Army Depot. Figure 4.45 shows the variation of calcium and chloride along the flow path. Like the Butter Creek flow path, calcium and chloride correlate better with nitrate than do sodium and sulfate. Variations observed along the flow path indicate more than one source contributes nitrate and the higher TDS water which carries the nitrate to groundwater.

Evaluation of Groundwater Chemistry Changes at a Wastewater Irrigation Circle

A goal of the geochemical effort was to identify and characterize the natural processes by which groundwater evolves along a flow path. Once the natural processes are identified, the influence of human activity upon the groundwater chemistry may be more readily recognized. The NETPATH groundwater chemistry computer model was used to accomplish this task.

Chemical variations along the Butter Creek flow path were analyzed and appropriate compositions were evaluated using the mass balance program NETPATH. To test the application of NETPATH to groundwater in the area, samples that were hydrogeologically well-constrained were selected. For this exercise, wells immediately upgradient and downgradient of a single Simplot irrigation circle (field 1A) were chosen. A pair of shallow and deep wells occur in both the up- and downgradient positions (Figure 4.88). The shallow wells are in the coarse-grained portion of the alluvial aquifer while the deep wells produce from the fine-grained portion of the alluvial aquifer.

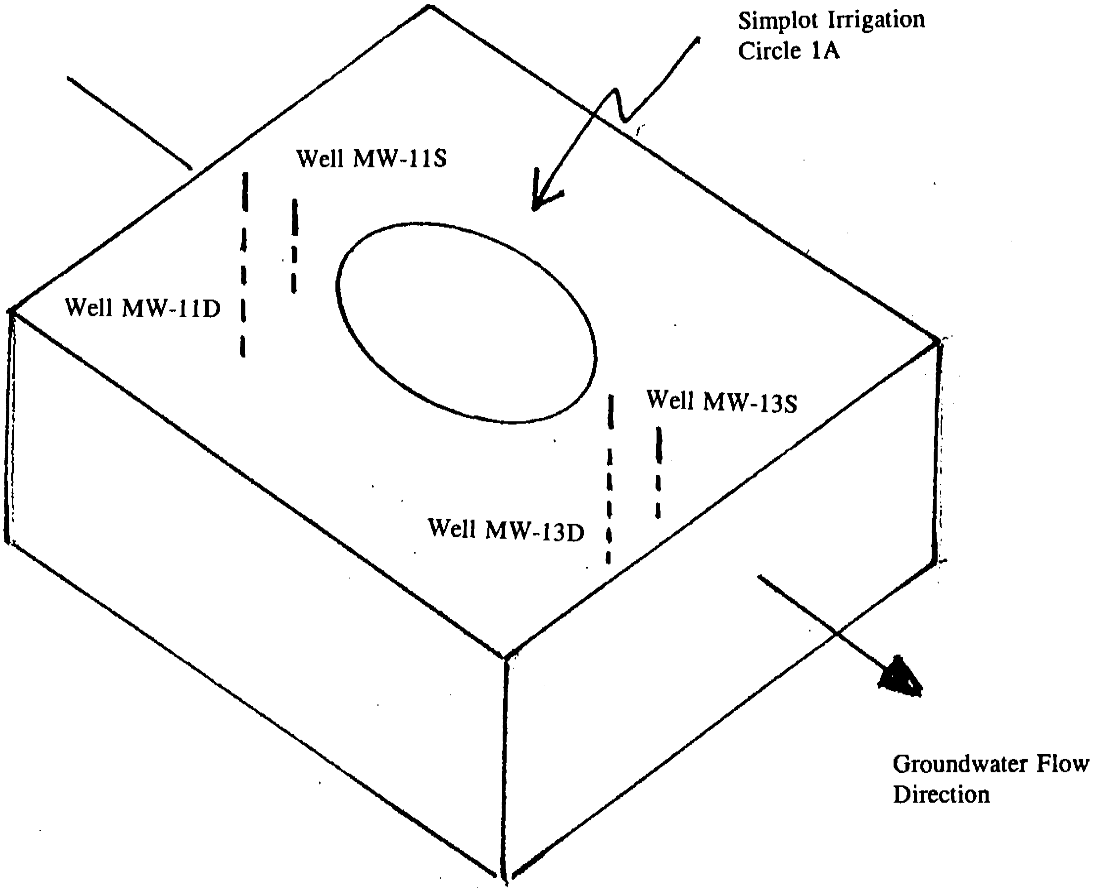


Figure 4.88 Schematic diagram of J.R. Simplot Company wastewater irrigation circle 1A showing shallow and deep well locations as well as groundwater flow directions.

Significant chemical differences exist between the shallow and deep wells and between the upgradient and downgradient wells as shown in Figure 4.89. The constituent concentrations in groundwater from the shallow well (Simplot MW-13S, UMA 246) are considerably higher than in groundwater from the corresponding deep well (Simplot MW-13D, UMA 247). Simplot well MW-13D is downgradient of Simplot well MW-11D (UMA 245). Most constituent concentrations in groundwater at MW-13D are higher than in groundwater at the upgradient well MW-11D.

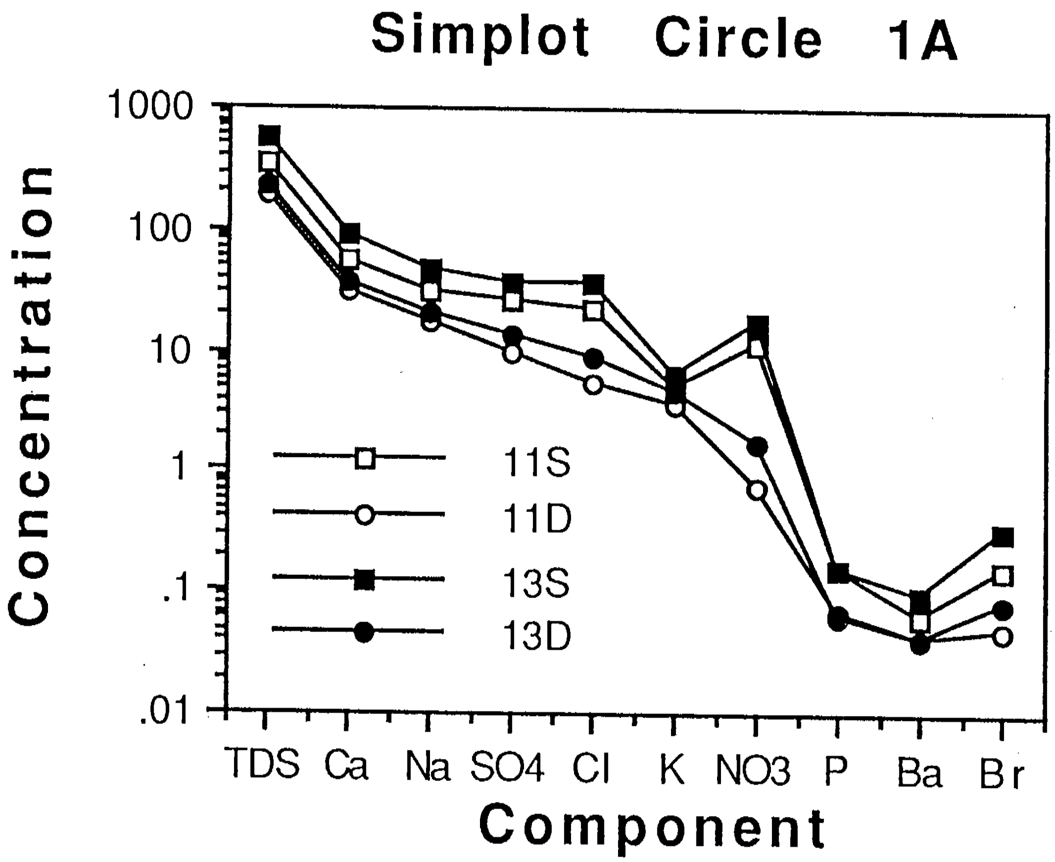


Figure 4.89 Schoeller Diagram showing constituent concentrations in alluvial groundwater sampled from shallow and deep upgradient wells (MW-11S, MW-11D) and shallow and deep downgradient wells (MW-13S, MW-11D) at Simplot wastewater irrigation circle 1A.

NETPATH was used to explore two hypotheses. First, could downward percolation of shallow unconfined alluvial groundwater explain the groundwater chemistry in groundwater samples from the deeper wells? Second, is the groundwater chemistry at the downgradient deep well a result of chemical evolution as groundwater flows from the upgradient deep well to the downgradient deep well? PCWATEQ was run on all four compositions in order to provide modeling constraints.

Relevant to the first question is the observation that groundwater from both the shallow and deep wells are undersaturated with respect to halite (NaCl) and gypsum. If the deeper groundwater originated solely through downward percolation of the shallow water, modeling results suggest it could do so only through extensive precipitation of these two phases which is not possible given the undersaturated conditions. This does not preclude the presence of the some shallow water in the deeper zone. It is evident, though, that the deeper groundwater must contain a significant portion of regional groundwater moving downgradient.

In evaluating the second question, a significant issue is the nitrate increase from 0.72 mg/L at the upgradient Simplot well MW-11D to 1.7 mg/L at the downgradient Simplot well MW-13D. No natural source of nitrate is known to occur in the alluvial groundwater. So, the increase implies the addition of nitrate from above. As a result, the evolution of deeper groundwater from Simplot MW-11D to Simplot MW-13 was considered to involve both water-mineral reactions and mixing between the deep and shallow waters.

The NETPATH program was used to search for solutions for the equation:

MW-11D + MW-13S + minerals dissolved = MW-13D + minerals precipitated

The program was directed to base its search on the constituents sulfur, calcium, magnesium, sodium, chloride, and carbon, and to assume that basalt glass, mirabilite, dolomite and halite could only dissolve, and smectite and clinoptilite could only precipitate. Cation exchange involving calcium, magnesium, and sodium was also allowed to operate. No unique solution was determined. The following summarizes the computer's solutions:

MW-13D = [88-92% MW-11D] + [8-12% MW-13S]
+ [dissolving minerals (mirabilite, halite, calcite, with lesser dolomite, augite and basaltic glass)]
- [precipitating minerals (smectite, clinoptilite and calcite)]
+ [cation exchange (Na replacing Ca and Mg on clay surfaces)]

All model runs required the dissolution of mirabilite. Most runs involved calcite either dissolving or precipitating and the precipitation of smectite. Dissolution of halite and the precipitation of clinoptilite occurred in many of the model runs. Dissolution of the primary phases augite and basalt glass appeared less important. Many model run results suggested that carbon dioxide was lost during the reaction.

Given the short distance between the shallow and deep wells (less than 1 mile), it is considered that mixing constitutes the bulk of the evolutionary changes along the flow path. To independently test this model, the concentrations of a number of components not considered in the model above were subjected to simple mass balance calculations to determine how predicted versus observed concentrations compared. Table 4.39 provides the results of the comparison. Although some discrepancies exist, the NETPATH model is supported by the calculations in Table 4.39. The results indicate that shallow groundwater, presumably originating as water applied within the irrigation circle, has impacted deeper regional groundwater.

Table 4.39 Comparison of upgradient versus observed and predicted downgradient constituent concentrations in MW 13D groundwater at Simplot wastewater irrigation circle 1A.

Component	11D	13S	Predicted	Observed	Difference
NO_3-N	0.72	18	2.8	1.7	1.1
K	3.6	6.5	3.9	4.5	0.6
Br	0.05	0.32	0.08	0.08	0
Ba	0.04	0.09	0.046	0.04	0.006
PO_4-P	0.07	0.15	0.08	0.06	0.02
TDS	190	550	233	230	3

Note: NETPATH model suggests an evolution involving ~88% upgradient deep well (MW-11D) + ~12% of the downgradient well (MW-13S) composition ± mineral reactions. The predicted values below are based on simple mass balance calculations alone using the above proportions of end members.

Note: All concentrations are in mg/L.

The origin of the shallow groundwater remains somewhat equivocal, although its location certainly suggests a relationship to land applied food processing wastewater. Comparison of the Simplot irrigation lagoon (project sampling site 404487) water chemistry with the chemistry of groundwater from MW-13S (UMA 246) indicates significant differences between the two. However, a direct comparison between the two is not conclusive, because of the potential processes that could occur in the unsaturated zone after the wastewater is land applied.

The impact of cyclic wetting and drying (Drever and Smith, 1978) on water chemistry was explored using the NETPATH model. In this process, complete evaporation of the applied water occurs during the periods between irrigation. All of the solutes within the water are deposited as mineral phases within the soil or vadose zone (Tedaldi and Loehr, 1992). Re-dissolution occurs during subsequent irrigation or precipitation. If sufficient water is applied, leaching of the "remobilized" solutes may occur.

To test this hypothesis, it was assumed that water similar to the lagoon water was allowed to evaporate to dryness within the vadose zone. The final concentration of solutes within the brine at the final stages of evaporation would be much higher than observed by this investigation. Obtaining samples with these concentrations should not be expected given the small volume of water remaining after evaporation. Evaporation would presumably cause all of the solutes to precipitate as solid phases. Using the model of Hardie and Eugster (1970), as modified by Drever (1982), and the chemistry of the lagoon water, specifically the ratio of alkalinity to calcium and magnesium, the following phases were considered likely to precipitate: magnesium-calcite, dolomite, nahcolite ($NaHCO_3$), mirabilite ($Na_2SO_4 \cdot 10H_2O$), halite (NaCl), potassium-smectite and magnesium-smectite. Cation exchange involving calcium and sodium ions was also considered.

Flushing the system with the lagoon water or water from Simplot's main production well (#3) could not account for the observed composition in groundwater from Simplot well MW-13S. The elevated chloride concentrations in these sources required the precipitation of halite, a process considered unlikely here.

Dilute water, represented as the Umatilla River water (project sampling site 404488), was allowed to flush through the system. This process yielded five successful model runs, involving the dissolution of variable proportions of the above phases. So, a possible origin of the shallow unconfined groundwater in MW-13S is cyclic evaporation-dissolution, where repeated application-evaporation of wastewater leads to the precipitation of dissolved salts in the soil and vadose zone. Subsequent "flushing" of this zone with more dilute waters leads to dissolution of those phases and leaching of the components downward.

Evaluation of Groundwater Chemistry Changes Along Butter Creek Flow Path Segments

Analysis of UMA 185 to UMA 120: Natural Water-Mineral Reactions

In order to recognize the various sources of nitrate loading that may have affected groundwater compositions in the Lower Umatilla Basin area, it is useful to understand the compositional controls that are the result of natural water-mineral reactions within the saturated zone. Because of the diverse and widespread array of potential nitrate sources within the Butter Creek drainage, it is difficult to find an unimpacted segment along the flow path. The most likely segment is upgradient from the TDS high, represented by wells UMA 185 and UMA 120. However, because of the short length of this flow path segment, chemical variations that occur along it are small. Real variations, here assumed to be greater than 5 percent, occur only in calcium, magnesium, and potassium.

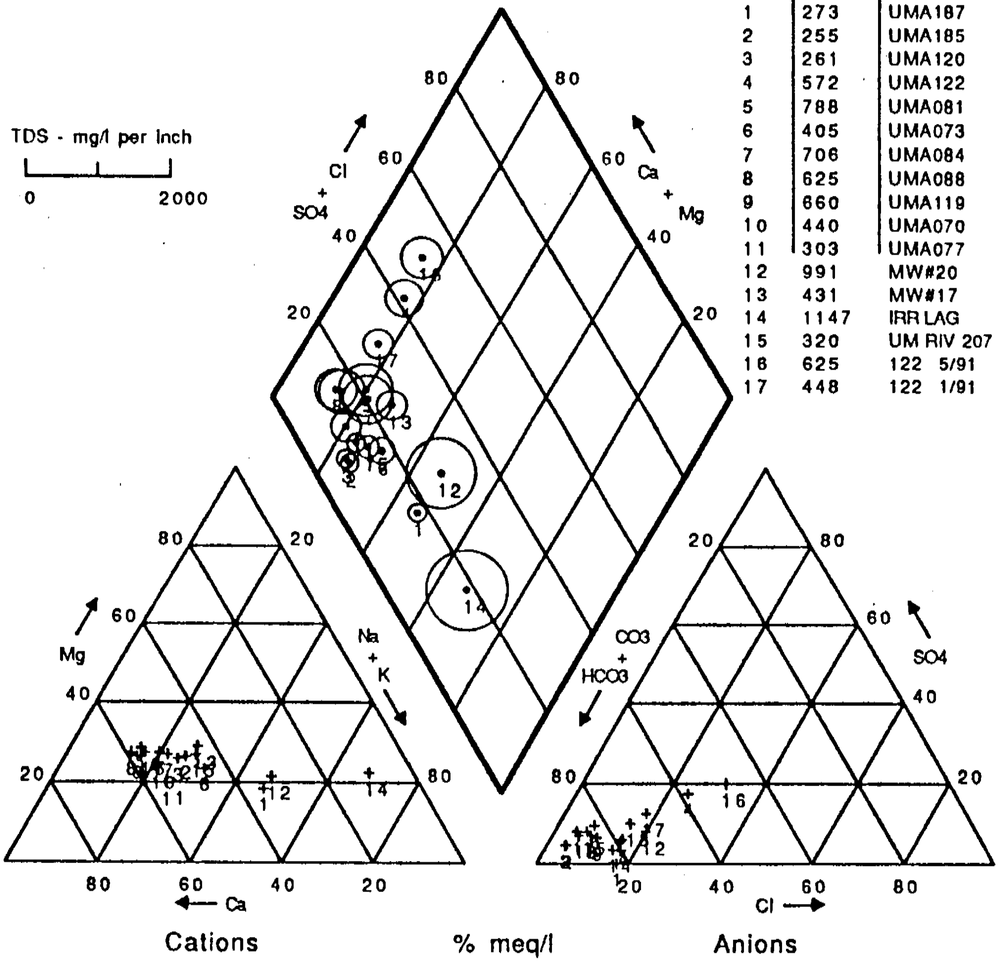
The following solid phases were allowed to participate in the model: basalt glass, plagioclase and clinopyroxene, calcium-, magnesium- and potassium-montmorillonite (a clay mineral), calcite, dolomite, gypsum. Note that mirabilite could not be modeled because sodium and sulfate did not show significant variations. Basalt glass, plagioclase, and clinopyroxene are primary solid phases in basalt whereas the other phases represent minerals formed during the low temperature alteration of basalt. Modeling scenarios that required the precipitation of calcite or dolomite were rejected for reasons based on SI values found in Figure 4.83.

NETPATH generated a significant number of "solutions" since the model was constrained by only three elements. The "successful" models indicated that the bulk of the variation could be accounted for by interaction of the groundwater with basalt glass and clay minerals, with less contribution from the secondary minerals gypsum, calcite and dolomite. Primary phases, such as plagioclase or clinopyroxene, played only a minor role in the models. These results confirmed those generated from the SIMPLOT circle: groundwater does undergo minor changes along the flow path as a result of water-mineral reactions, typical of a groundwater-basalt system.

Compositional Anomalies

Abrupt constituent variations were observed along the Butter Creek flow path between UMA 120 and UMA 122 and between UMA 081 and UMA 073 (see Figure 4.85). In the first case, a significant increase in dissolved constituents occur, which includes nitrate. In the second case, an abrupt decrease in the same constituents is observed. Modeling was performed in order to determine the potential origin of these anomalies and how they might affect the distribution of nitrate in the area.

The local data plot as linear arrays on a Piper trilinear diagram (see Figure 4.89). The linear arrays are consistent with mixing as an evolutionary process. Two distinct trends diverge from Wells UMA 120 and UMA 185. One trend is defined by increasing potassium and sodium toward the chemistry of waters from a food-processing irrigation lagoon and a nearby Simplot monitoring well (MW-20, UMA 258). The second trend is defined by increasing chloride and sulfate ions. It is represented by temporal variation in Well UMA 122. An end member for this trend has yet to be identified, although the trend may be related to the evaporation-dissolution process discussed above. Similar arguments may be applicable to temporal variation observed in UMA 190, along the North Hermiston Terrace and in the Echo-Stanfield area discussed earlier in this chapter. Given the implication for mixing from the Piper diagrams, the evolution of the compositional anomalies was modeled as a combination of water mineral reactions (UMA 185 to UMA 120) and mixing with additional source waters.



No.	TDS	Sample Site
1	273	UMA187
2	255	UMA185
3	261	UMA120
4	572	UMA122
5	788	UMA081
6	405	UMA073
7	706	UMA084
8	625	UMA088
9	660	UMA119
10	440	UMA070
11	303	UMA077
12	991	MW#20
13	431	MW#17
14	1147	IRR LAG
15	320	UM RIV 207
16	625	122 5/91
17	448	122 1/91

Figure 4.90 Piper Trilinear Diagram of Butter Creek flow path data.

Analysis of UMA 120 to UMA 122: Mixing and Evaporation-Dissolution Influences.

Abrupt increases in most constituents were detected in groundwater between the UMA 120 and UMA 122 sites during the June-July 1992 project synoptic sampling (see Figure 4.85). Figure 4.90, a modified Schoeller diagram (Tedaldi and Loehr, 1992) shows this increase. The various concentrations are normalized to (divided by) the least evolved chemical composition which is the sample from UMA 185. The pattern produced on the diagram represents a compositional fingerprint of the water. Also plotted on Figure 4.90 is the chemistry for shallow unconfined groundwater from Simplot monitoring well MW-20 (UMA 258). Although the chemistry related to MW-20 does not lie on the mixing line defined by temporal variations in UMA 122, the overall pattern is very similar. Similar arguments can be made based on ionic ratios. The ratio of elements shown in Figure 4.91 indicates the groundwater chemistry at UMA 185 and UMA 120 are very similar. Groundwater at UMA 122 differs significantly from groundwater at UMA 185 and UMA 120, but it is similar to groundwater at MW-20 as shown in Figure 4.90.

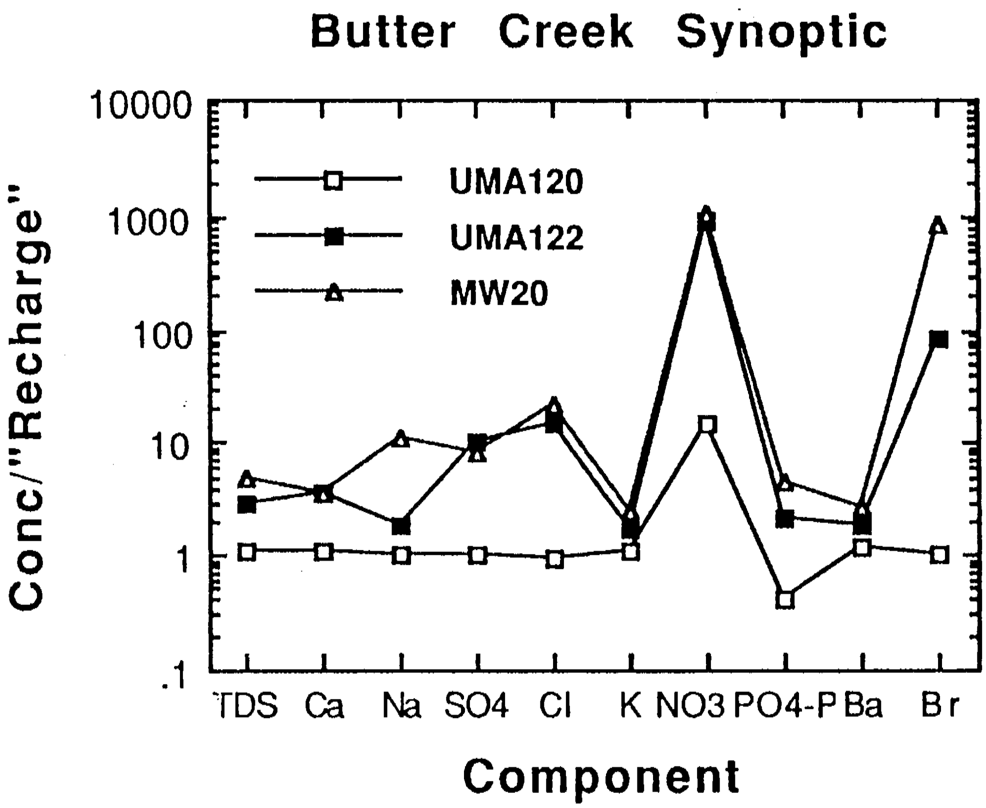


Figure 4.91 Modified Schoeller Diagram of the groundwater chemistry at UMA 120, UMA 122 and Simplot MW-20 (UMA 258).

Note: The "recharge" water compositions are normalized using UMA 185.

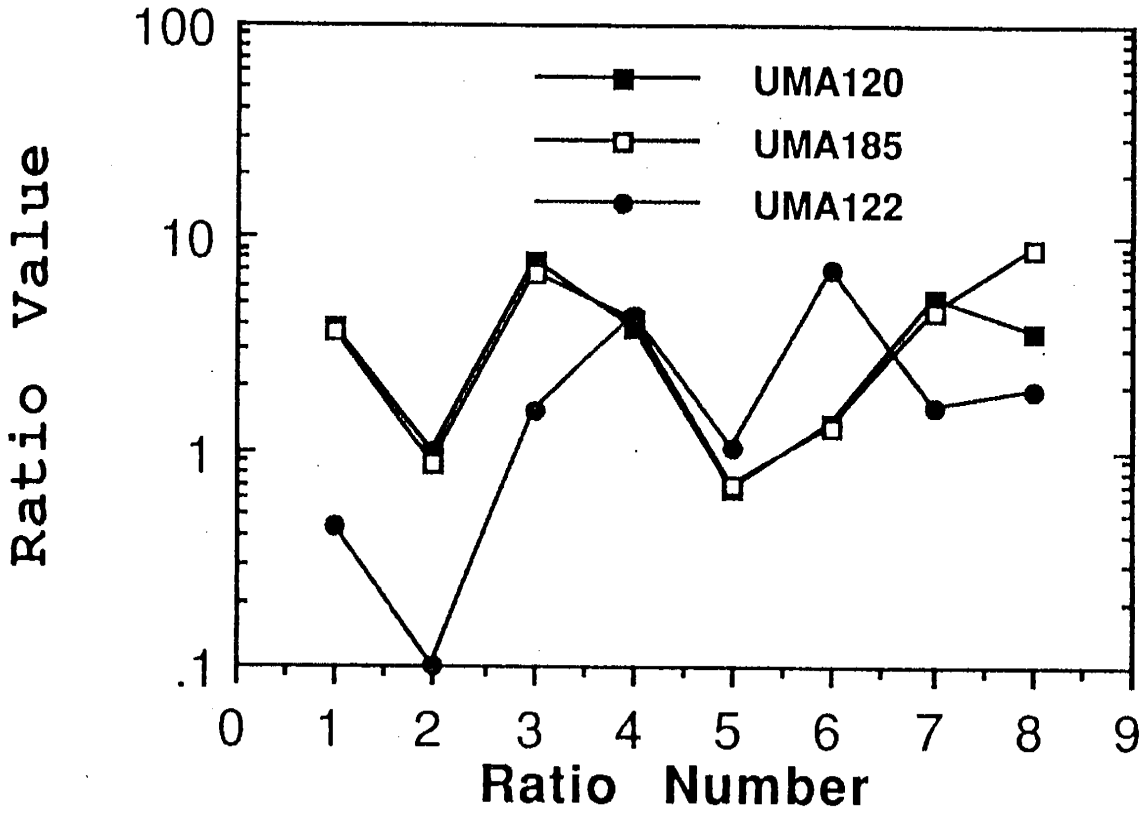


Figure 4.92 Ionic ratios for constituents in groundwater at UMA 185, UMA 120, UMA 122.

Note: There is a marked difference between UMA 122 and the upgradient compositions at UMA 120 and UMA 185.

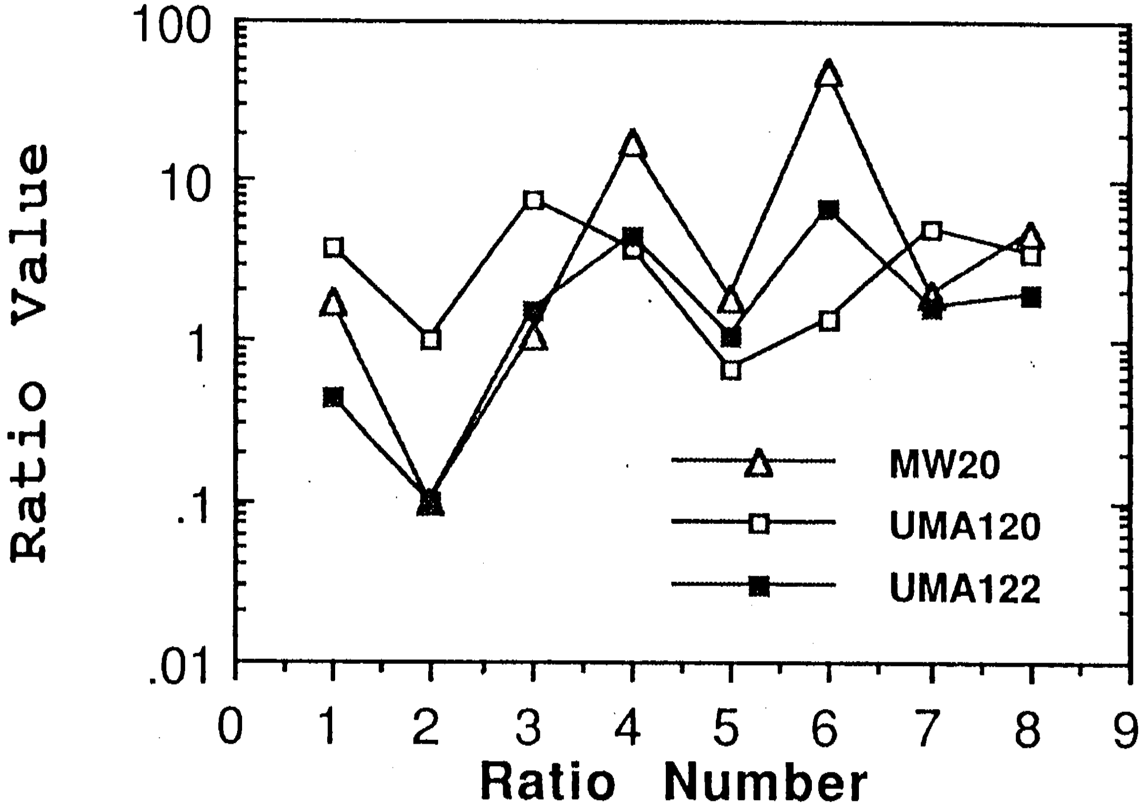


Figure 4.93 Ionic ratios for constituents in groundwater at UMA 120, UMA 122, and Simplot MW-20 (UMA 258).

Note: There is similarity between UMA 122 and MW-20.

The chemical evolution of groundwater from UMA 120 to UMA 122 was modeled by NETPATH as a mixing model. The shallow unconfined groundwater at Simplot well MW-20 (UMA 258) was mixed with groundwater from UMA 120. The natural evolution of groundwater from UMA 185 to UMA 120 was allowed to proceed. Ion exchanges were incorporated into the model to evaluate calcium, magnesium, and sodium variations. The calcium/magnesium molar ratio was held constant during this exercise. Model runs that involved the dissolution of calcite were considered unreasonable given the saturation indices found in Figure 4.83.

Dissolution of a sulfate phase, such as mirabilite, and the exchange of sodium for calcium and magnesium on clay mineral surfaces were common to all "successful" model runs. Typical results, with mixing of end members represented as percentages, are summarized in the following reactions:

UMA 122 = [34% UMA 120] + [66% MW-20]
+ [0.15 glass] + [0.25 mirabilite] - [0.72 calcite]
- [1.03 smectite] - [1.99 Na exchanging for 1.0 (Ca, Mg)] - [2.99 CO$_2$]

UMA 122 = [67% UMA 120] + [33% MW-20]
+ [0.39 mirabilite] + [0.77 NaCl] + [0.09 basalt glass]
- [1.04 CO$_2$] - [0.28 smectite]
- [1.54 Na exchanging for 0.77 (Ca, Mg)]

A few model runs indicated a much lower contribution of groundwater from Simplot well MW-20 in the reaction. The contribution was as low as 7 percent. These solutions were considered unreasonable, because of they failed to explain the total dissolved solids concentrations.

Given that it is unlikely that the highly soluble halite phase could remain in the saturated zone, the model runs containing that phase and mirabilite may reflect additional interactions with water from the vadose zone. Attempts to model the groundwater variation from UMA 120 to UMA 122 that included mixing shallow unconfined groundwater from Simplot well MW-13S (UMA 246) required an unreasonable amount of groundwater from MW-13S. The amount required exceeded 60 percent.

The modeling effort also included using the chemistry for shallow unconfined groundwater at Simplot well MW-17 (UMA 248). The well is located within the Umatilla River floodplain upgradient of UMA 122. Model runs suggest that MW-17 may reflect a mixture of groundwater similar to MW-20 and groundwater derived from infiltration of water from the Umatilla River. It is possible that the groundwater that interacts with the Butter Creek flow path has a similar history. Similar constraints and phases to those above were utilized, yielding the following as potential solutions:

UMA 122 = [41% UMA 120] + [59% MW-17]
+ [0.40 dolomite] + [1.10 halite] + [0.40 gypsum or mirabilite] - [0.11 calcite]
- [0.94 sodium exchanging for 0.47 calcium and/or magnesium]
- [0.56 carbon dioxide]

UMA 122 = [68% UMA 120] + [32% MW-17]
+ [0.53 dolomite] + [0.46 gypsum/mirabilite] + [0.6 basalt glass]
+ [1.32 halite] -[0.20 calcite] - [1.03 sodium for 0.52 calcium and/or magnesium]

Significant seasonal variations are observed in UMA 122, with higher nitrate and TDS occurring primarily in the summer months. NETPATH model runs of UMA 122 using a more dilute January 1991 analysis indicated that mixing of UMA 120 with an additional source was still required. However proportions of that source, such as shallow unconfined groundwater at MW-20, were less than that required for the summer samples, as was the extent of mineral reactions.

The model runs underestimate the nitrate concentration significantly. Figure 4.93 demonstrates that the nitrate concentration of Simplot MW-20 water used in the current calculation (14 mg/L) is significantly lower than the 1988 to 1992 four-year average (~25 mg/L). It is clear that the current levels of nitrate in the end members may not reflect the current nitrate levels in transit through the aquifer. It is apparent from the temporal variation in groundwater at UMA 122 that this conclusion may be extended to other constituents as well. It is significant that the overall chemistry pattern for impacted groundwater at well UMA 122 closely resembles the chemistry pattern of shallow unconfined groundwater at Simplot well MW-20 (UMA 258). Because the shallow unconfined groundwater chemistry at Simplot MW-20 and MW-17 reflects the infiltration of food processing wastewater, it is logical to extend that conclusion to UMA 122 as well.

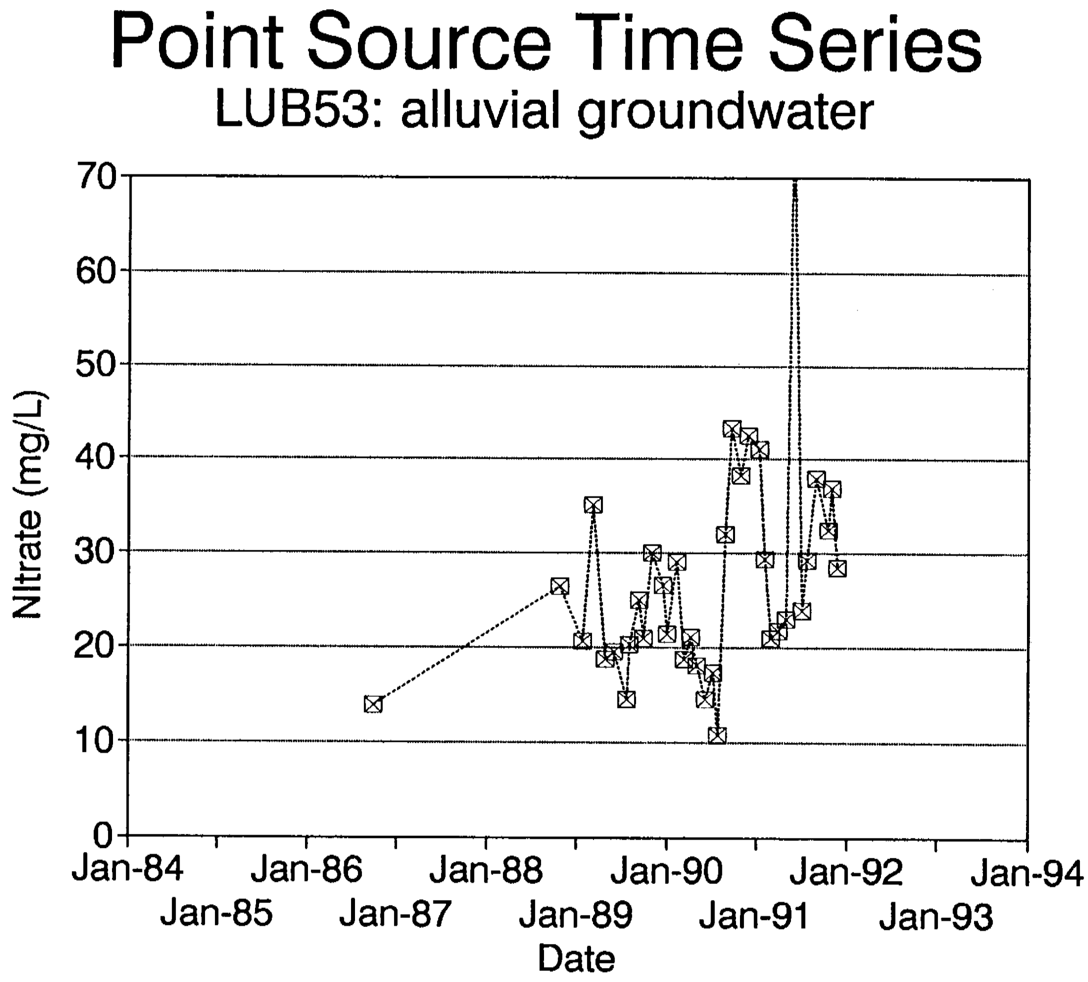


Figure 4.94 Nitrate-nitrogen versus time in shallow unconfined alluvial groundwater collected at Simplot monitoring well MW-20 (UMA 258, LUB 053).

Although the mass balance models presented here are consistent with a source of impact on groundwater being food processing wastewater, it must be noted that this application has focused upon a small area within the Lower Umatilla Basin. Therefore, although the approach to the problem can be applied elsewhere, the conclusions may not. Although there is evidence of food processing wastewater influencing groundwater at the wells discussed, additional evidence that follows indicates that food processing wastewater is not the sole contributor of nitrate within the basin.

Analysis of Groundwater at UMA 122: Evaporation Influence

An explanation for the observation that the temporal UMA 122 groundwater chemistry variation does not lie along a line towards the food processing wastewater end member in Figure 4.89 may be related to secondary processes that affect it.

As previously discussed, evaporation of vadose water or groundwater can occur in arid regions. With respect to groundwater, the evaporation may occur in the capillary fringe directly above the water table (Drever, 1982). It is notable that when evaporation occurs, the concentrations of the various constituents will increase, however, unless there is a precipitation or dissolution of a mineral phase accompanying the evaporation, the molar ratios of the constituents should remain constant. Groundwater at UMA 122 is oversaturated with respect to calcite. However, because of kinetic difficulties (Stumm and Morgan, 1981), precipitation may not occur over short time intervals unless the saturation is overstepped significantly (Krauskopf, 1979).

An evaluation of the molar ratios of the UMA 122 groundwater samples indicates that the ratios of calcium/magnesium (1.96-2.14) and calcium/sodium (1.89-2.13) show little temporal variations. In the cation portion of the Piper plot (left small triangle in Figure 4.89), the sample data will plot virtually on top of one another. In the anion field (right small triangle in Figure 4.89), significant variations are observed. It is notable that the molar ratio of sulfate to chloride also shows little variation (0.33-0.36). Similar observations have been recorded at wells elsewhere in the basin: UMA 190, north Hermiston terrace and in the Echo-Stanfield area.

The reason for the apparent anion variations is the bicarbonate concentration. This component remains relatively fixed in concentration while sulfate and chloride vary significantly. It is suggested that the bicarbonate concentration is buffered by carbon dioxide open to the surface. In the pH range of these waters, most of the carbon dioxide in the water will occur as bicarbonate [HCO_3^-]. If carbon dioxide does not vary significantly, it is unlikely that bicarbonate will vary. Under open system conditions, the partial pressure of carbon dioxide will remain fixed because the water is in chemical communication with the atmosphere (Freeze and Cherry, 1979). As a result, evaporation may not affect dissolved bicarbonate to the extent that it affects other constituents. Note that cation concentration (not necessarily proportions) changes must accompany the anions in order to maintain a charge balance.

In summary, two factors may be influencing the composition of groundwater at UMA 122. Mixing of ambient groundwater with infiltrating wastewater produces the characteristic pattern seen in Figure 4.90. A secondary process of evaporation-dissolution in the vadose zone, coupled with periodic rise and fall of the water table, produces variations in concentrations of certain constituents in the water.

Analysis of UMA 081 to UMA 073: Surface Water Influence

June-July 1992 project synoptic sampling detected a marked decrease in dissolved constituents in groundwater along the UMA 081 to UMA 073 segment of the Butter Creek flow path followed by an abrupt increase along the next segment, UMA 073 to UMA 084. Such reversals are difficult to explain along a presumably continuous flow path. Careful review of the hydrogeology suggested that the UMA 073 well was potentially influenced by the Umatilla River. The groundwater divide to the southeast of this well also suggests that a component of groundwater movement in this area is to the northwest towards the river.

The groundwater chemistry at UMA 081 and UMA 073 as well as the Umatilla River water chemistry is shown on Figure 4.94. The figure is a modified Schoeller diagram. The chemical compositions were normalized using UMA 185 data. It is apparent that groundwater at UMA 073 more closely resembles the chemical pattern of the Umatilla River waters. NETPATH model runs were successful in relating UMA 081 to UMA 073 through water-mineral reactions and significant interaction with the river. Potential solutions include the following:

UMA 073 = [5% UMA 081] + [95% Umatilla River]
+ [0.08 calcite] + [0.38 carbon dioxide] + [0.02 dolomite]
+ [0.13 (calcium, magnesium) exchanging for 0.26 sodium on clay minerals] + [0.04 mirabilite] - [0.03 clinoptilite]

UMA 073 = [5% UMA 081] + [95% Umatilla River]
+ [0.29 carbon dioxide] + [0.11 dolomite]
+ [0.12 (calcium, magnesium) exchanging for 0.24 sodium on clay minerals] + [0.04 mirabilite] - [0.04 potassium-smectite] - [0.13 smectite]

UMA 073 = [5% UMA 081] + [95% Umatilla Rive]
+ [0.50 carbon dioxide] + [1.08 potassium-smectite]
+ [0.04 mirabilite] + [0.72 basalt glass]
- [0.76 clinoptilte] - [0.06 smectite]

The data suggests that UMA 073 represents a mixture of surface water and groundwater. This conclusion is supported by the modified Schoeller diagram shown in Figure 4.94. Additional evidence comes from the project's investigation of the local hydrogeology. That investigation found the Umatilla River locally loses water to groundwater.

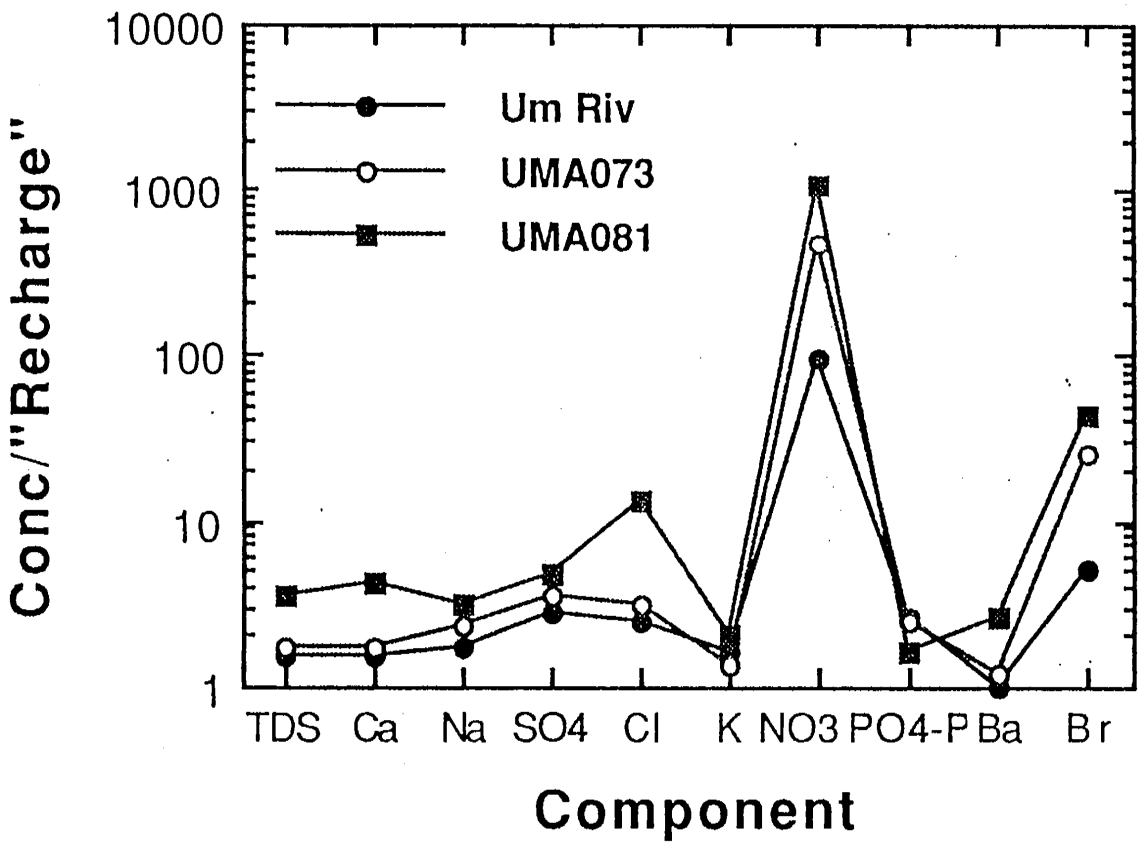


Figure 4.95 Modified Schoeller Diagram of UMA 073 and UMA 081 and Umatilla River water chemistry data.

Note: There is compositional similarity between UMA 073 and the Umatilla River.

Spatial versus Temporal Variations

The data presented thus far indicates that real variations in groundwater chemistry occur across the basin (spatial variations) and in some areas, significant compositional changes occur as a function of time (temporal variation). Discussions earlier in this document indicated that spatial variations most likely reflect source effects: specific surface activities in the area such as animal lots, septic systems, food processing waste water application or irrigated agriculture, or a mixture of these sources. Temporal variations, on the other hand, are related to process effects, reflecting changes in the type and/or magnitude of the processes such as canal leakage, proportion and composition of blending water during irrigation, evaporation-dissolution processes, mixing proportions, precipitation, and other processes.

Commonly we find separate wells bearing both similarities and differences with respect to groundwater composition. As an example, UMA 122 bears the impact of food processing waste water, UMA 190 has characteristics that suggest irrigation influence, and wells on the north Hermiston terrace have been impacted by septic systems, local irrigation and animal waste. All of these sites differ as a result of source effects, However, all display a similar temporal variation of increased chloride + sulfate with respect to bicarbonate as depicted in trilinear diagrams. This temporal variation is interpreted to reflect a process effect, specifically the evaporation-dissolution process within the vadose zone.

As a result of the combined source and process effects, the groundwater chemistry associated with a specific well is often difficult to interpret. The process effect, can obscure the signature of the source(s) effect.

Stable Nitrogen Isotope Analysis

Introduction

During Fall 1993 through Fall 1994, extensive nitrogen isotope sampling was performed in the Lower Umatilla Basin. Funding from the U.S. Environmental Protection Agency was obtained to determine the delta ^{15}N composition of nitrate from selected sampling points in the basin. Dr. Dennis Nelson of the Oregon Health Division and Margot Truini, a Portland State University graduate student, conducted sampling at over 20 wells, 3 lysimeters, and a food processing wastewater surge pond.

A description of the procedures used in collecting the samples can be found in the Materials and Methods section of this chapter. Preliminary results are reported here. At this writing, Truini is in the process of preparing a more comprehensive report with interpretation details for a Portland State University Masters thesis.

Sampling Results

A compilation of the isotopic sampling results is provided in Table 4.40. Samples were collected from:

- private wells in the Butter Creek drainage,
- wells in the area of the Depot's explosive washout lagoon,
- wells associated with the application of food processing wastewater,
- wells associated with past and present animal lots, and
- wells associated with irrigated agriculture that applies commercial fertilizers.

Most wells were sampled twice in order to capture temporal variation. With the exception of a few wells, most repeat samples showed only minor variation.

Table 4.40 Compilation of nitrogen isotopic sampling results

Land-Use	Site Identification	Date Collected	NO3-N (mg/L)	Delta 15N (per mil)
Animal Yard	UMA 183	F93	37	5.1
	UMA 183	S94	55-56*	6.3-6.4*
	UMA 183	F94	52.5	5.4
	UMA 184	F93	11	5.3
	UMA 133	F93	17	10.4
	UMA 133	S94	17	8.5
	UMA 133	F94	16.8-17.1*	9.9-10.0*
Depot: Explosive Washout Lagoon	UMA 226	F93	10	4.7
	UMA 225	F93	13	4.9
	UMA 227	F93	10	4.8
	UMA 224	F93	18	4.6
Food-Processing Wastewater Land Application Area	UMA 058	F93	8	4.8
	UMA 058	S94	9	5.5
	UMA 058	F94	17.8	5.1
	UMA 258	F93	11	29.5
	UMA 258	S94	6.4	33.4-33.7*
	UMA 258	F94	22.6	20.3
	UMA 246	F93	15	7.6
	UMA 246	S94	13	5.5
	UMA 246	F94	9.9	5.9
	UMA 248	F93	15	7.3
	LY1	F94	37.9-39.9*	21.1-21.9*
	LY2	F94	3.0-3.1*	6.4-6.5*
	LY4	F94	5.4	9.1
	Effluent	F94	60.5-60.9*	3.5-6.5*
Irrigated Agriculture	UMA 173	F93	48-50*	4.0-4.1*
	UMA 161	F93	75	4.7
	UMA 161	S94	81-87*	4.1-4.6*
	UMA 159	F93	28	3.1
	UMA 159	S94	29*	2.9-3.0*
	UMA 159	F94	25.0-28.5*	2.8-3.0*
	UMA 182	S94	15	4.5
	UMA 182	F94	16.2	4.9
Butter Creek: Domestic Wells	UMA 122	F93	12	5
	UMA 122	S94	18.1	2.7
	UMA 122	F94	9.3	4.5
	UMA 134	F93	19	6.8
	UMA 134	S94	21	6.9
	UMA 134	F94	15.2	6.8
	UMA 069	F93	10*	7.1*
	UMA 069	S94	19.5	6.5
	UMA 069	F94	6.2	6.1

Note:
Land-use = Dominant land use practice in the well vicinity.
Date = Fall 1993 (F93), Spring 1994 (S94), or Fall 1994 (F94)
UMA ### = Well identification number
LY# = Lysimeter
Eff = Effluent from the J.R.Simplot Company wastewater purge pond
* = Duplicate analysis result

The data from the sampling are displayed in Figures 4.95 and 4.96. Analysis of the data in Table 4.40 and the figures indicates that the range of delta ^{15}N for the sampled wells is +3.0 to +33.6 per mil. Only two categories of nitrate source can be clearly distinguished: UMA 258, a Simplot monitoring well, having a delta ^{15}N of +29.5 to +33.6 per mil and the Western Empire wells (UMA 159, -161, -173 and -182) which have delta ^{15}N ranging from +3.0 to +4.7 per mil.

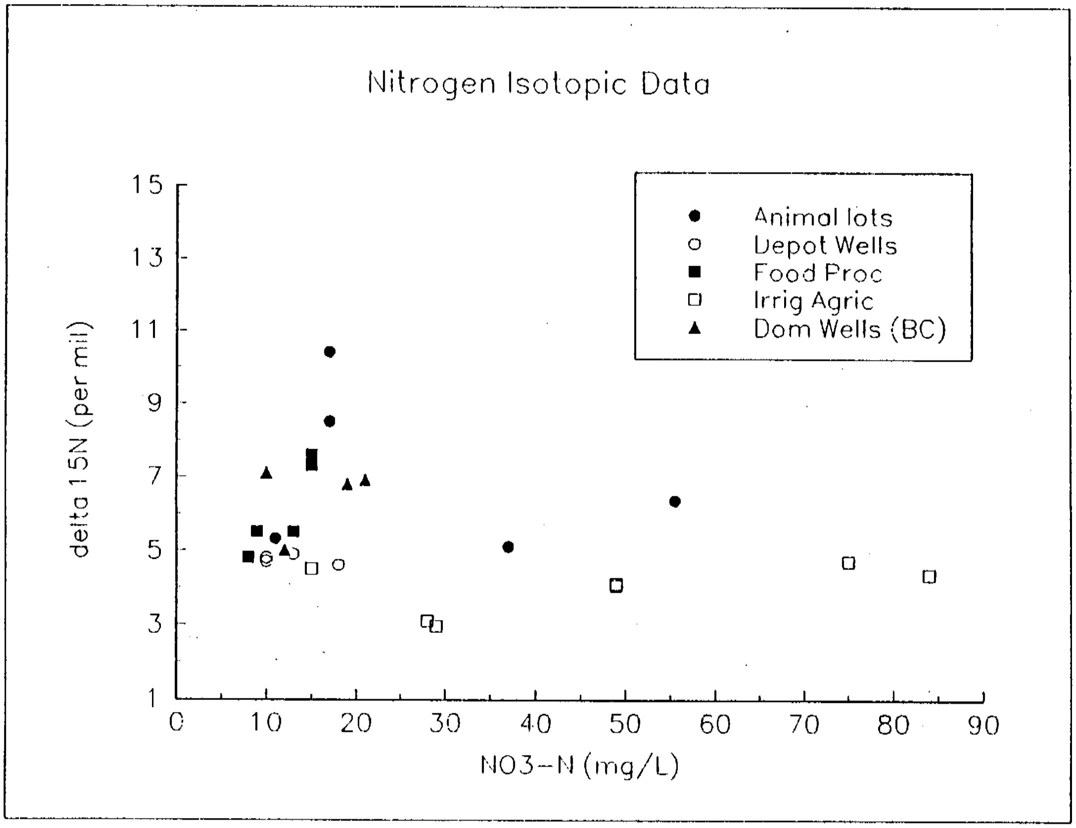


Figure 4.96 Delta ^{15}N versus nitrate-nitrogen concentration in groundwater from some of the Lower Umatilla Basin wells sampled for nitrogen isotopic analyses.

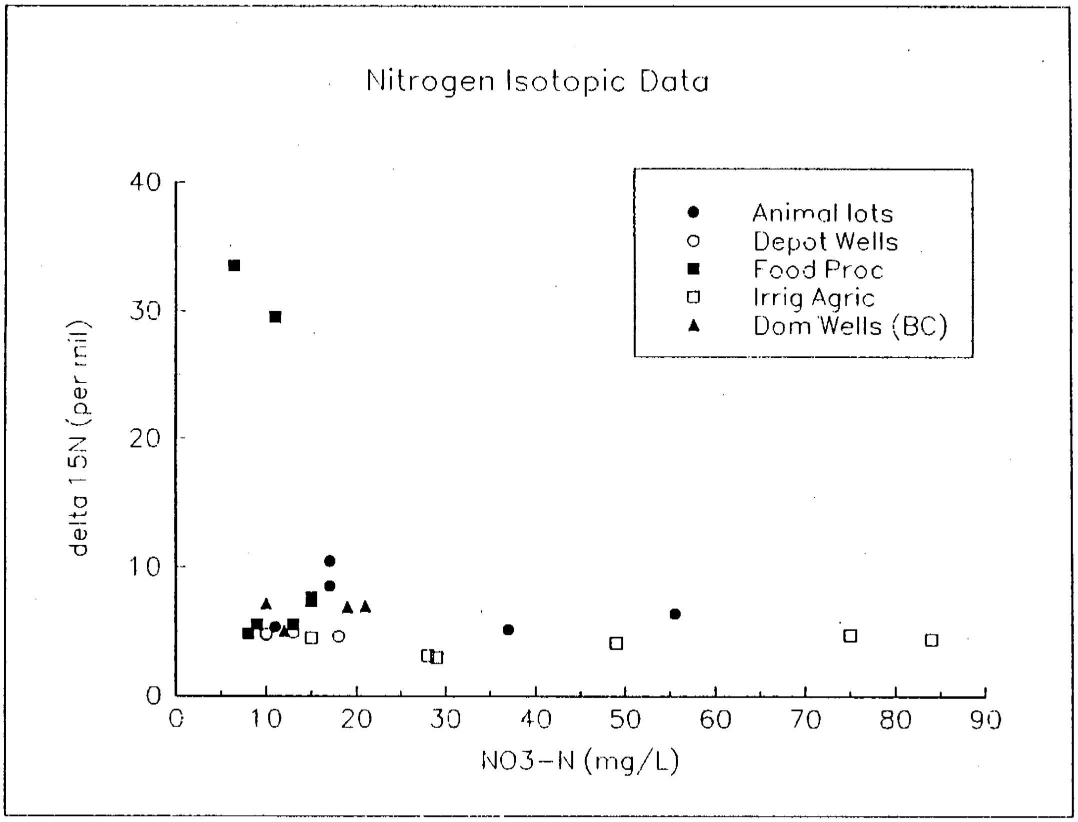


Figure 4.97 Delta ^{15}N versus nitrate-nitrogen concentration in groundwater from all Lower Umatilla Basin wells sampled for nitrogen isotopic analyses.

Analysis of Groundwater at UMA 258

The elevated delta ^{15}N for UMA 258 indicates organic wastes as a nitrogen source. Organic waste could indicate either food processing, animal waste effluent, or septic system effluent source. Well UMA 258 is located on J.R. Simplot Company property where food processing wastewater is land applied. The wastewater is identified as the primary nitrogen source at UMA 258. Samples from other wells at the Simplot facility yield lower delta ^{15}N values ranging from +4.8 to +7.6 per mil (see Figure 4.95). A question remains as to whether the elevated isotopic composition indicates organic nitrogen sources or reflects denitrification of the nitrogen represented isotopically by groundwater sampled from the other Simplot wells.

The sampling data shown in Figure 4.96 suggests a denitrification impact upon groundwater at UMA 258. A decrease in nitrate abundance and an increase in delta ^{15}N is considered an indication of denitrification (Mariotti and others, 1988). The fractionation of nitrogen isotopes during denitrification can be described by equations using the isotopic enrichment factor (ef). The equation is as follows:

$$\text{delta}_{(f)} = \text{delta}_{(i)} + \text{ef}(\ln[C_{(f)}/C_{(i)}])$$

where delta refers to the isotopic composition of the final (f) and initial (i) nitrate, C refers to the final (f) and initial (i) concentrations of nitrate, and ln is the natural log (Mariotti and others, 1988).

Using the initial (delta $^{15}N = +29.5$ per mil, NO_3-N = 11 mg/L) and final (delta $^{15}N = +33.55$ per mil, NO_3-N = 6.4 mg/L) values for UMA 258, the enrichment factor is calculated to be -7.5 per mil. This is within observed ranges reported elsewhere for denitrification in groundwater (Mariotti and others, 1988).

The hypothesis can be tested as to whether the elevated delta ^{15}N values of UMA 258 are derived from the lower isotopic values observed in groundwater samples collected elsewhere on the Simplot property using the above equation and the calculated enrichment factor. The Fall 1993 nitrate concentration and delta ^{15}N values for UMA 258 (11 mg/L and +29.5 per mil) and the Fall 1993 delta ^{15}N value of UMA 248 of +7.3 per mil can be used to determine whether the predicted concentration of UMA 248 is consistent with the denitrification model or not. Solving the equation with this new data indicates that in order for the UMA 258 values to have been derived from nitrate having a delta ^{15}N of +7.3, the concentration of the nitrate would have had to have been in excess of 200 mg/L. Producing the appropriate isotopic compositions and nitrate concentrations of UMA 258 solely through denitrification of typical Simplot well data would require enrichment factors of approximately -70 per mil, considerably different from any reported values in the literature (Mariotti and others, 1988). Consequently, the nitrogen in the nitrate from UMA 258 is considered to reflect organic waste material (delta $^{15}N = +10$ to $+22$) (see Appendix 4B).

Analysis of Wastewater from the J.R. Simplot Company Surge Pond

A sample was collected from the wastewater surge pond near the Simplot plant. As indicated in Table 4.40, the isotopic composition of nitrate in the sample is low. It measured less than +6.5 per mil. That is considerably less than what would be considered normal for organic wastes. A possible explanation for this low value is the presence of ammonia, carrying the bulk of the nitrogen. An earlier sample of this pond water indicated most of the nitrogen was in the form of ammonia and organic nitrogen. Progressive volatilization of ammonia would leave residual ammonia substantially enriched in delta ^{15}N (Mariotti and others, 1988). Nitrification of that ammonia would lead to nitrate having a significantly higher delta ^{15}N composition. Because the wastewater is stored in lagoons prior to land application, volatilization and nitrification are considered likely processes. This, coupled with additional volatilization and nitrification during and subsequent to land application may lead to the residual water having nitrate with much higher delta ^{15}N values.

Analysis of Lysimeter Samples

Table 4.40 and Figures 4.95 and 4.96 show the isotopic results from samples collected in shallow (5 to 7 feet) lysimeters located in Section 6, T3N, R28E. The lysimeters are located in an area where corn is grown and food processing wastewater is land applied. Two of the lysimeters, LY1 and LY2, are located adjacent to each another. LY4 is located within 100 feet of LY1 and LY2. As such, the lysimeter data indicate the potential diversity of nitrate concentrations (3.0 - 38.9 mg/L) and isotopic compositions (+6.4 to +21.5) within the area. Although the reason(s) for the diversity in nitrogen isotopic composition is not clear at this point, what is evident is that the lysimeters LY1 and LY2 cannot be related through denitrification processes. LY1 not only has a higher isotopic composition than LY2, it also has a significantly higher nitrate concentration.

Analysis of Western Empire Farm Samples

The delta ^{15}N of nitrate in groundwater sampled from Western Empire Farm wells are consistently low: +3.0 to +4.7 per mil. These low values are consistent with commercial fertilizer (-4 to +4 per mil) as the primary nitrate source. The delta ^{15}N values are consistent over a wide range of nitrate concentrations (see Figure 4.95). That suggests a constant uniform source of the nitrogen. The data for groundwater sampled from the Western Empire Farm wells produce a nearly horizontal trend, as shown in Figure 4.96. This trend suggests simple dilution affects the nitrate concentrations.

Analysis of Groundwater Sampled at the U.S. Army Umatilla Depot Activity

Groundwater samples were collected at the U.S. Army Depot in proximity to the explosive washout lagoon. Delta ^{15}N values for the samples range from +4.6 to +4.9 per mil. Explosives have low delta ^{15}N values similar to commercial fertilizers, because atmospheric nitrogen is incorporated in their manufacture. A. E. Fryer (personal communication, October, 1994) has studied nitrate contamination of groundwater in the vicinity of the U.S. Department of Energy's Pantex Plant near Amarillo, Texas. He reports that the nitrate derived from explosives, including RDX, a contaminant at the Depot site, has a delta ^{15}N varying from -4 to +4 per mil. Although slightly more enriched in delta ^{15}N, the data for the Depot indicates that the bulk of the nitrate in the groundwater near the explosive washout lagoon was derived from explosive contaminants.

Analysis of Groundwater Sampled at UMA 133

Site UMA 133 is located in the vicinity of a former turkey and dairy operation, an existing cattle operation, and grazing sheep. The well is also located adjacent to a horse pen. The delta ^{15}N is significantly greater than the bulk of the samples analyzed thus far. The values range from +8.5 to 10.4 per mil for UMA 133. These values are at the low end of the range generally accepted for nitrate derived from animal wastes (+10 to +22 per mil). It is reasonable to conclude that animal waste contributed nitrate to groundwater at this site.

Analysis of Groundwater Sampled from Other wells

Groundwater sampled from other Lower Umatilla Basin wells listed in Table 4.40 have delta ^{15}N for nitrate within the range of +4.8 to +7.6 per mil and are thus not diagnostic of any one particular source. A mineralized soil nitrate source is considered unlikely, because the history of tillage in the area would have depleted that source (Reinhorn and Avnimelech, 1974).

Influence of Mixing

Nitrogen isotope data for groundwater collected from wells at Hansell Brothers Inc., and J.R. SIMPLOT Company wells display positive slopes in the nitrate versus delta ^{15}N graph (see Figure 5-35). These slopes, along with the intermediate isotopic compositions suggest a potential mixing of two sources: a low nitrate-low ^{15}N source(s) and a high nitrate-high ^{15}N source(s). It is apparent that the same high nitrate end member probably does not contribute to groundwater at both the Simplot and Hansell Brothers wells. It is also apparent that the variation observed in the Simplot and Hansell Brothers wells is not simple dilution. Dilution would lower the nitrate concentrations, but would not decrease the delta ^{15}N value (Mariotti and others, 1988).

The water chemistry data from the UMA 122 well is suggestive of the result of mixing of groundwater from the Butter Creek drainage (UMA 120) with groundwater derived from below fields in which food processing wastewater has been applied (MW-17 and MW-20).

Figure 4.95 indicates that UMA 122 is located near the low delta ^{15}N of the Simplot array, qualitatively supporting a mixing origin. The isotopic data for the UMA 122 well, however, virtually precludes MW-20 (see Figure 4.96) as being an end member in the mixing process. The isotopic composition of UMA 120 (not available) would have to be unreasonably low. In contrast, if MW-17 is the end member, the delta ^{15}N of UMA 120 would have to be in the vicinity of +2.0, not an unrealistic value. Both the water chemistry and the isotopic data then are consistent with UMA 122 being derived by mixing of ambient groundwater and water derived from land application of food processing wastewater.

Assessment of Natural Processes to Reduce Groundwater Nitrate Concentrations

Two principle natural processes which can reduce nitrate concentrations in an aquifer include denitrification and hydraulic flushing. Denitrification converts dissolved nitrate into nitrogen gas. Hydraulic flushing involves relying upon natural groundwater movement to carry nitrate from recharge areas to discharge areas where the nitrate exits the aquifer.

Denitrification

Denitrification converts dissolved nitrate into nitrogen gas (Mariotti and others, 1988, Smith and others, 1991) which is accomplished by active bacteria (Korom, 1992). These bacteria require the presence of organic carbon and the absence of oxygen in order to accomplish the denitrification process. If oxygen is present in the aquifer, any organic carbon will be oxidized by the oxygen with no effect on the nitrate. Once oxygen is depleted, denitrifying bacteria may use nitrate as the electron acceptor during carbon oxidation.

As previously discussed, denitrification was recognized in groundwater sample from a single monitoring well (UMA 258) on the Simplot property. This well is located on the flood plain of the Umatilla River. The denitrification process may act locally, at sites like UMA 258: Holocene alluvium flood plain deposits proximal to existing drainages and a combination of high organic matter and a shallow water table providing an adequate reducing environment.

Chemical analyses of this water indicate a high dissolved organic carbon (DOC) content (7 mg/L), consistent with a reducing environment (Mariotti and others, 1988), where denitrification is occurring. UMA 248 is also located on the flood plain, but closer to the river. The DOC content of this water is considerably lower (3 mg/L), suggesting denitrification is not occurring. In the coarse alluvial sediments and in the basalt, organic carbon levels are generally too low to be effective as a reducing agent for dissolved nitrate.

There is no evidence of area-wide denitrification in the Lower Umatilla Basin. This may be a result of low concentrations of organic matter in the aquifer (Starr and Gillham, 1993) and the thick unsaturated zone. The trend of decreasing nitrate with increasing delta ^{15}N, considered indicative of denitrification (Mariotti and others, 1988), is not seen on an area-wide basis in the Lower Umatilla Basin. Trends in the Western Empire data suite are nearly horizontal (the isotopic composition is constant over a large range of nitrate concentrations). This trend reflects simple dilution. The data trend defined by the temporal variation in the Hansell Brothers wells and in the bulk of the Simplot wells is positive, reflecting some mixing (not denitrification).

Hydraulic Flushing

Hydraulic flushing refers to the natural processes of groundwater recharge, flow and discharge to remove nitrate from an aquifer. Three areas were identified in the Hydrogeology chapter as having coarse-grained flood deposits with high hydraulic conductivity and very low hydraulic gradients (<2-5 feet per mile). These include the Hermiston area, the Boardman-Irrigon area, and the U.S. Army Umatilla Ordnance Depot Activity vicinity. Local groundwater may move only a few feet per day in these areas. Periodically, the hydraulic gradient is reversed as a result of river stage or pumping influences. These flow velocities and reversals may prolong or hinder the potential natural hydraulic flushing process in these areas. The natural groundwater flux (or rate) moving through the aquifer may not be sufficient to reduce the nitrate levels within the remediation time frame desired.

The nitrogen isotope sampling results provide further evidence of low groundwater flow velocities. Nitrogen isotopic analyses were conducted on groundwater from irrigation wells in the Boardman-Irrigon area (UMA 159, UMA 161 and UMA 173). Although these wells differ from one another in terms of nitrate concentrations, there is only a minor variation at each individual well throughout the 13 month period during which the samples were collected. The isotopic compositions of the waters at each individual well also show no significant variation during that time period. This lack of variation through seasonal irrigation and nonirrigation periods is consistent with the conclusions reached in the Hydrogeology chapter. The Boardman-Irrigon area is underlain by a large volume of very slow moving groundwater.

The low groundwater flow velocities in the Hermiston, U.S. Army Umatilla Depot Activity, and Boardman-Irrigon areas leads to an important conclusion: the process of natural hydraulic flushing of the existing nitrate from the groundwater in these areas will be slow. Natural hydraulic flushing may require decades. Therefore, any practices implemented to reduce future nitrate loading may not have an immediate impact on the observed groundwater nitrate concentrations in these areas.

Lower Umatilla Basin Groundwater Chemistry Summary and Conclusions

The Lower Umatilla Basin Groundwater Management Area technical investigation conducted a variety of activities to primarily understand the distribution and source of nitrate in local groundwater. Those activities included different sampling events, laboratory analyses for multiple chemical constituents, and multiple data analyses. Those activities and their results are summarized in this section.

Materials and Methods

The Lower Umatilla Basin technical investigation conducted a variety of sampling events to obtain data appropriate for different analyses. Reconnaissance sampling at 179 wells, 2 springs, and 1 drain occurred from July 1990 through October 1991. This sampling provided preliminary information about the occurrence of nitrate groundwater contamination in the basin and where future efforts should focus. On-going bimonthly groundwater sampling began in October 1991. The sampling occurs repeatedly at 35 to 40 sites to record groundwater chemistry changes over time. Synoptic sampling occurred during late June and early July 1992 at 207 wells and 26 surface water sites to obtain concurrent data for basin wide analyses. Local facilities participated in the synoptic sampling. An Oregon Strategic Water Management Group grant funded this sampling effort. Stable nitrogen isotope sampling occurred at approximately 20 wells, 3 lysimeters, and a food processing surge pond in 1993 and 1994. The effort was conducted to obtain data useful for identifying nitrogen sources and processes that may influence groundwater nitrate concentrations. An U.S. Environmental Protection Agency 319 Grant funded this effort.

Four laboratories chemically analyzed the samples collected. The Boston University Stable Isotope Laboratory analyzed the stable nitrogen isotope samples. The Oregon State University Agricultural Chemistry Laboratory participated by analyzing some reconnaissance samples for agricultural pesticides. The Oregon Department of Agriculture Laboratory analyzed the reconnaissance and selected bimonthly groundwater samples for agricultural pesticides. The Oregon Department of Environmental Quality Laboratory analyzed all reconnaissance, bimonthly, and synoptic samples for nitrate, other nutrients, major ions, metals, and other inorganic constituents. The laboratory analyzed reconnaissance and selected bimonthly samples for volatile organic compounds.

Multiple techniques were used to analyze and interpret the project and local facility data. All analyses were conducted in an effort to understand the source, distribution, and fate of nitrate in Lower Umatilla Basin groundwater. The analyses included general statistics, chemical constituent distribution maps, multiple graphical analyses, groundwater chemistry computer modeling for selected areas, and stable nitrogen isotope interpretations. Results were derived independently. Then, they were compared to each other and to the current understanding of local hydrogeolgy and land uses to assess their reasonableness.

General Observations and Interpretations

Nitrate Sources, Distribution, and Fate

Data analysis led to the following general observations and interpretations regarding nitrate in Lower Umatilla Basin Groundwater.

- Human activity appears responsible for nitrate concentrations greater than 1 mg/L. Evidence comes from observing the relationship between nitrate and other chemical constituents in groundwater.

- No single source is solely responsible for the elevated nitrate concentrations observed in Lower Umatilla Basin groundwater.

- Project sampling detected nitrate below 2 mg/L in groundwater sampled from approximately 26 percent of the project sampling sites. The occurrence of some of these lower concentrations appear related to either dilution influences or background conditions.

- Project sampling detected nitrate concentrations exceeding the 10 mg/L drinking water standard in nearly 30 percent of the groundwater samples collected which came from nearly 31 percent of the project sampling sites. The highest concentration detected by project sampling was 76 mg/L. Local facilities have reported concentrations greater than 100 mg/L.

- Nitrate concentrations greater than 10 mg/L in the Lower Umatilla Basin groundwater are not evenly distributed. Higher nitrate concentrations occur within:

    - Threemile and Sixmile Canyons,
    - the Boardman and Port of Morrow vicinities,
    - north, west, and south of the U.S. Army Umatilla Depot Activity,
    - two sites within the Depot,
    - the Butter Creek-Umatilla River confluence vicinity, and
    - the terrace south of Hermiston.

  The highest concentrations detected by project sampling occur between the Port of Morrow and Irrigon where center pivot irrigation is used. Nitrogen isotopic analysis identifies commercial fertilizer as the nitrate source.

- Hydrogeologic, nitrate distribution versus land use, and nitrogen isotopic analyses indicate local groundwater transport of nitrate is slow. For example, an apparent nitrate plume emanating from the U.S. Army Depot explosive washout lagoons has moved less than 4 miles in three to four decades.

- Analysis comparing nitrate concentrations versus time to groundwater elevations versus time indicate the time required for nitrate to travel from land surface to groundwater ranges from less than one month to 18 months depending upon local conditions and water available for transport. This travel time is faster than suggested by other investigators.

- Analyses identify food processing wastewater activity responsible for elevated nitrate concentrations occurring in groundwater at wastewater land application sites located northeast and south east of the Butter Creek-Umatilla River confluence, northeast of the U.S. Army Depot, and east of Boardman.

- Analyses identify irrigated crop agriculture as contributing to elevated nitrate concentrations occurring in groundwater at Threemile and Sixmile Canyons, south of Boardman, north, west, and south of the U.S. Army Depot, southwest of Hermiston, northeast of Hermiston, and the terrace south of Hermiston.

- Analyses identify animal waste as contributing to elevated nitrate concentrations occurring in groundwater at Threemile and Sixmile Canyons, south of Boardman, south of the U.S. Army Depot, and south of Hermiston near Highway 207. Analyses suggest animal waste contributes to elevated nitrate north of the Depot, but project investigators are not aware of livestock activity or animal waste use in that area. Animal waste is identified as locally contributing to nitrate concentrations approaching 10 mg/L north of Hermiston.

- Analyses identify septic systems as locally contributing to elevated nitrate concentrations in groundwater south of Boardman, between Irrigon and Umatilla, between the U.S. Army Depot and the Umatilla River, and sites on the terrace south of Hermiston.

- Analyses identify the U.S. Army Umatilla Depot Activity responsible for elevated nitrate concentrations in groundwater at the explosive washout lagoons and the active landfill. Outside sources appear responsible for elevated nitrate concentrations detected along the Depot's south and west borders.

Other Constituents in Lower Umatilla Basin Groundwater

Data analysis led to the following general observations and interpretations regarding other constituents in Lower Umatilla Basin Groundwater.

- Project sampling detected total dissolved solids concentrations exceeding the 500 mg/L secondary (aesthetic) drinking water standard in more than 20 percent of the groundwater samples collected which came from more than 25 percent of the project sampling sites. Groundwater samples with the highest concentrations detected came from Threemile and Sixmile Canyons area and from between Boardman and Irrigon.

- Four project groundwater samples contained arsenic at concentrations greater than the 0.050 mg/L drinking water standard. Those samples came from dispersed sites.

- Project sampling detected sodium at concentrations greater than the 20 mg/L limit for physician prescribed sodium restricted diet in groundwater at 85 percent of the sampling sites.

- Project sampling detected vanadium at concentrations considered unusual. Investigating vanadium was beyond the scope of this project.

- Project sampling detected agricultural pesticides and/or volatile organic compounds (VOCs) in groundwater sampled from 16 sites. Pesticides were detected in groundwater from 10 sites. VOCs were detected in groundwater from 7 sites. Most of the sites are located east of the U.S. Army Depot. The presence of the constituents indicate a human activity influence.

- The U.S. Army Depot reports the presence of explosives in groundwater at some Depot sites. The presence of these constituents indicate a human activity influence.

Other General Observations and Interpretations

Analyses led to the following miscellaneous observations and interpretations.

- Both spatial and temporal variations are observed in basin groundwater, reflecting source and process effects.

- A hydraulic connection exists between alluvial groundwater and some basalt water bearing zones.

- Multiple influences affect the groundwater chemistry in the basin. Not all of these influences contribute nitrate.

- Cyclic evaporation and dissolution processes in the vadose (unsaturated) zone above groundwater influences the groundwater chemistry (such as increasing TDS) in the basin.

- Water-rock interactions cause minor groundwater chemistry variations in the basin.

- Mixing of groundwater with other groundwaters, infiltrating water from the surface, and with surface water is identified as an important contribution to variations in groundwater chemistry.

- Canal leakage does locally influence the groundwater chemistry. It dilutes constituent concentrations in the Hermiston vicinity.

- Food processing wastewater, irrigation, animal waste, and septic system influences on groundwater chemistry could be distinguished on some constituent versus constituent graphs.

- Most Lower Umatilla Basin groundwater graphs as mixed-cation/bicarbonate dominated or calcium/bicarbonate dominated on Piper trilinear graphs.

- Chloride and sulfate proportion variations in groundwater sampled often correlated to nitrate concentration variations. Chloride and/or sulfate proportions increased with higher nitrate concentrations. This was observed to occur between sampling sites and over time.

Area Specific Observations and Interpretations

Threemile Canyon and Sixmile Canyon Area Summary and Conclusions

Analysis of Threemile Canyon and Sixmile Canyon groundwater chemistry data led to the following observations and interpretations:

- Nitrate concentrations in Threemile Canyon and Sixmile Canyon area groundwater ranges from non-detect to 70 mg/L.

- Nitrate concentrations remained below 1 mg/L in groundwater samples collected from basalt wells constructed more than 500 feet deep.

- Nitrate concentrations were detected below 2 mg/L in shallow basalt water bearing zone groundwater samples collected near Interstate 84 east of Sixmile Canyon.

- Nitrate concentrations exceeding 10 mg/L were detected in alluvial and shallow basalt water bearing zone groundwater samples collected near the J.R. Simplot Feedlot wastewater lagoons, near or within Taggares Farm along Sixmile Canyon, and the PGE ash disposal area.

- A review of available nitrate, ammonia and Total Kjeldahl Nitrogen (TKN) data and local land uses indicates animal waste or another organic nitrogen source influences groundwater in the J.R. Simplot Feedlot wastewater lagoon vicinity and the PGE 101 (UMA 274) vicinity at least.

- Graphical analyses indicate a combination of nitrate sources and natural processes influences groundwater along Sixmile Canyon.

- Graphical analyses indicate Taggares Farm activities contributes nitrate to alluvial and shallow basalt water bearing zone groundwater within the farm vicinity.

- Carty Reservoir appears to dilute shallow basalt water bearing zone groundwater near the reservoir.

- The source of nitrate in groundwater within the PGE ash disposal area remains unresolved. Ash from the electric generating coal fired plant appears not to be a nitrate source, and Carty Reservoir is between the ash disposal area and Taggares Farm. Agricultural activity does occur south of the ash disposal area, but no data from that area was obtained for comparison analyses.

- Total dissolved solids (TDS) concentrations in local groundwater are among the highest detected in the Lower Umatilla Basin.

- Arsenic concentrations in alluvial groundwater sampled from UMA 275 (PGE 103) approached the drinking water standard of 0.05 mg/L.

- Sodium concentrations in local groundwater generally exceeded the 20 mg/L standard recommended for persons on a physician prescribed sodium restricted diet.

- Chloride concentrations exceeded the 250 mg/L secondary (aesthetic) drinking water standard in some shallow basalt water bearing zone groundwater samples from the Taggares vicinity and PGE ash disposal area vicinities.

- Some sulfate concentrations measured in local groundwater samples are among the highest concentrations detected in the Lower Umatilla Basin.

Boardman to West Umatilla Area Summary and Conclusions

Project analyses used data from project sampling and data reported or provided by local facilities. The analyses led project investigators to the following observations and interpretations:

- Groundwater nitrate concentrations detected by this project or reported by local facilities range from non-detect to more than 100 mg/L.

- Groundwater with nitrate concentrations exceeding 10 mg/L occurs in large areas located:
  - south of Boardman,
  - between Boardman and Irrigon,
  - between Irrigon and the Umatilla River,
  - the northeast corner area of the U.S. Army Umatilla Depot Activity,
  - the Depot's washout lagoons area, and
  - south of the Depot.

- Elevated nitrate concentrations in groundwater south of Boardman appears to come primarily from irrigation activity with some contribution from animal operations and septic systems.

- Port of Morrow and Lamb-Weston wastewater land application activity east of Boardman and adjacent to the U.S. Army Depot, respectively, appear responsible for the elevated nitrate concentrations at their respective sites.

- Irrigated agriculture appears responsible for elevated nitrate concentrations detected in groundwater between the Port of Morrow and Irrigon as well as the elevated nitrate concentrations detected along the U.S. Army Depot's western boundary.

- Irrigation and septic systems appear responsible for elevated nitrate concentrations detected in groundwater north of the U.S. Army Depot. Analyses also suggest an animal waste influence. However, this investigation has no information to confirm or refute the use of animal waste in this area.

- Elevated groundwater nitrate concentrations detected in the U.S. Army Depot active landfill area appears derived from a Depot source rather than from the upgradient Lamb-Weston wastewater land application site. Dried domestic sludge disposed at the landfill is a potential source.

- Historic activity at the U.S. Army Depot washout lagoons appears responsible for elevated groundwater nitrate concentrations detected in the central portion of the Depot. Nitrate movement away from the lagoons appears to be less than four miles over three to four decades if the apparent plume on Plate 4.2 is real. Otherwise, nitrate has moved less than 0.5 miles over the same period.

- Irrigated crop agriculture and animal operations appear primarily responsible for the elevated nitrate concentrations detected in groundwater south of the U.S. Army Depot.

- Groundwater nitrate concentrations below 10 mg/L were detected in samples from sites west of Irrigon along the Columbia River, south of Irrigon through the western portion of the U.S. Army Depot, and the Lost Lake vicinity.

- Total dissolved solids concentrations exceeded the 500 mg/L secondary (aesthetic) drinking water standard in groundwater:

    - south of Boardman,
    - between Boardman and Irrigon,
    - the east Irrigon area,
    - the U.S. Army Depot active landfill area,
    - the immediate vicinity of the Depot's explosive washout lagoons, and
    - south of the Depot.

- Sodium concentrations in the Boardman to west Umatilla area groundwater commonly exceed the 20 mg/L limit recommended for persons on a physician prescribed sodium restricted diet.

- Arsenic concentrations exceeded the drinking water standard of 0.050 mg/L in groundwater at several U.S. Army Depot sites and at a Lamb-Weston wastewater land application area site.

- Groundwater samples with relatively higher (0.10 mg/L or greater) maximum total phosphate concentrations came from wells located within the Port of Morrow wastewater land application area east of Boardman, the Irrigon area, most of the U.S. Army Depot, south of the Depot, and the Lamb-Weston land application area.

- Samples with relatively lower total phosphate concentrations often came from within or near irrigated agriculture areas.

- Explosives are present in groundwater at some U.S. Army Depot sites.

- Agricultural chemicals have been sporadically detected in Boardman to west Umatilla area groundwater samples. Atrazine was detected in groundwater sampled south of Boardman and between the Port of Morrow and Irrigon. Dacthal acid was detected in groundwater sampled south of the U.S. Army Depot.

- Nitrate movement through the area appears slow. Decades may be required for nitrate to move through the local alluvial groundwater system.

Butter Creek to City of Umatilla Area Summary and Conclusions

Project analyses used data from project sampling and local facilities. Data analysis led project investigators to the following observations and interpretations:

- Nitrate+nitrite-nitrogen concentrations detected in local project or facility groundwater samples ranged from non-detect to 74 mg/L in regional alluvial groundwater and non-detect to 100 mg/L in shallow unconfined alluvial groundwater.

- The time required for nitrate to locally travel from land surface to groundwater appears to vary from less than 1 month to 18 months given sufficient moisture is available for transport.

- Food processing wastewater appears responsible for elevated nitrate concentrations detected in groundwater at established wastewater land application areas.

- Food processing wastewater appears primarily responsible for a stationary nitrate concentration peak in the Butter Creek-Umatilla River confluence vicinity.

- C&B Livestock appears responsible for elevated nitrate concentrations in alluvial groundwater sampled at nearby sites downgradient of the facility.

- Dacthal acid was detected in an alluvial groundwater sample collected at UMA 119 located northwest of C&B Livestock. That detection indicates an irrigated crop agriculture influence.

- Septic systems appear to be an important influence upon groundwater west of the Umatilla River and north of Interstate 84.

- Water-mineral interactions contribute minor changes to the groundwater chemistry in the area.

- Mixing of groundwater with other water sources plays an important role in groundwater chemistry.

- Cyclic evaporation-dissolution in the soil and vadose (unsaturated) zone is an important influence upon the groundwater constituent chemistry.

- Significant mixing between Umatilla River water and groundwater appears to occur north of Interstate 84 and east of the Umatilla River.

- Total dissolved solids (TDS) concentrations greater than the 500 mg/L secondary (aesthetic) drinking water standard generally occurred east of Highway 207 and south of Minnehaha Road.

- The distribution of some lower TDS concentration areas suggest dilution from canal and/or surface water leakage.

- Arsenic greater than the 0.050 mg/L drinking water standard occurred in a sample collected from a site within the Lamb-Weston wastewater land application area next to the U.S. Army Depot.

- Sodium in area groundwater commonly exceeds the 20 mg/L limit recommended for persons on a physician prescribed sodium restricted diet.

- The distribution of total phosphate concentrations in area groundwater is nearly divided. Lower concentrations were generally found in groundwater sampled north of Interstate 84 and west of the Umatilla River. Higher concentrations were generally found in samples collected along or near Highway 207, south of Hermiston.

City of Umatilla to Hat Rock to Echo Meadows Area Summary and Conclusions

Project analyses for this area used data primarily from project sampling. The analysis led project investigators to the following observations and interpretations:

- Nitrate+nitrite-nitrogen concentrations in samples collected from the area ranged from non-detect to 31 mg/L.

- Total dissolved solids concentration exceeded the 500 mg/L secondary (aesthetic) drinking water standard in some samples from Hat Rock, and the terraces north and south of Hermiston.

- Arsenic detections occurred primarily in samples from the Stanfield vicinity. One shallow unconfined alluvial groundwater sample from the A.E. Staley Manufacturing Company wastewater land application site contained arsenic greater than the 0.050 mg/L drinking water standard.

- Area groundwater samples commonly had sodium concentrations greater than the 20 mg/L limit recommended for persons on a physician prescribed sodium restricted diet. Some groundwater samples from the terraces north and south of Hermiston contained sodium greater than 50 mg/L.

- Project and City of Hermiston sampling detected pesticides and volatile organic compounds in alluvial and basalt groundwater. Project sampling detected these constituents in samples from the Hermiston basin, the terrace south of Hermiston, Stanfield, and City of Echo sewage treatment facility areas.

- Analysis indicate dilution from canal leakage influences groundwater within the Hermiston basin and part of the terrace south of Hermiston.

- Nitrate+nitrite-nitrogen remained below 10 mg/L in project groundwater samples collected in the City of Hermiston and Hat Rock areas. Analyses indicate mixed influences.

- Nitrate+nitrite-nitrogen concentrations in most project samples from the terrace north of Hermiston generally measured less than 10 mg/L. However, samples from two sites had concentrations of 12 and 31 mg/L. Analyses indicate a variety of influences. Septic systems appear to influence groundwater at sites where measured nitrate concentrations are low. Septic systems, irrigation, and animal waste appear to independently influence groundwater at different sites where concentrations approach 10 mg/L. Irrigation appears responsible for concentrations exceeding 10 mg/L in groundwater at the two sites mentioned despite the proximity of a feedlot at one of those sites.

- Nitrate+nitrite-nitrogen concentrations measured less than 5 mg/L in project groundwater samples from the Hermiston basin despite the presence of numerous unsewered homes in some areas. Graphical analysis indicates septic systems do influence the local alluvial groundwater chemistry. However, analyses also indicate a significant dilution influence from canal leakage.

- Nitrate+nitrite-nitrogen concentrations exceeded the 10 mg/L drinking water standard in groundwater sampled from several sites on the terrace south of Hermiston. The detection of pesticides in some of these samples and analyses indicate an irrigated crop agriculture influence. Analyses also indicate a septic system influence at some sites.

- Nitrate+nitrite-nitrogen concentrations generally remained below 10 mg/L in project groundwater sampled from the Echo and Umatilla Meadows area. Analyses indicate wastewater influences groundwater at the A.E. Staley Manufacturing Company land application site. Irrigation related activity and canal leakage appear to influence groundwater at other locations.

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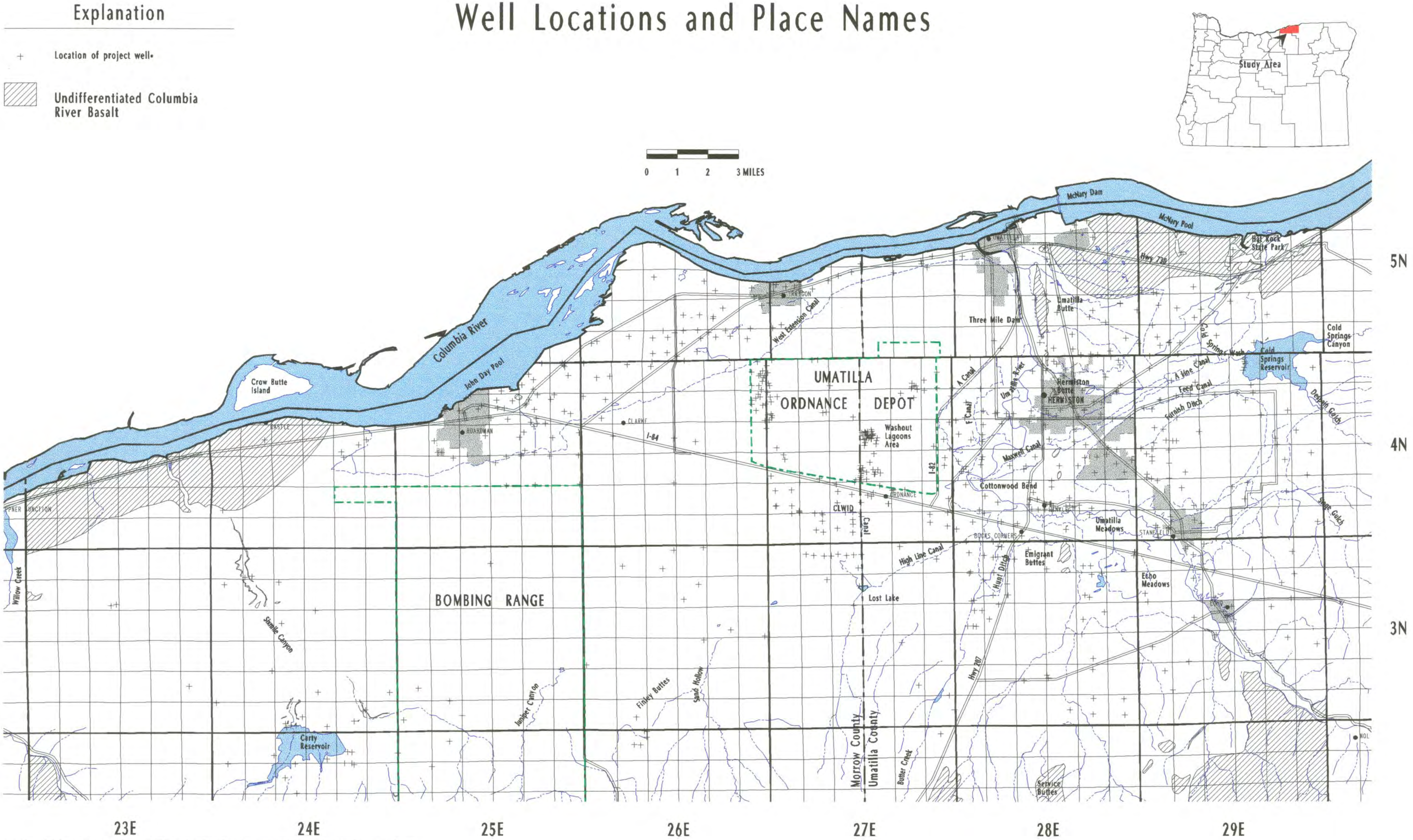
Well Locations and Place Names

Explanation

\+ Location of project well*

▨ Undifferentiated Columbia River Basalt



*Well names and well information not shown at this reduced scale. Request 1:62,500 scale map for more detail.

Geologic Map Showing Structure Contours on Top of the Columbia River Basalt Group

Explanation

+ Location of well used to constrain contours•

Geologic contact - dashed where approximate

• • • • Fault - inferred location (U - Upthrown side; D - Downthrown side)

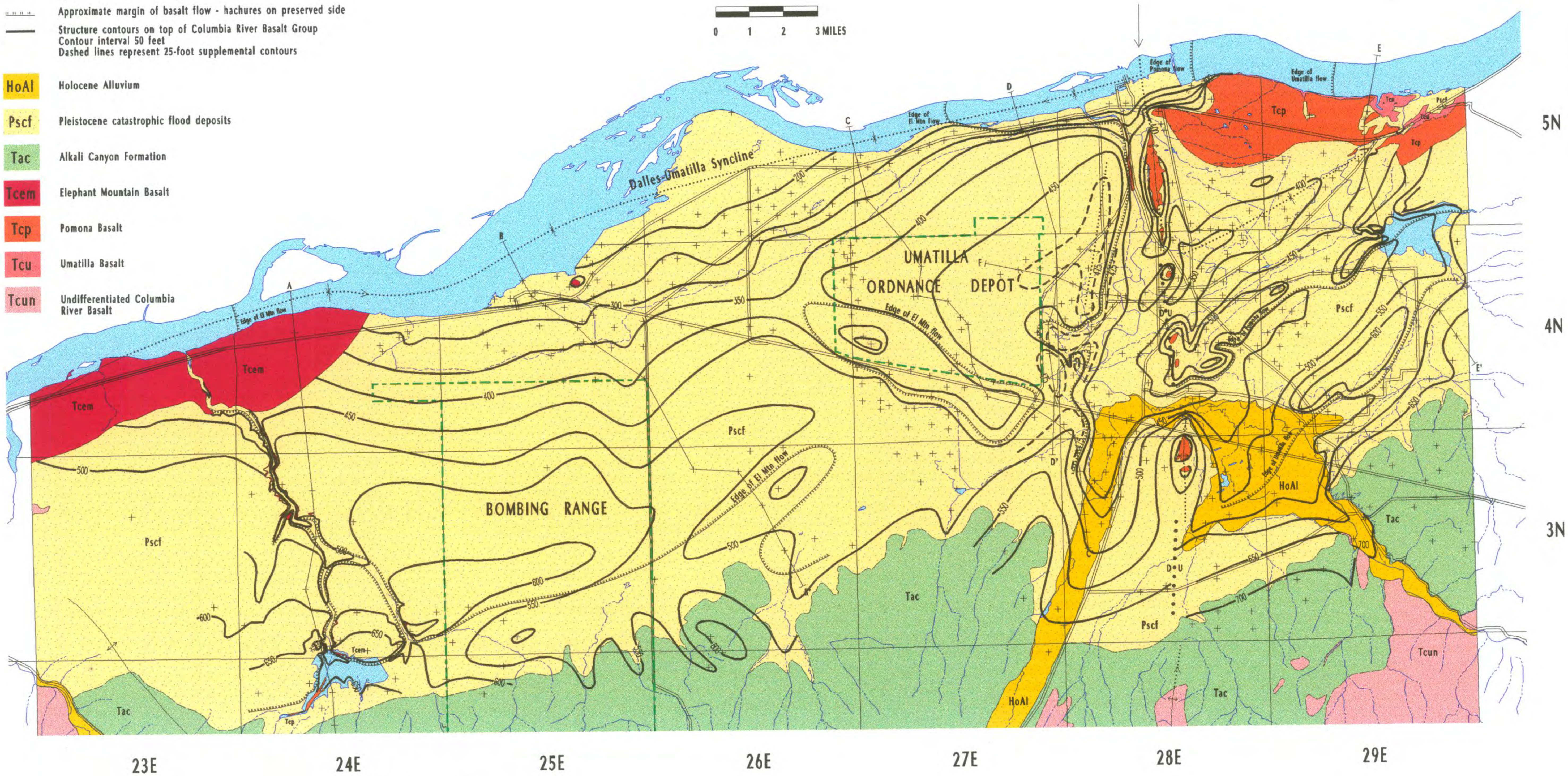
Anticline - dashed where approximate, dotted where inferred in subsurface

Syncline - dashed where approximate, dotted where inferred in subsurface

Approximate margin of basalt flow - hachures on preserved side

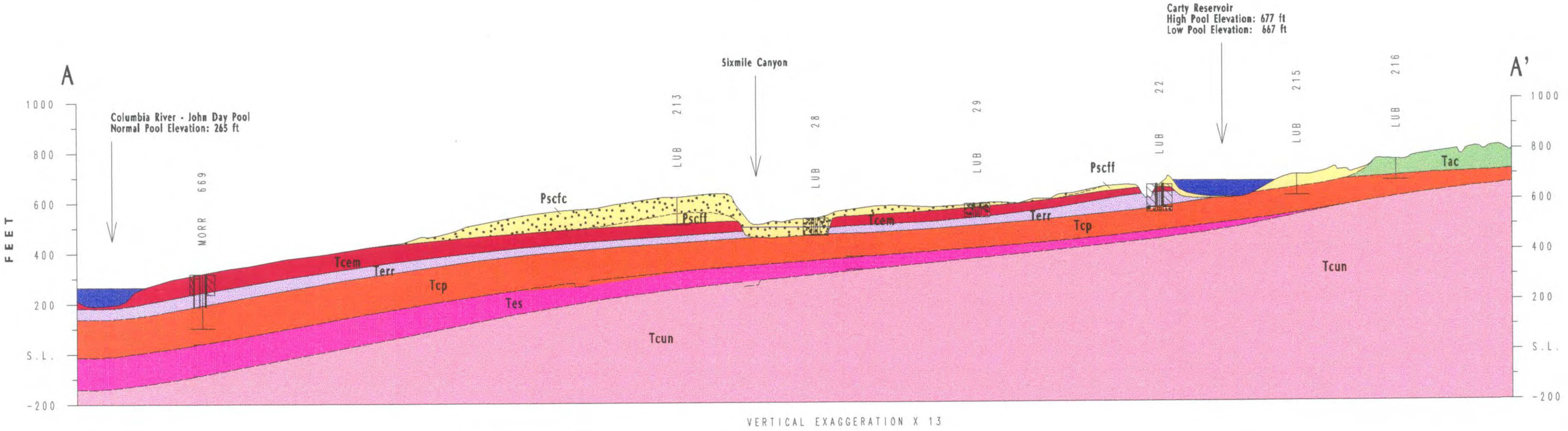
Structure contours on top of Columbia River Basalt Group
Contour interval 50 feet
Dashed lines represent 25-foot supplemental contours

HoAl	Holocene Alluvium
Pscf	Pleistocene catastrophic flood deposits
Tac	Alkali Canyon Formation
Tcem	Elephant Mountain Basalt
Tcp	Pomona Basalt
Tcu	Umatilla Basalt
Tcun	Undifferentiated Columbia River Basalt



•Well numbers and basalt elevations not shown at this reduced scale. Request 1:62,500 scale map for more detail.

Geologic Cross Sections



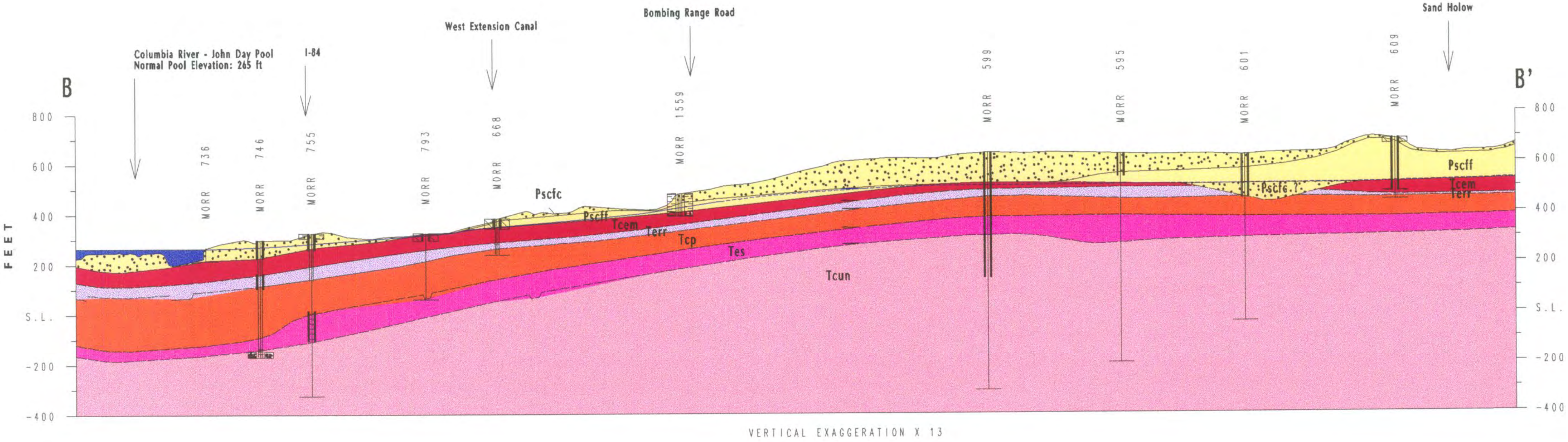
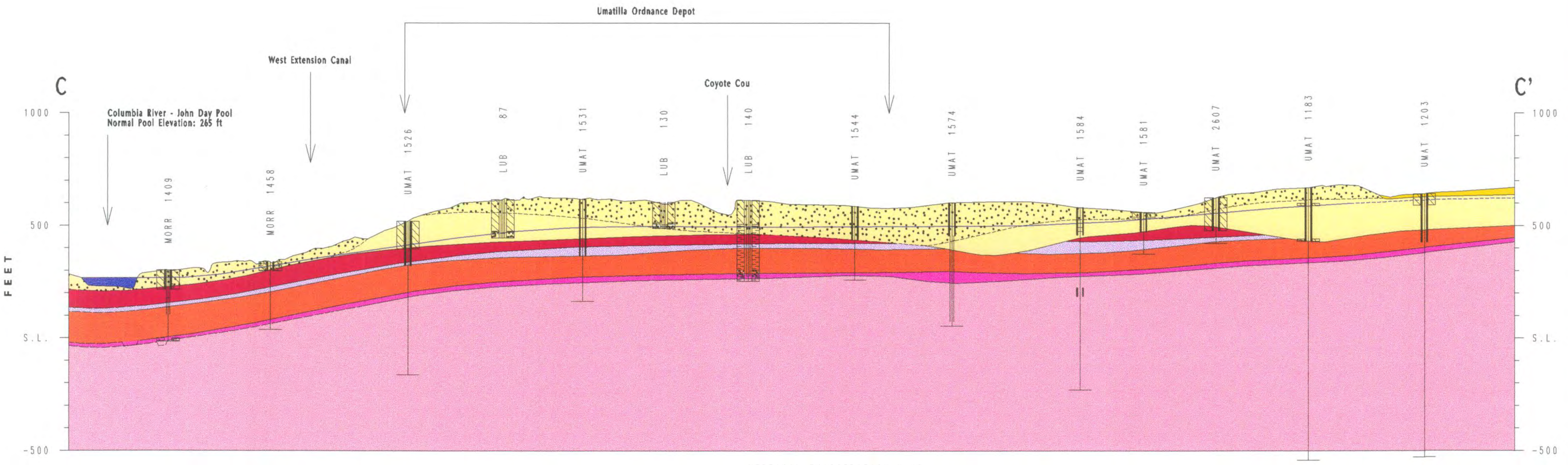
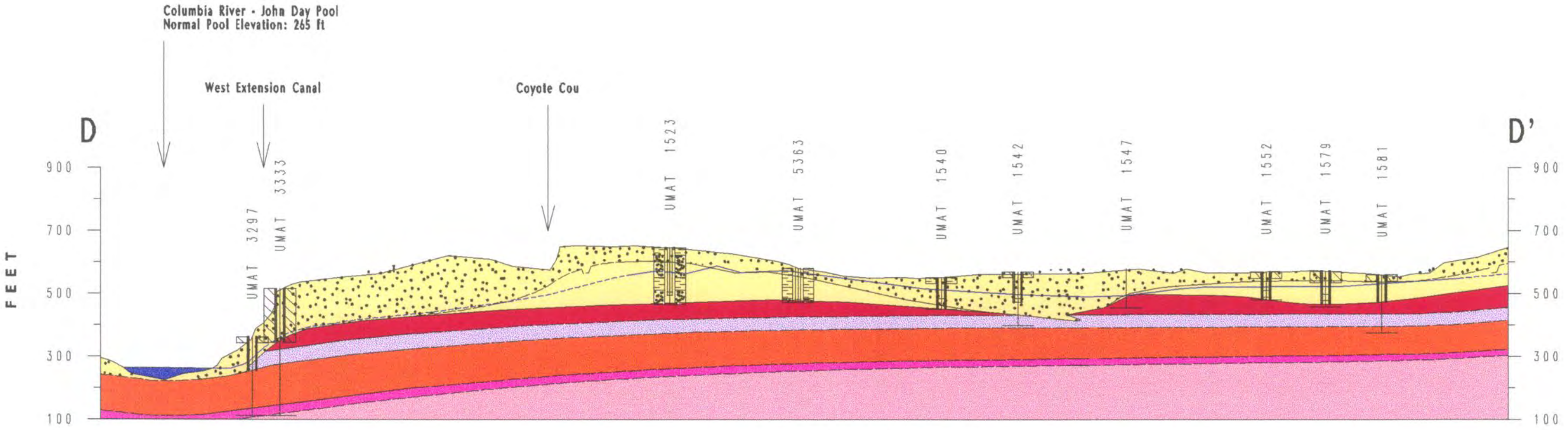


PLATE 2.3B (2 of 3)
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Geologic Cross Sections

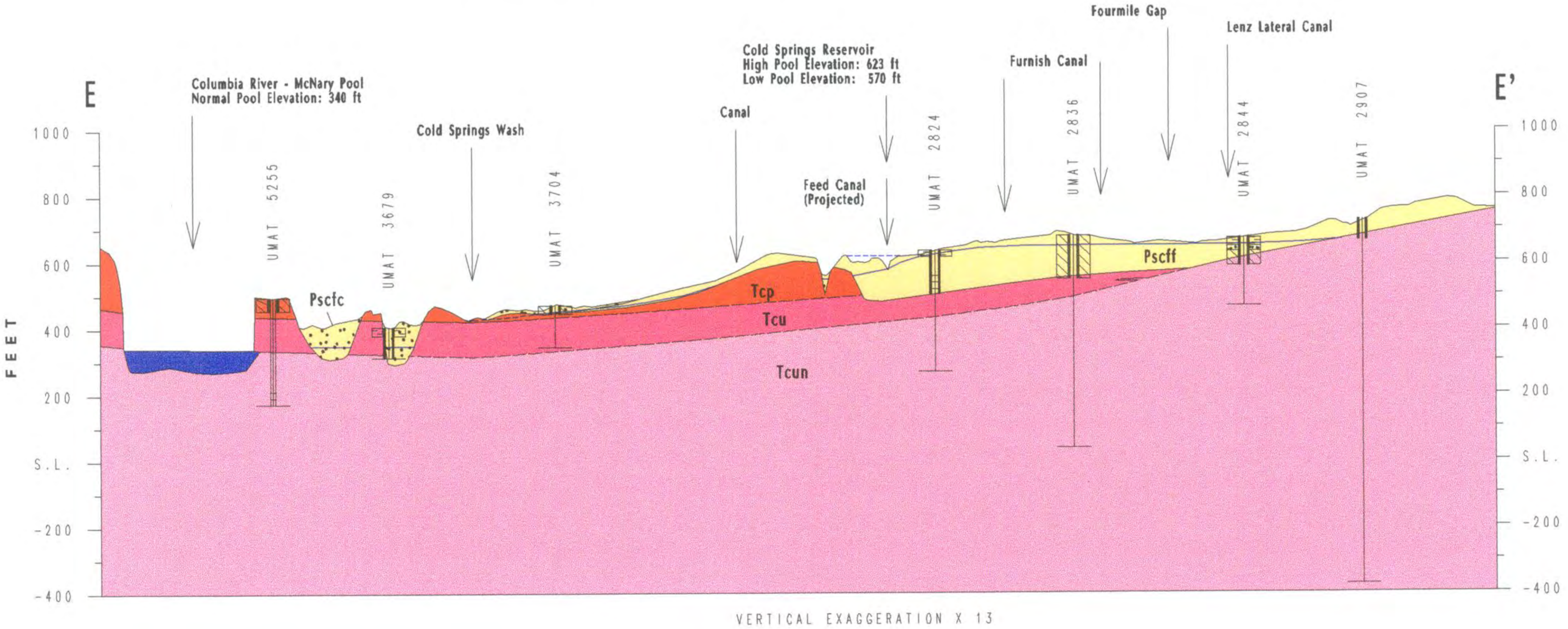


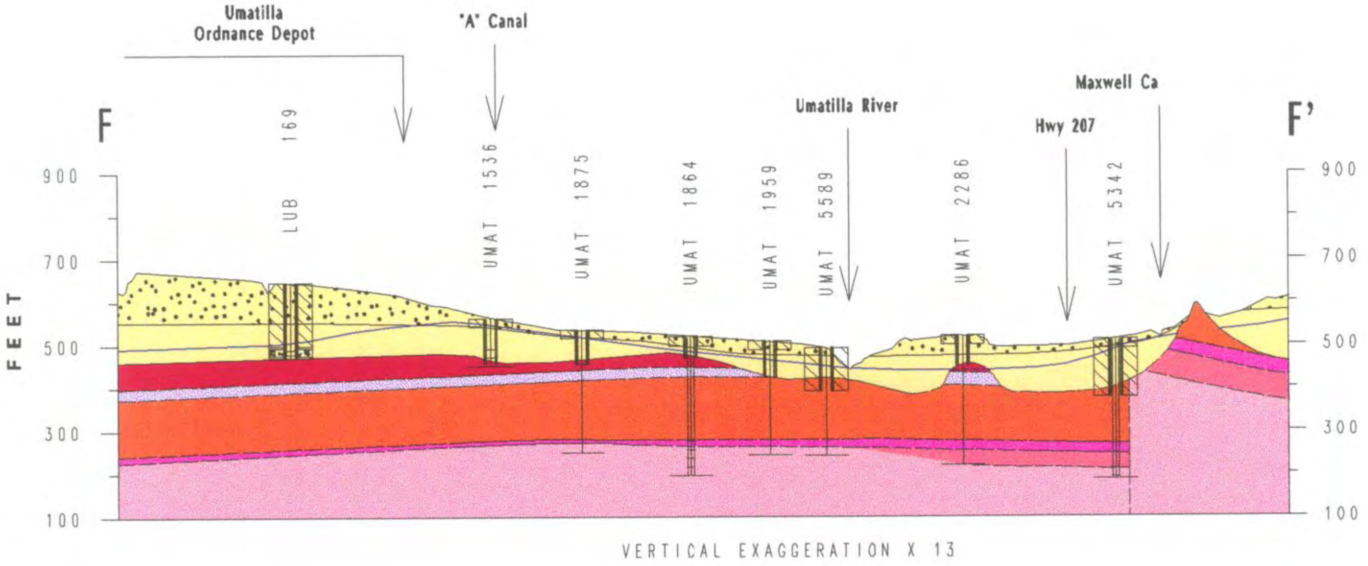
VERTICAL EXAGGERATION X 13



VERTICAL EXAGGERATION X 13

Geologic Cross Sections





Water-Level Contours of the Alluvial Aquifer

February 1991

Explanation

\+ Well location•

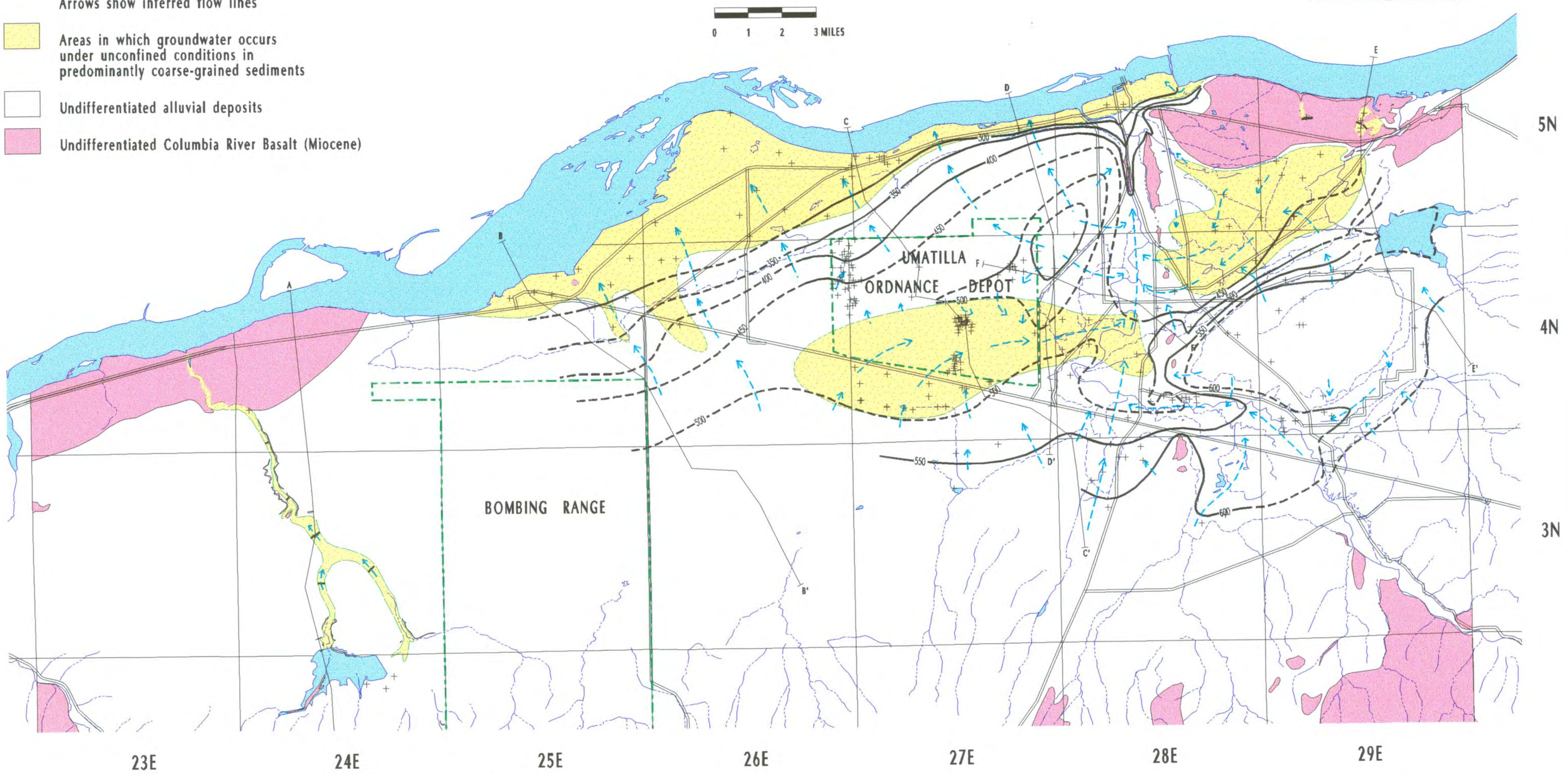
— Water-level contour
Dashed where inferred
Contour interval 50 feet

Arrows show inferred flow lines

🟨 Areas in which groundwater occurs under unconfined conditions in predominantly coarse-grained sediments

☐ Undifferentiated alluvial deposits

🟪 Undifferentiated Columbia River Basalt (Miocene)



•Well information and water levels at wells not shown at this reduced scale. Request 1:62,500 scale map for more detail

Well Density

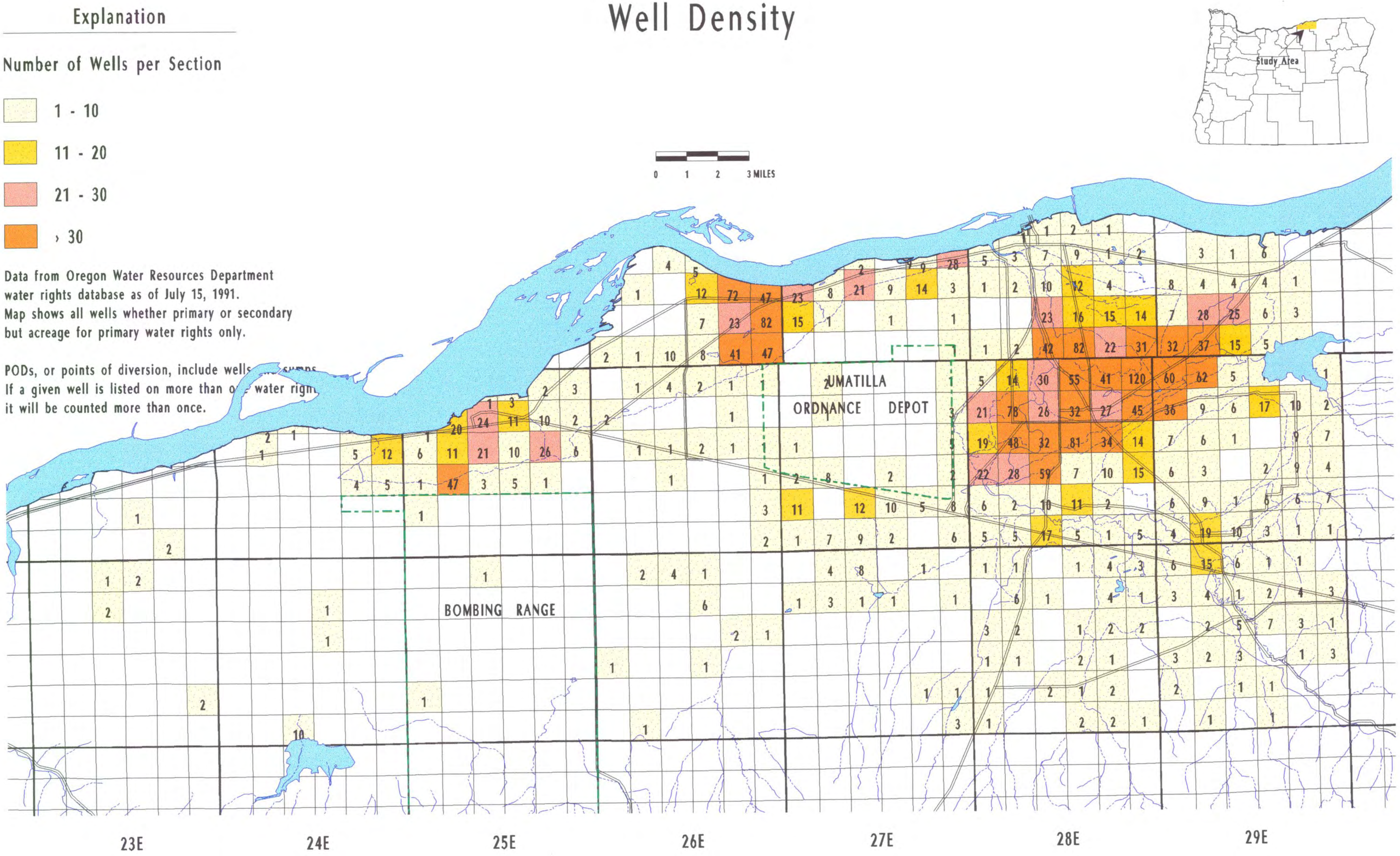
Explanation

Number of Wells per Section

- ▨ 1 - 10
- 🟨 11 - 20
- 🟥 21 - 30
- 🟧 › 30

Data from Oregon Water Resources Department water rights database as of July 15, 1991. Map shows all wells whether primary or secondary but acreage for primary water rights only.

PODs, or points of diversion, include wells [illegible] sumps. If a given well is listed on more than o[illegible] water righ[illegible] it will be counted more than once.



Irrigated Acreage and Permitted Alluvial Aquifer Wells

Explanation

▨	Lands irrigated by surface water or groundwater from basalt aquifers
🟨	Lands irrigated by groundwater from the Alluvial Aquifer System

Number of Alluvial Aquifer PODs per Quarter-Quarter Section

●	1
●	2
●	3
●	›3

Data from Oregon Water Resources Department water rights database as of July 15, 1991. Map shows all wells whether primary or secondary but acreage for primary water rights only.

PODs, or points of diversion, include wells and sumps. If a given well is listed on more than one water right, it will be counted more than once.

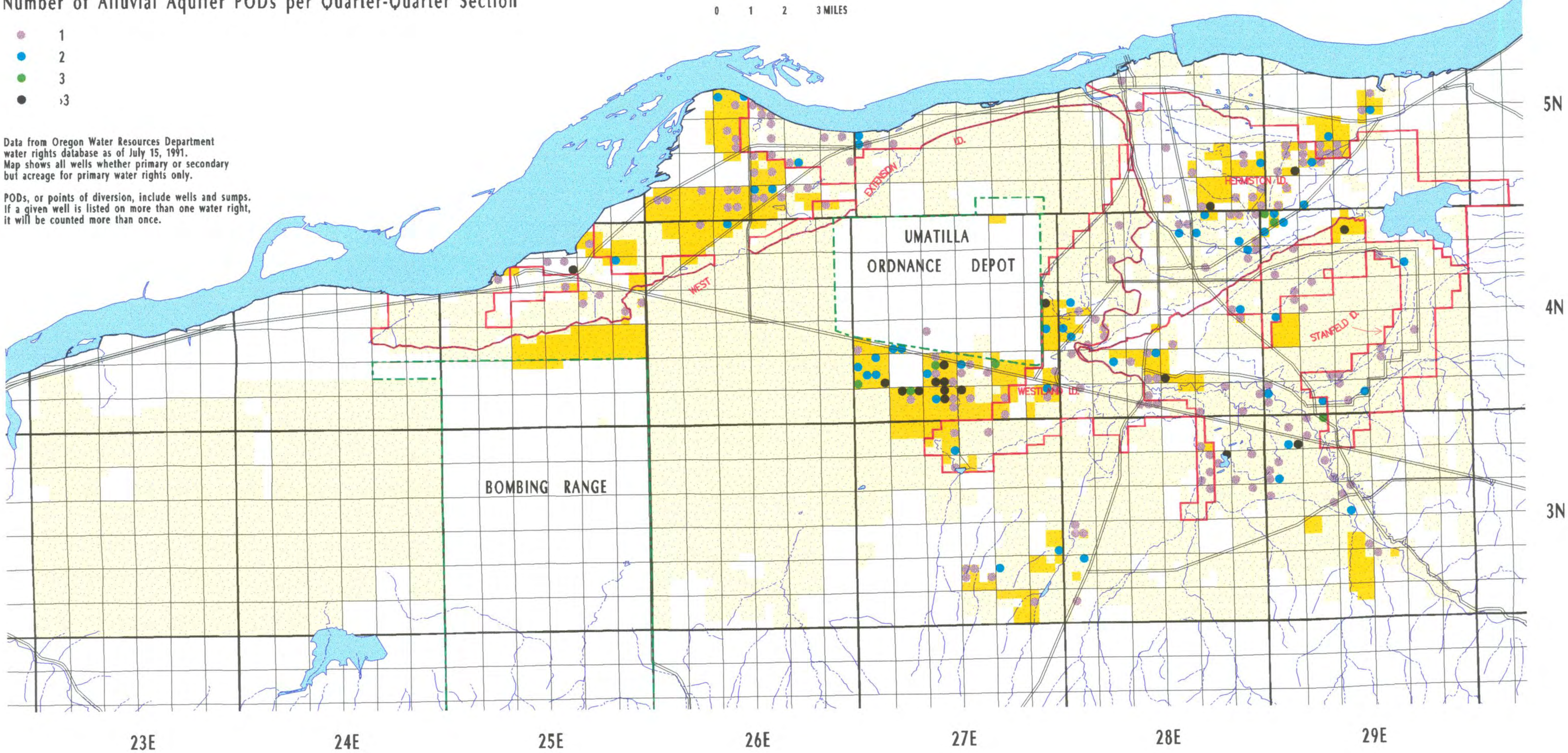
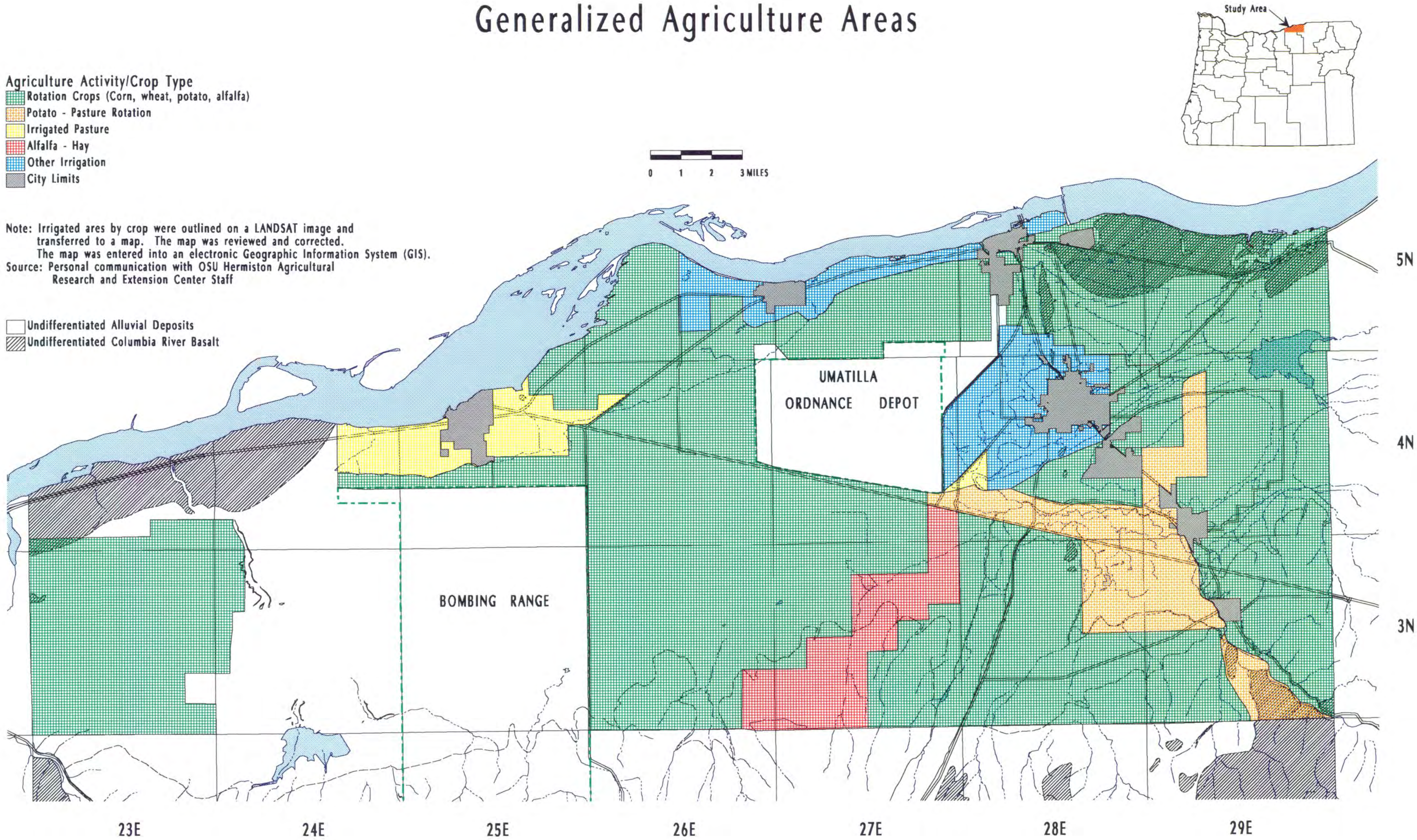
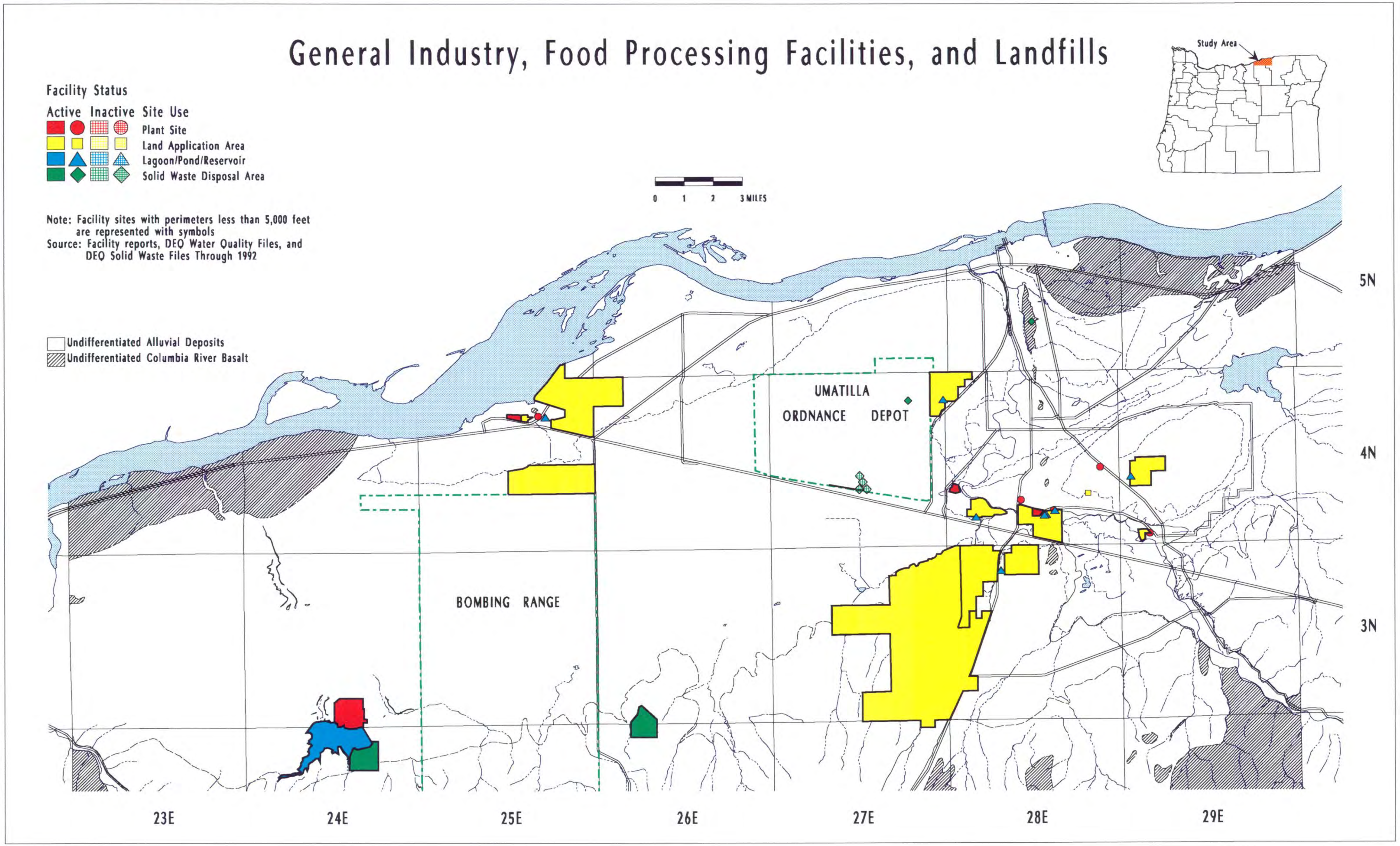


PLATE 3.1
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Generalized Agriculture Areas



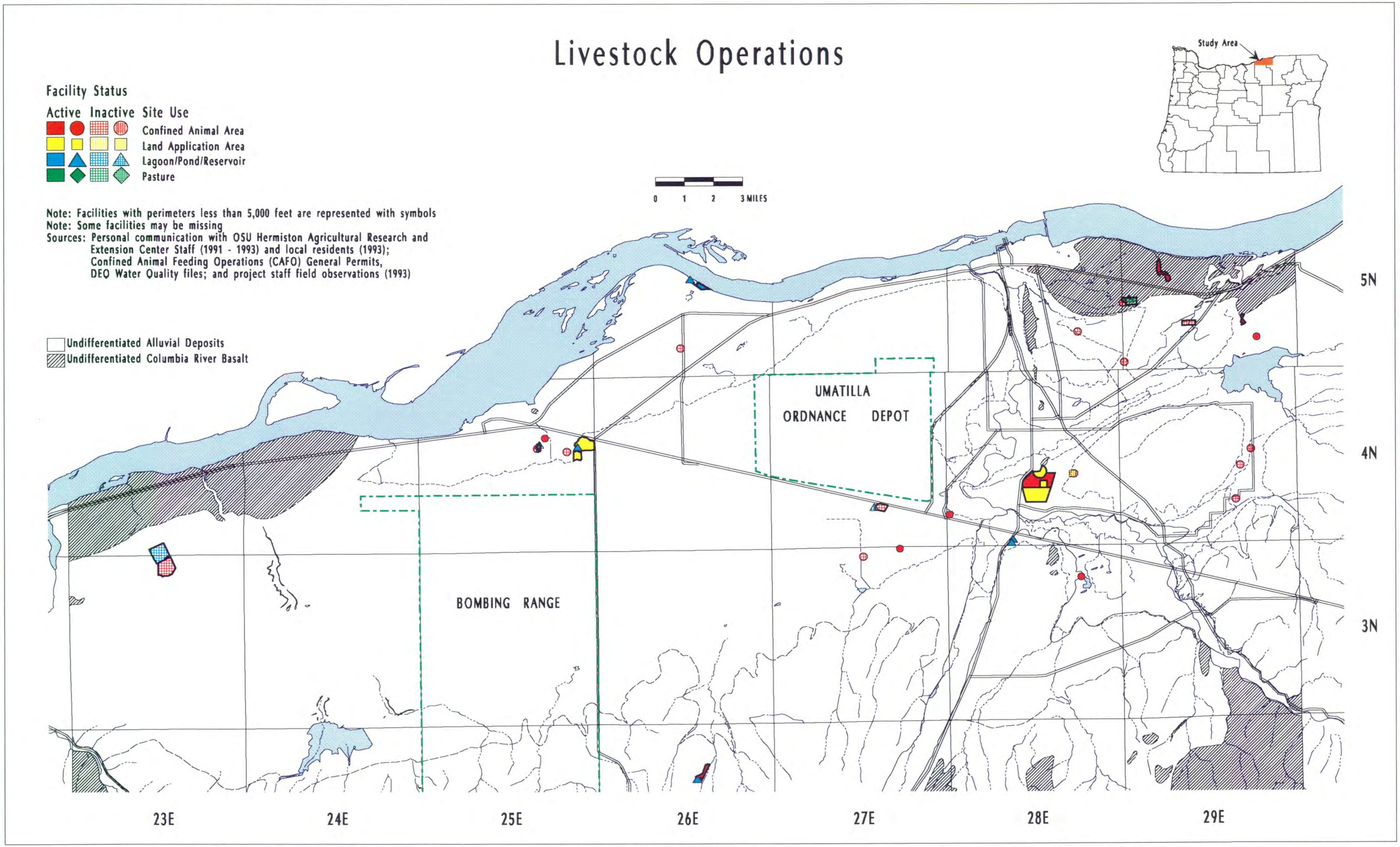
Note: Irrigated ares by crop were outlined on a LANDSAT image and transferred to a map. The map was reviewed and corrected. The map was entered into an electronic Geographic Information System (GIS).
Source: Personal communication with OSU Hermiston Agricultural Research and Extension Center Staff



General Industry, Food Processing Facilities, and Landfills

Note: Facility sites with perimeters less than 5,000 feet are represented with symbols

Source: Facility reports, DEQ Water Quality Files, and DEQ Solid Waste Files Through 1992

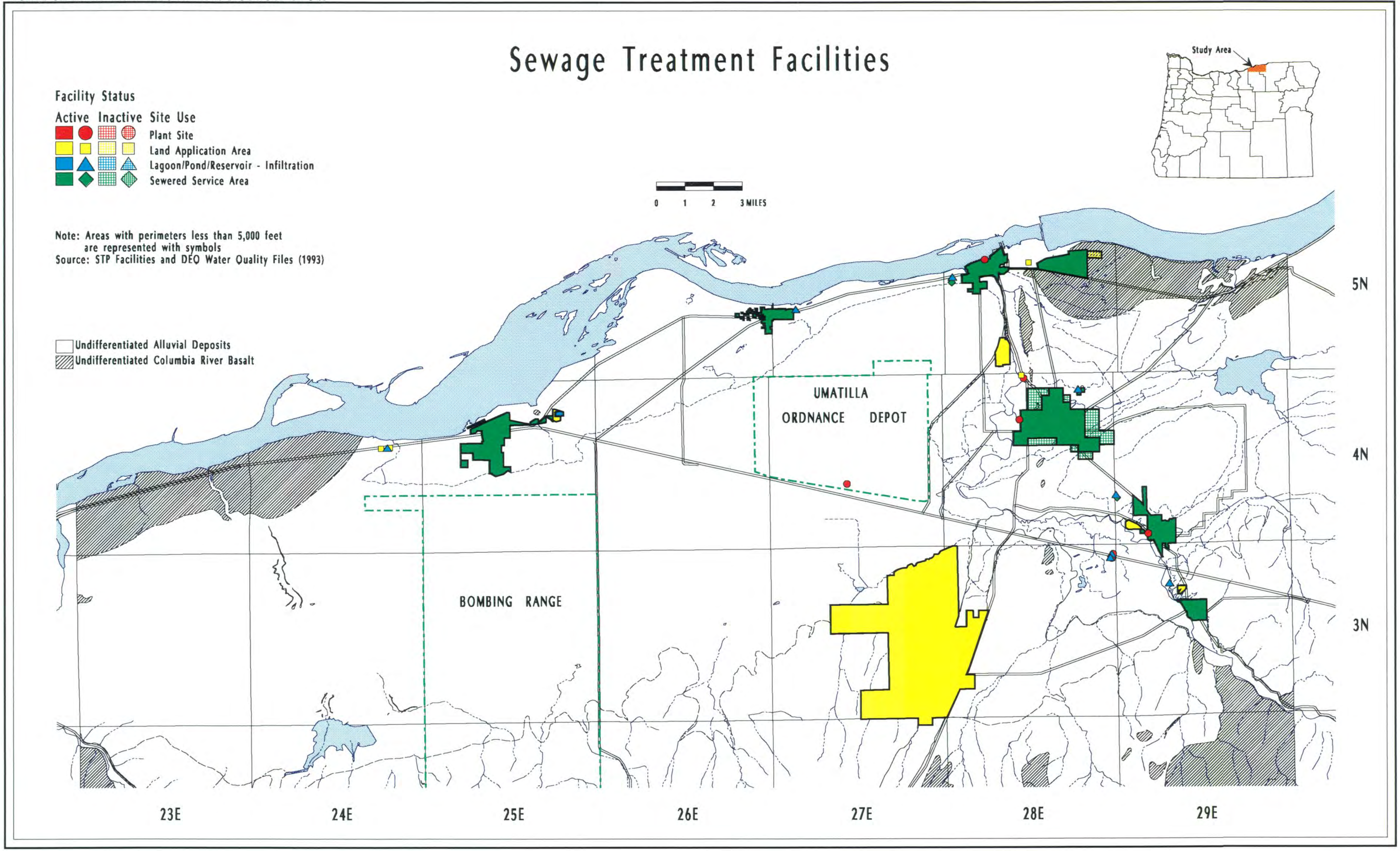


Livestock Operations

Note: Facilities with perimeters less than 5,000 feet are represented with symbols
Note: Some facilities may be missing
Sources: Personal communication with OSU Hermiston Agricultural Research and Extension Center Staff (1991 - 1993) and local residents (1993); Confined Animal Feeding Operations (CAFO) General Permits, DEQ Water Quality files; and project staff field observations (1993)

PLATE 3.4
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Sewage Treatment Facilities



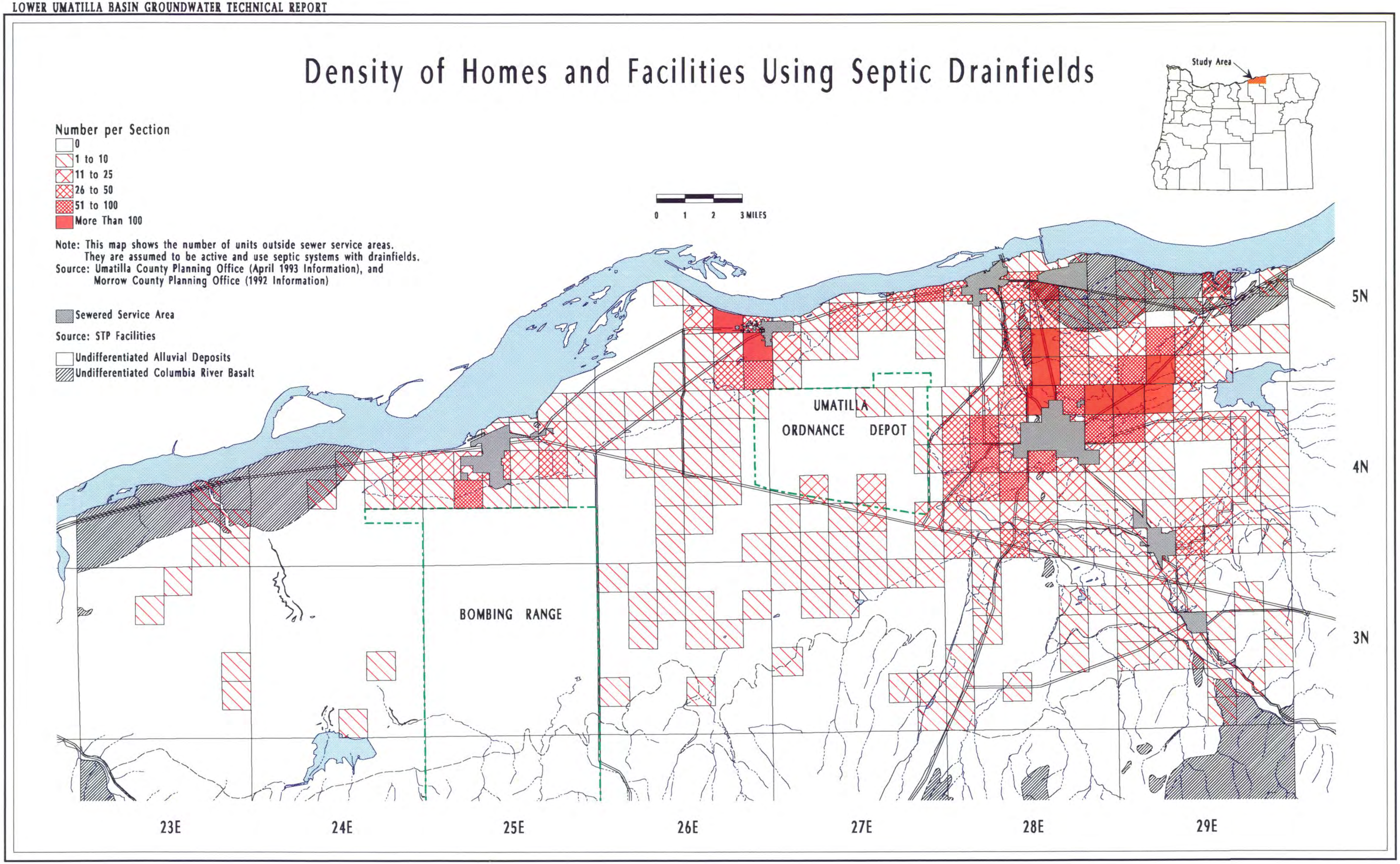
Facility Status

Active	Inactive			Site Use
🟥	●	▦	●	Plant Site
🟨	■	▦	■	Land Application Area
🟦	▲	▦	▲	Lagoon/Pond/Reservoir - Infiltration
🟩	◆	▦	◆	Sewered Service Area

Note: Areas with perimeters less than 5,000 feet
are represented with symbols
Source: STP Facilities and DEQ Water Quality Files (1993)

☐ Undifferentiated Alluvial Deposits
▨ Undifferentiated Columbia River Basalt

Density of Homes and Facilities Using Septic Drainfields

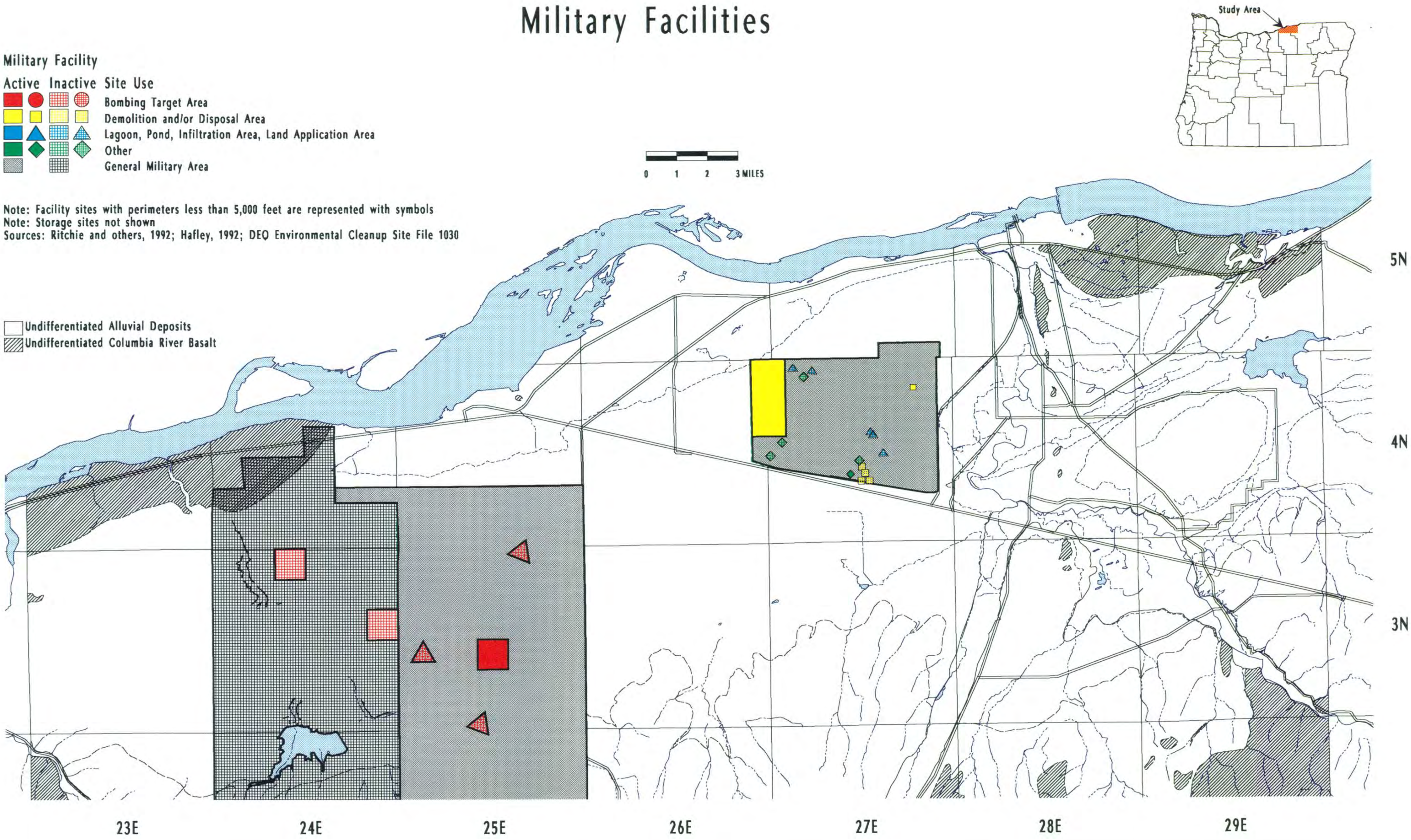


Note: This map shows the number of units outside sewer service areas. They are assumed to be active and use septic systems with drainfields.
Source: Umatilla County Planning Office (April 1993 Information), and Morrow County Planning Office (1992 Information)

Source: STP Facilities

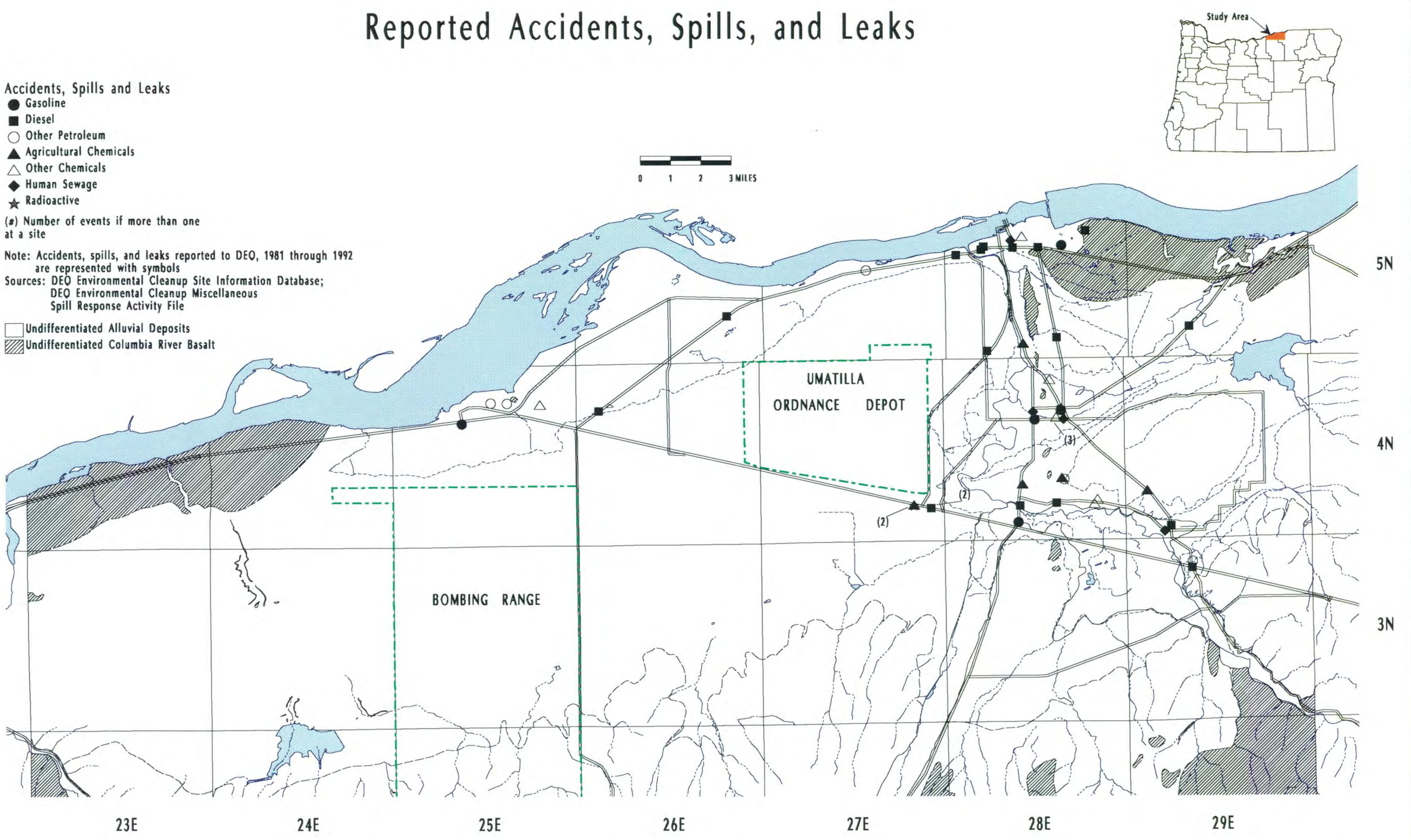
PLATE 3.6
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Military Facilities



Note: Facility sites with perimeters less than 5,000 feet are represented with symbols
Note: Storage sites not shown
Sources: Ritchie and others, 1992; Hafley, 1992; DEQ Environmental Cleanup Site File 1030

Reported Accidents, Spills, and Leaks



Accidents, Spills and Leaks

- ● Gasoline
- ■ Diesel
- ○ Other Petroleum
- ▲ Agricultural Chemicals
- △ Other Chemicals
- ◆ Human Sewage
- ★ Radioactive

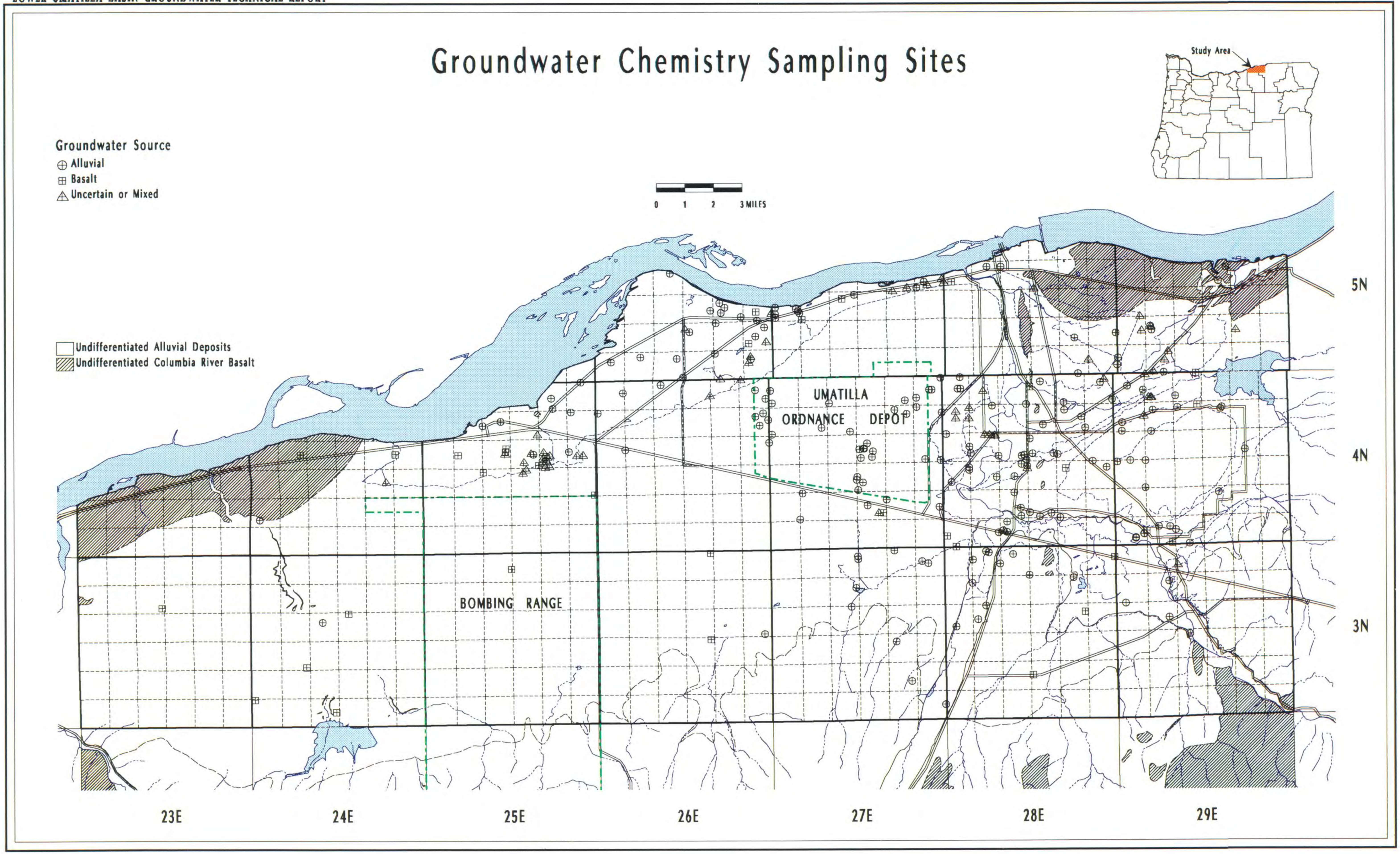
(#) Number of events if more than one at a site

Note: Accidents, spills, and leaks reported to DEQ, 1981 through 1992 are represented with symbols

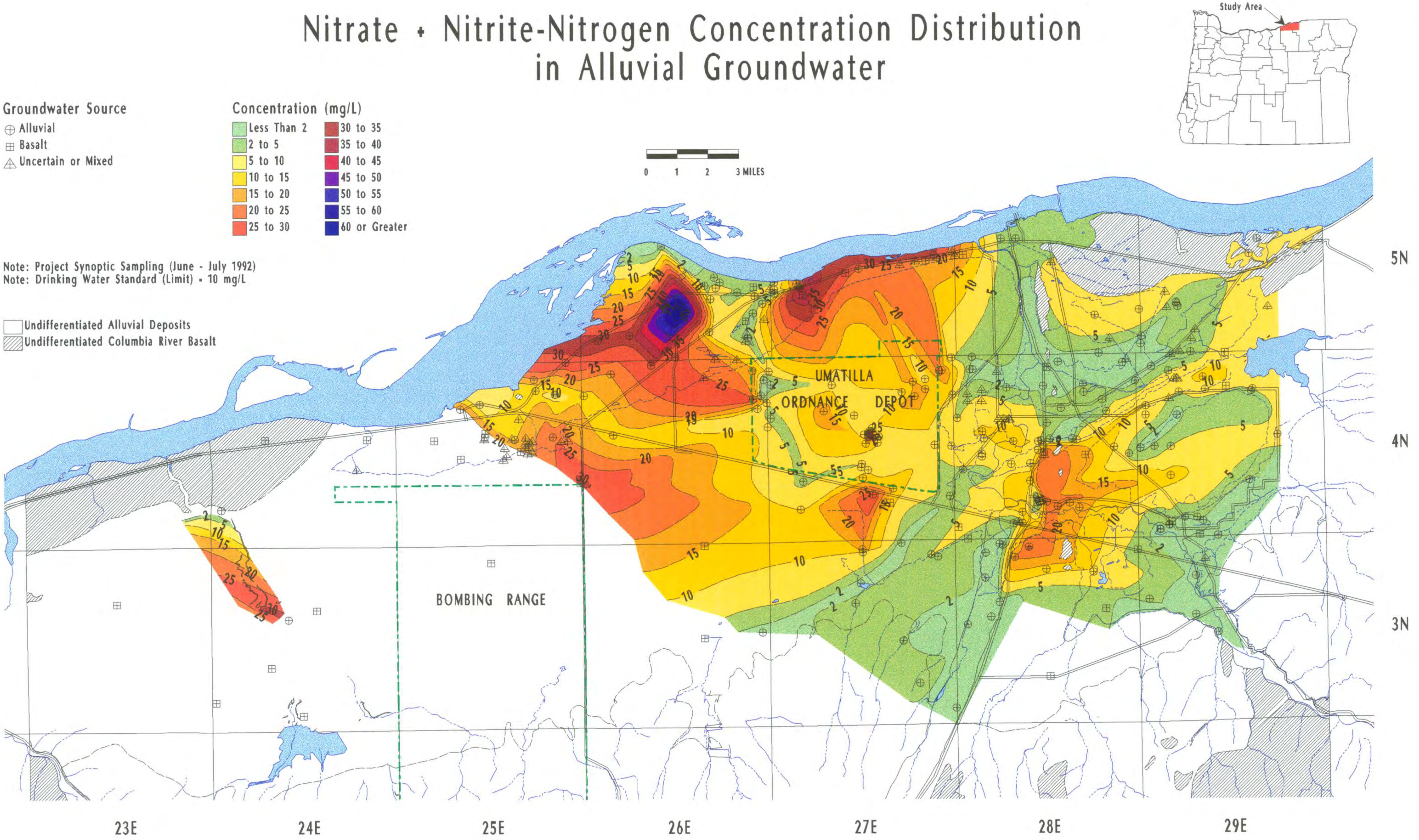
Sources: DEQ Environmental Cleanup Site Information Database;
DEQ Environmental Cleanup Miscellaneous
Spill Response Activity File

- □ Undifferentiated Alluvial Deposits
- ▨ Undifferentiated Columbia River Basalt

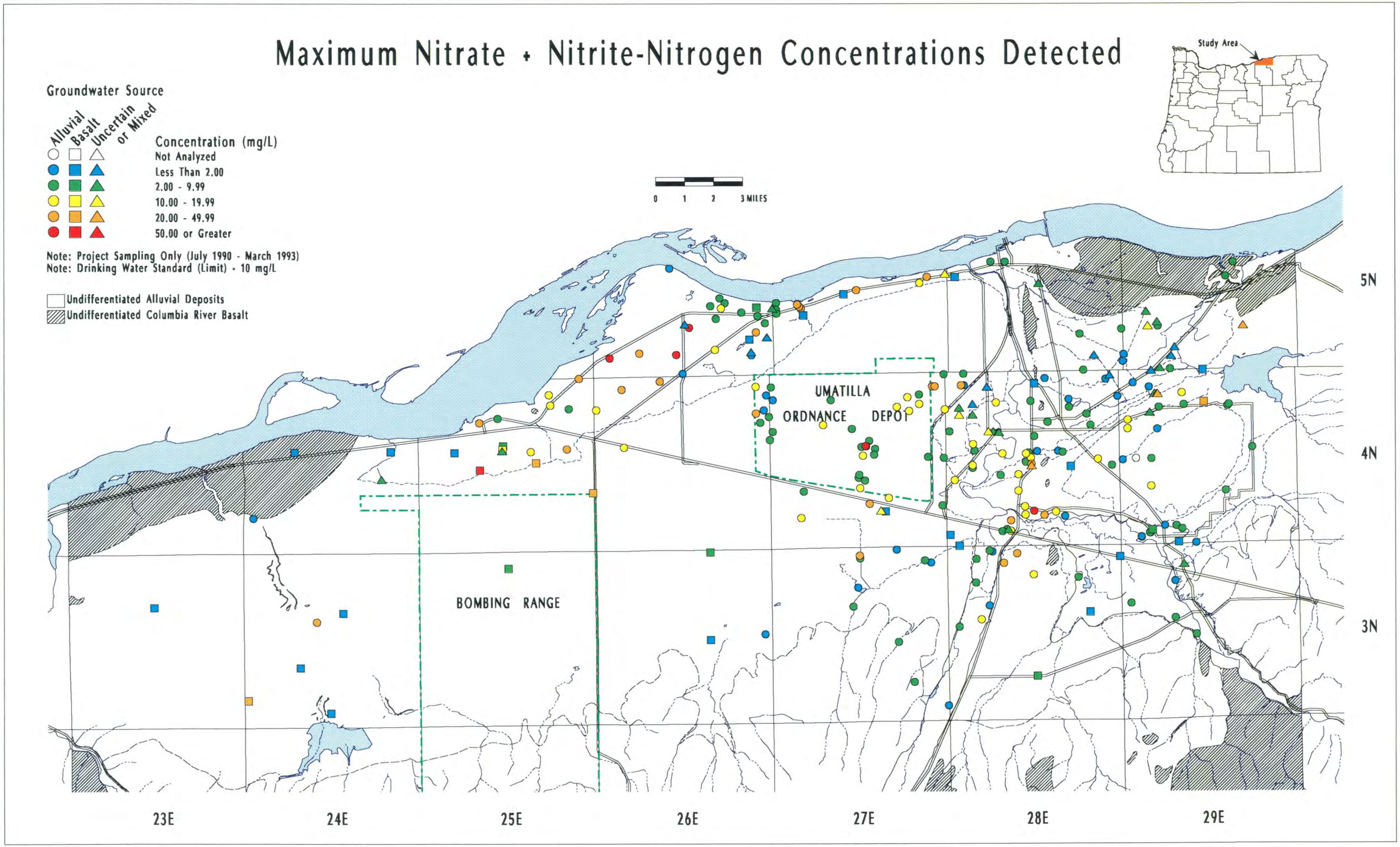
Groundwater Chemistry Sampling Sites



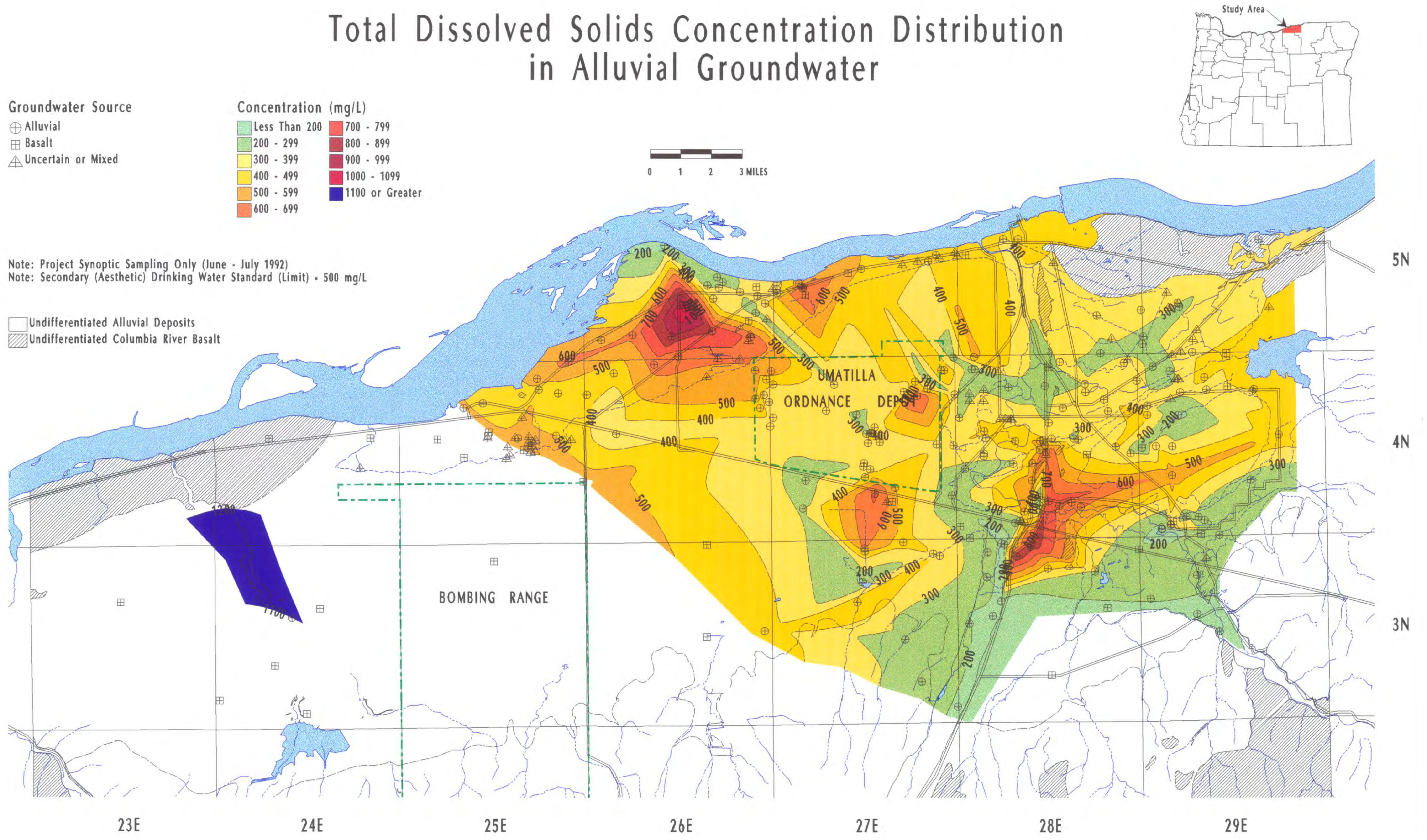
Nitrate + Nitrite-Nitrogen Concentration Distribution in Alluvial Groundwater



Maximum Nitrate + Nitrite-Nitrogen Concentrations Detected

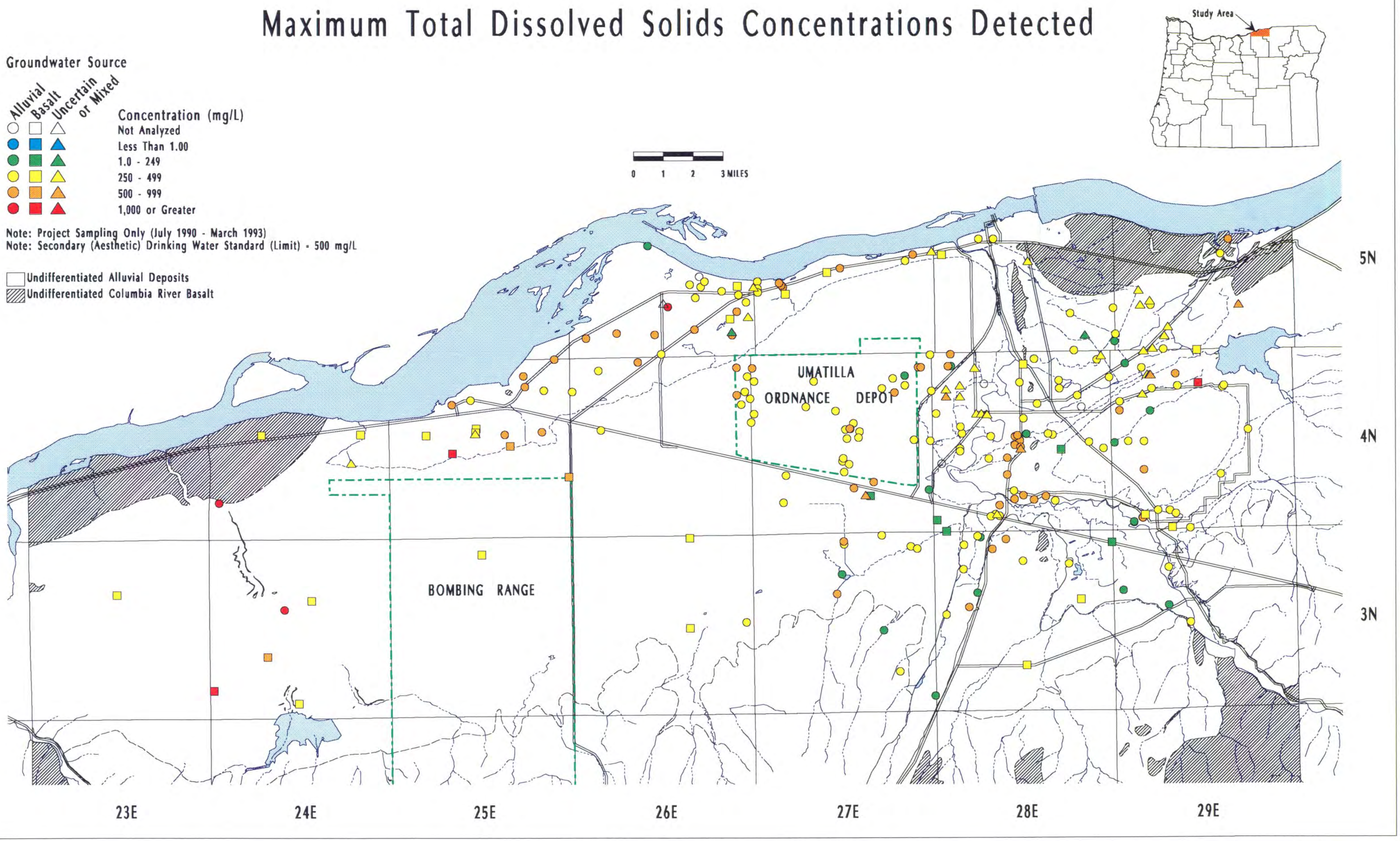


Total Dissolved Solids Concentration Distribution in Alluvial Groundwater



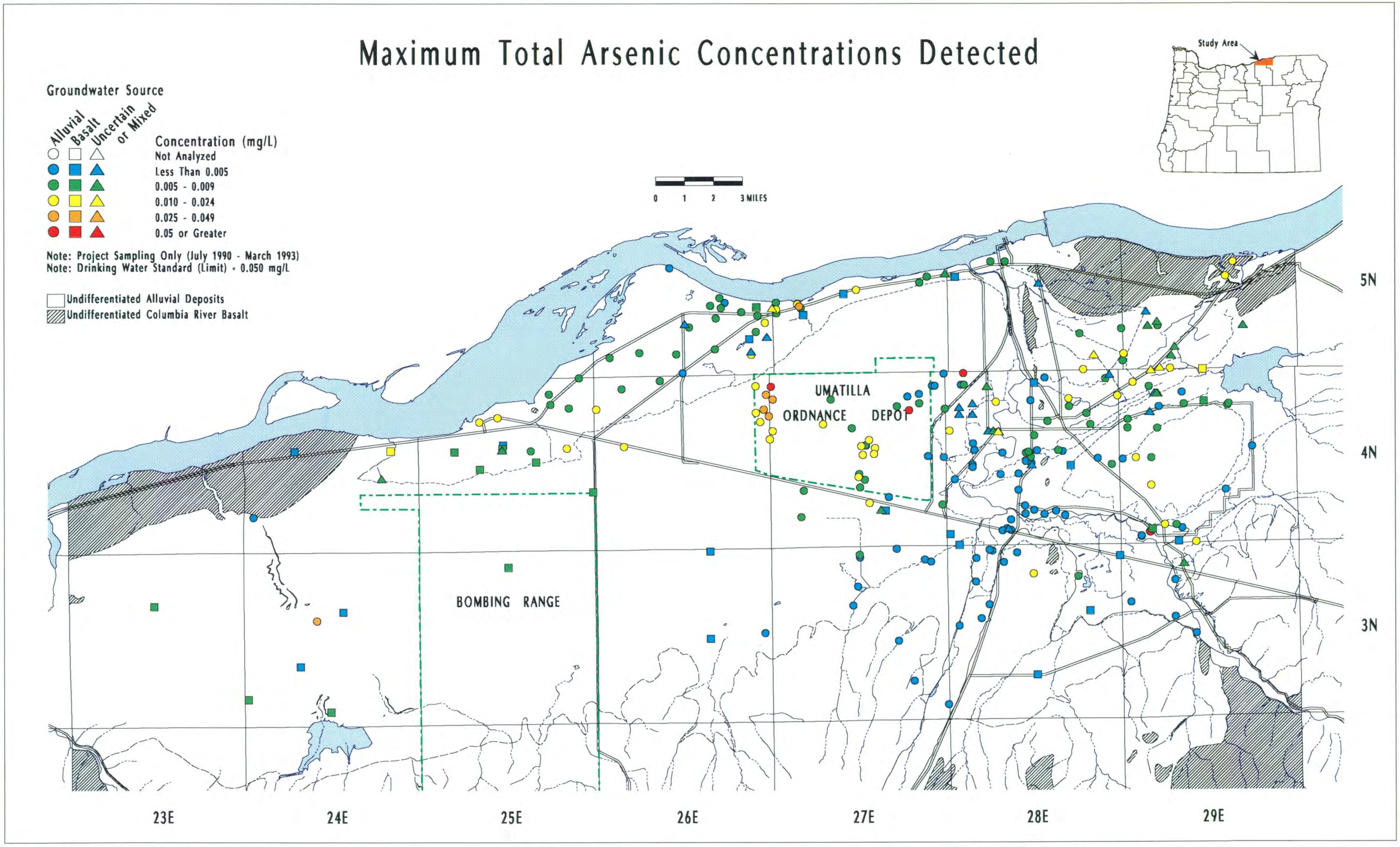
Note: Project Synoptic Sampling Only (June - July 1992)
Note: Secondary (Aesthetic) Drinking Water Standard (Limit) = 500 mg/L

Maximum Total Dissolved Solids Concentrations Detected

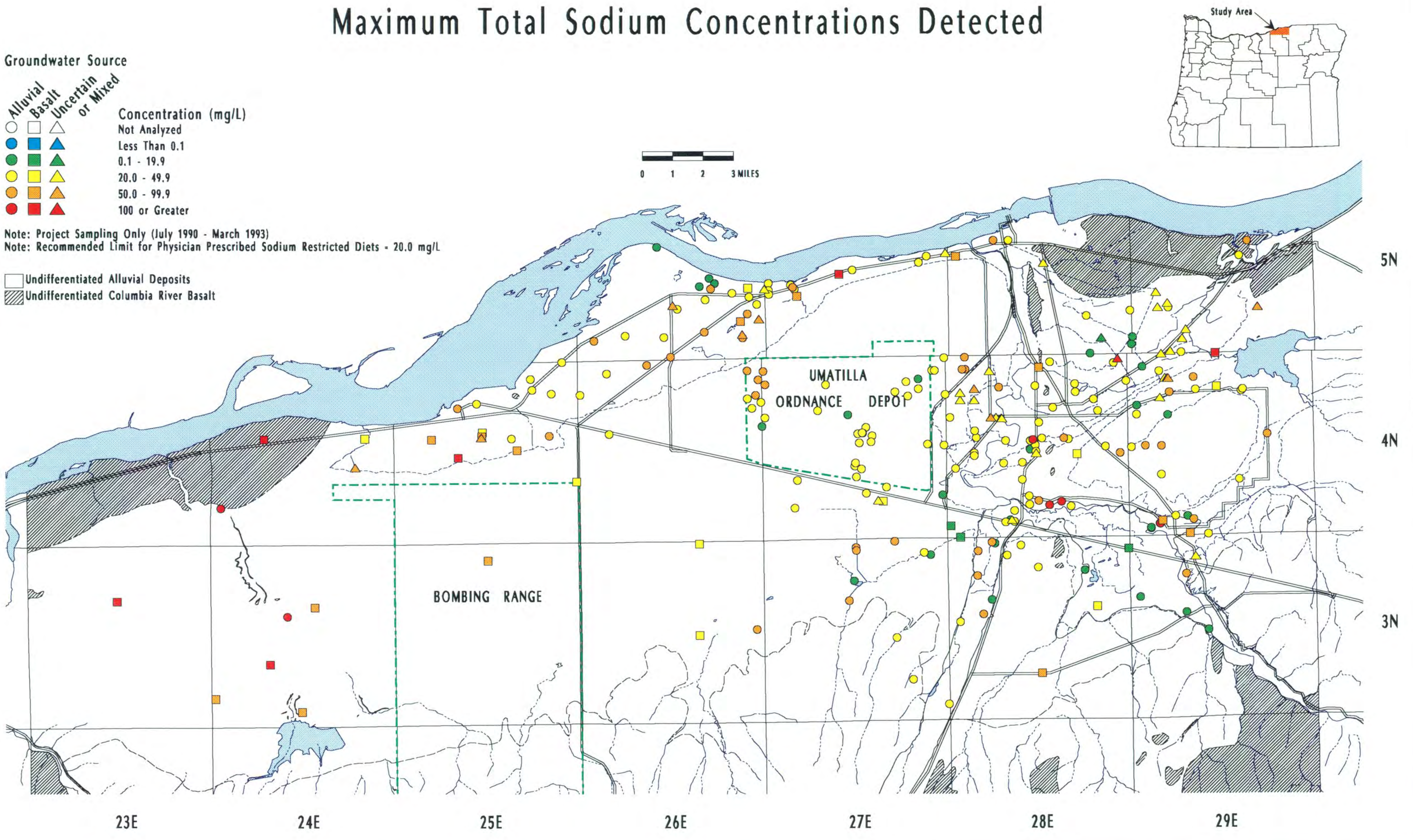


Note: Project Sampling Only (July 1990 - March 1993)
Note: Secondary (Aesthetic) Drinking Water Standard (Limit) = 500 mg/L

Maximum Total Arsenic Concentrations Detected



Maximum Total Sodium Concentrations Detected



Maximum Chloride Concentrations Detected

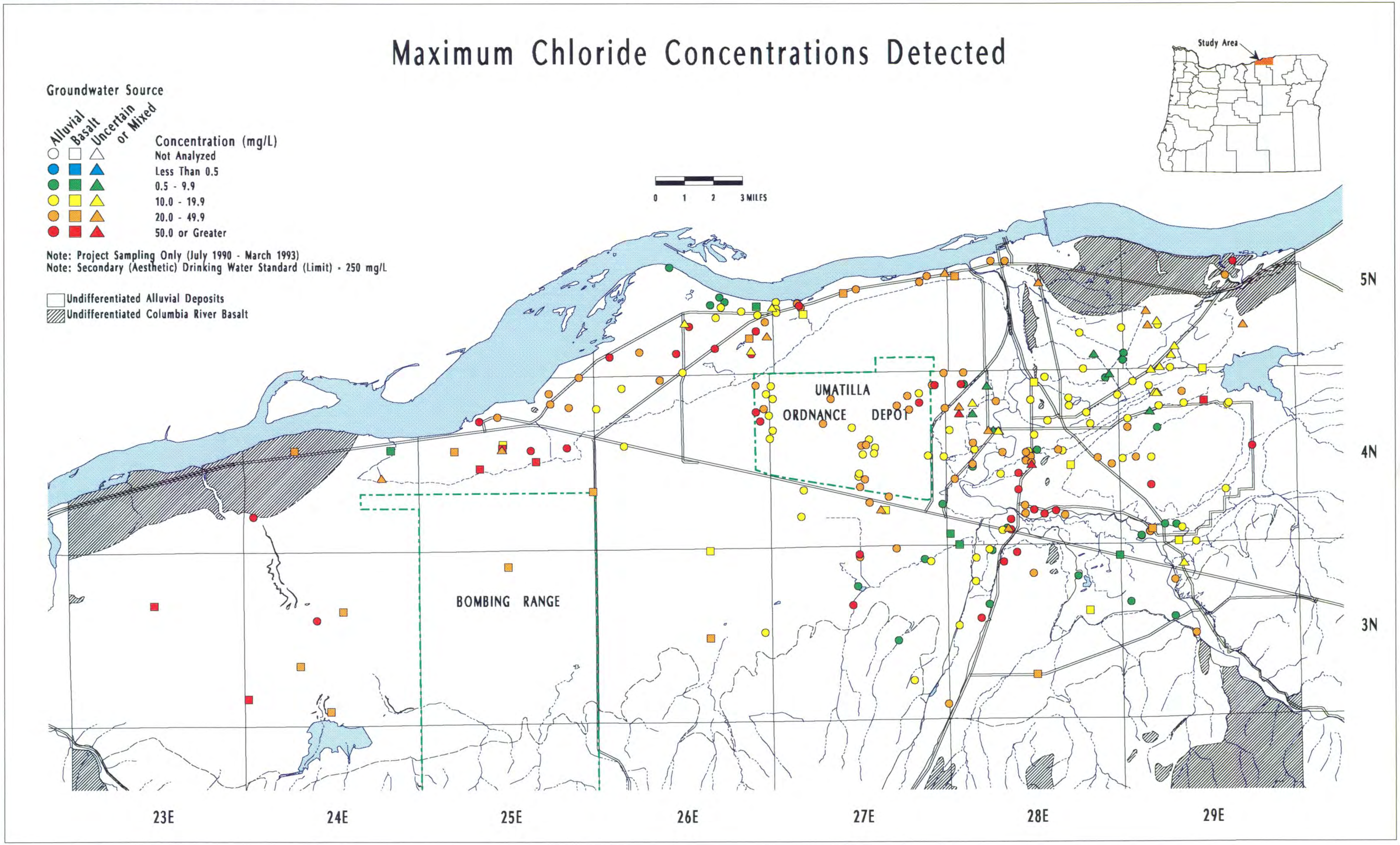
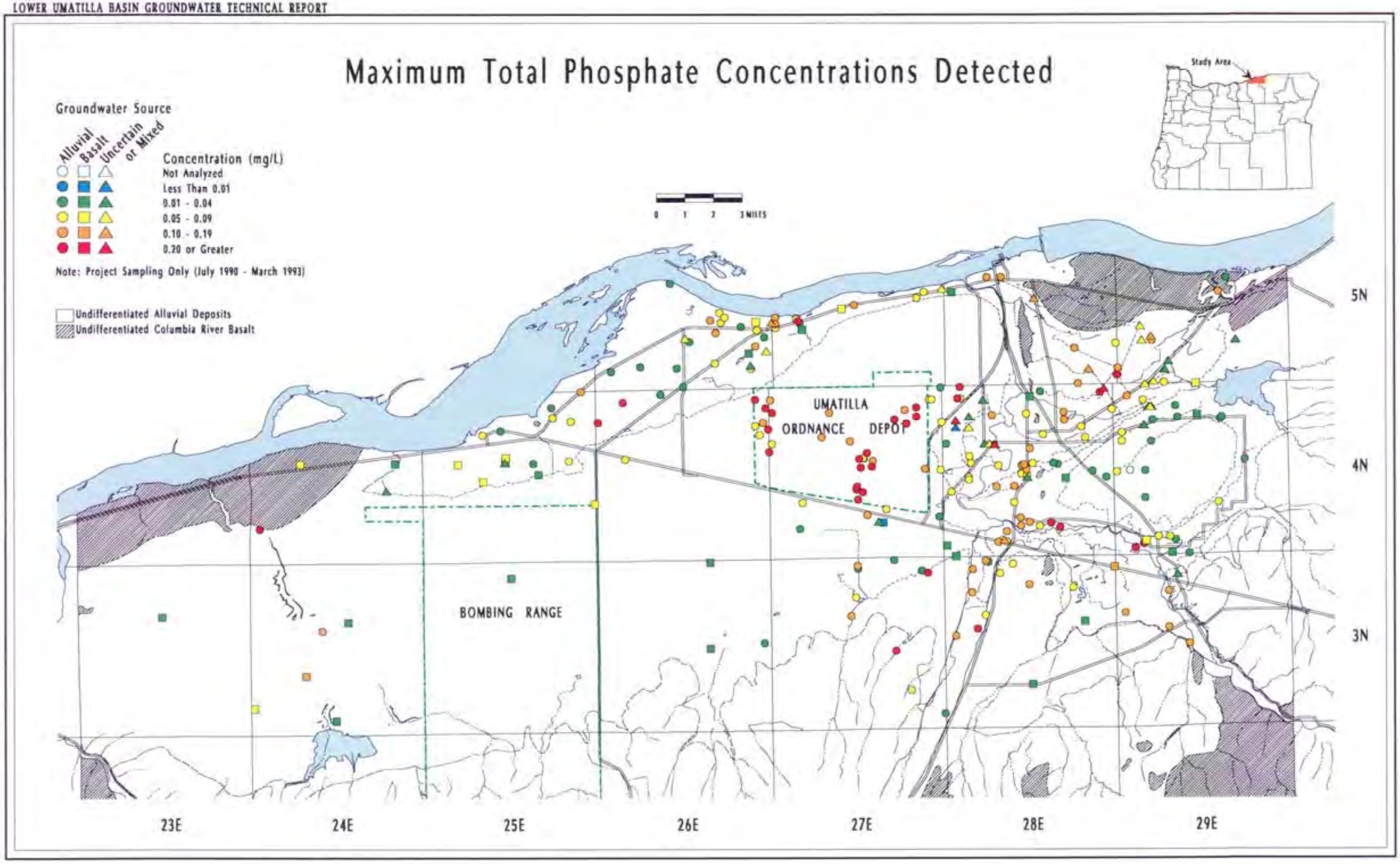


PLATE 4.9
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT



Maximum Total Phosphate Concentrations Detected

PLATE 4.10
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Maximum Boron Concentrations Detected

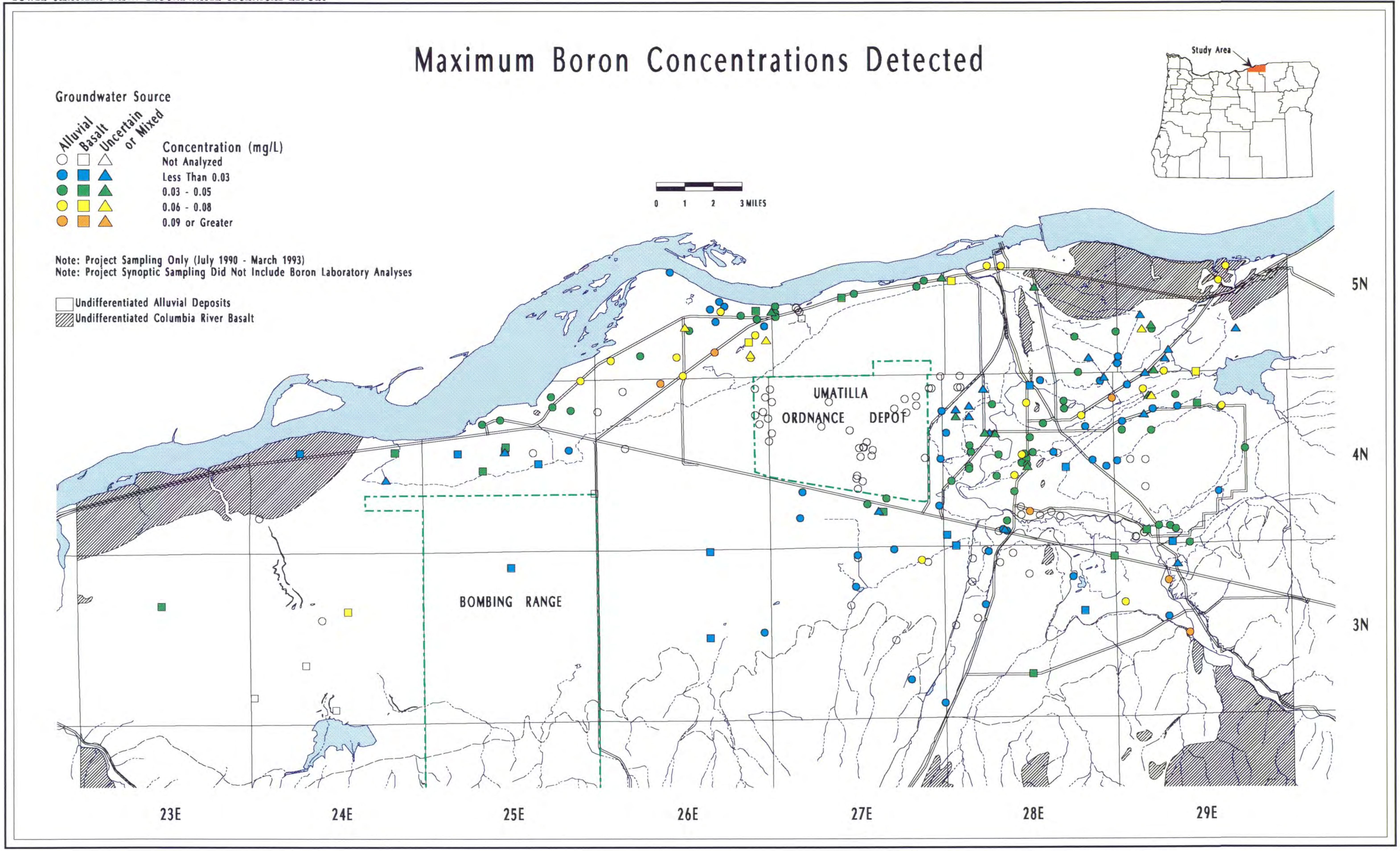
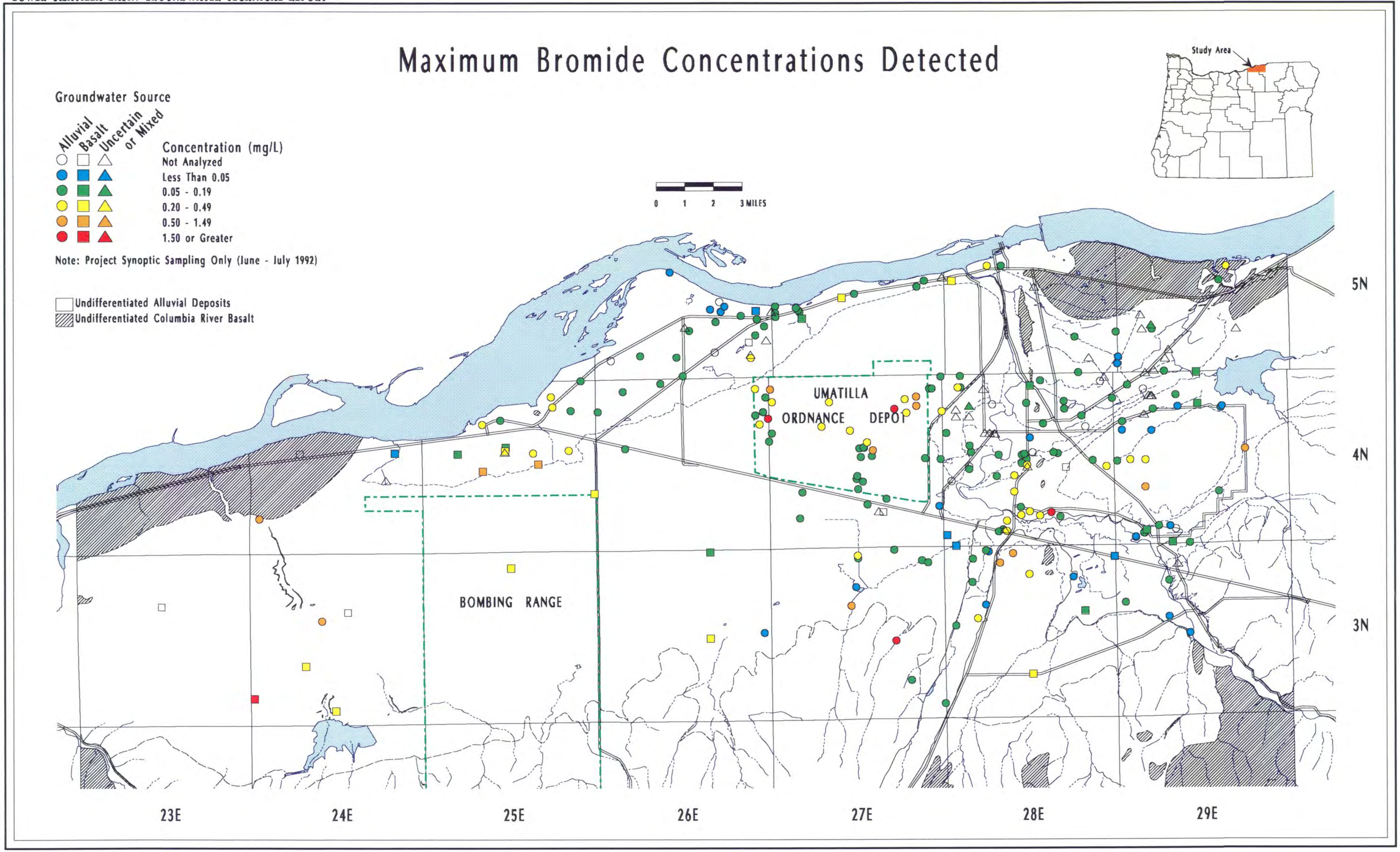
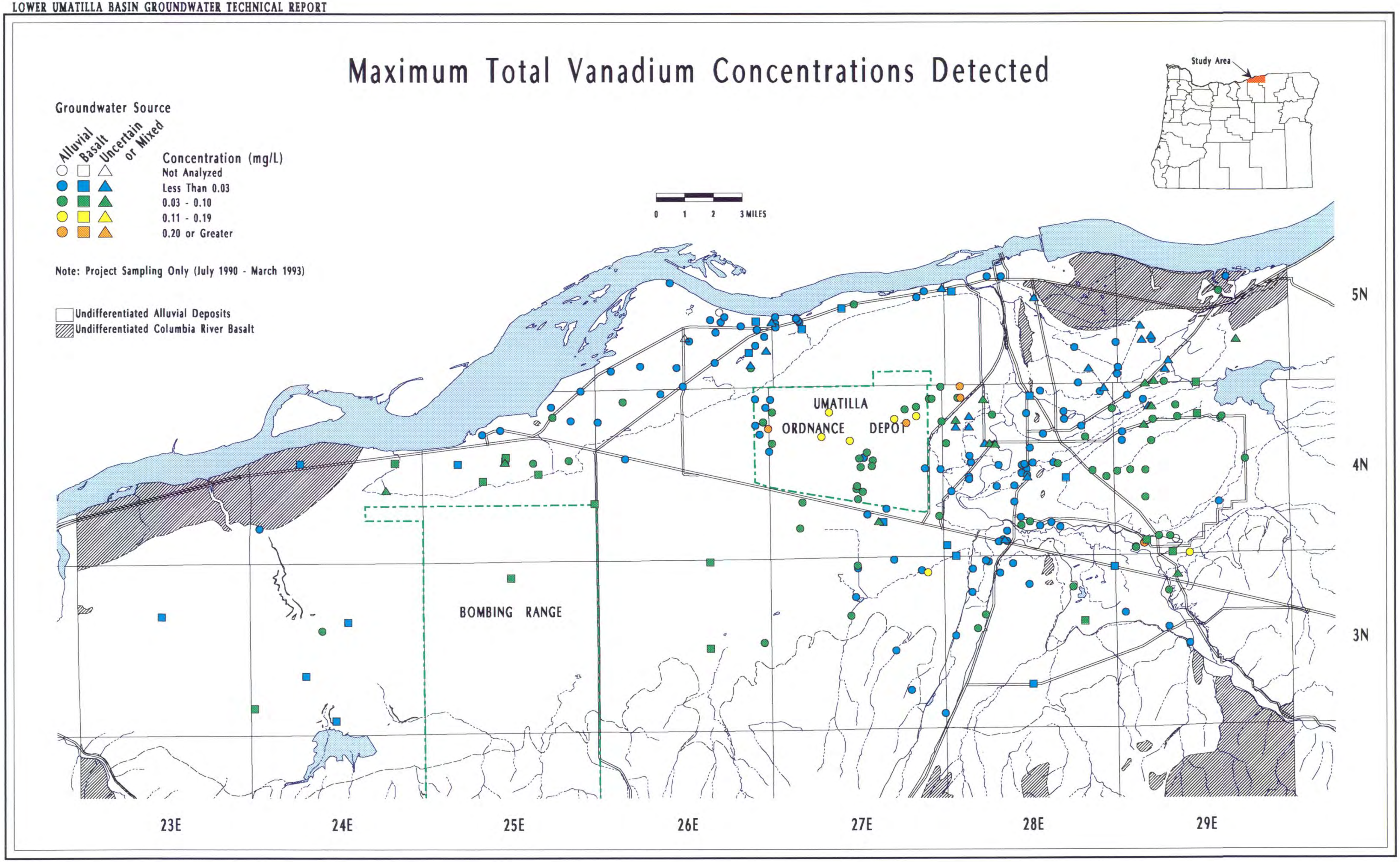


PLATE 4.11



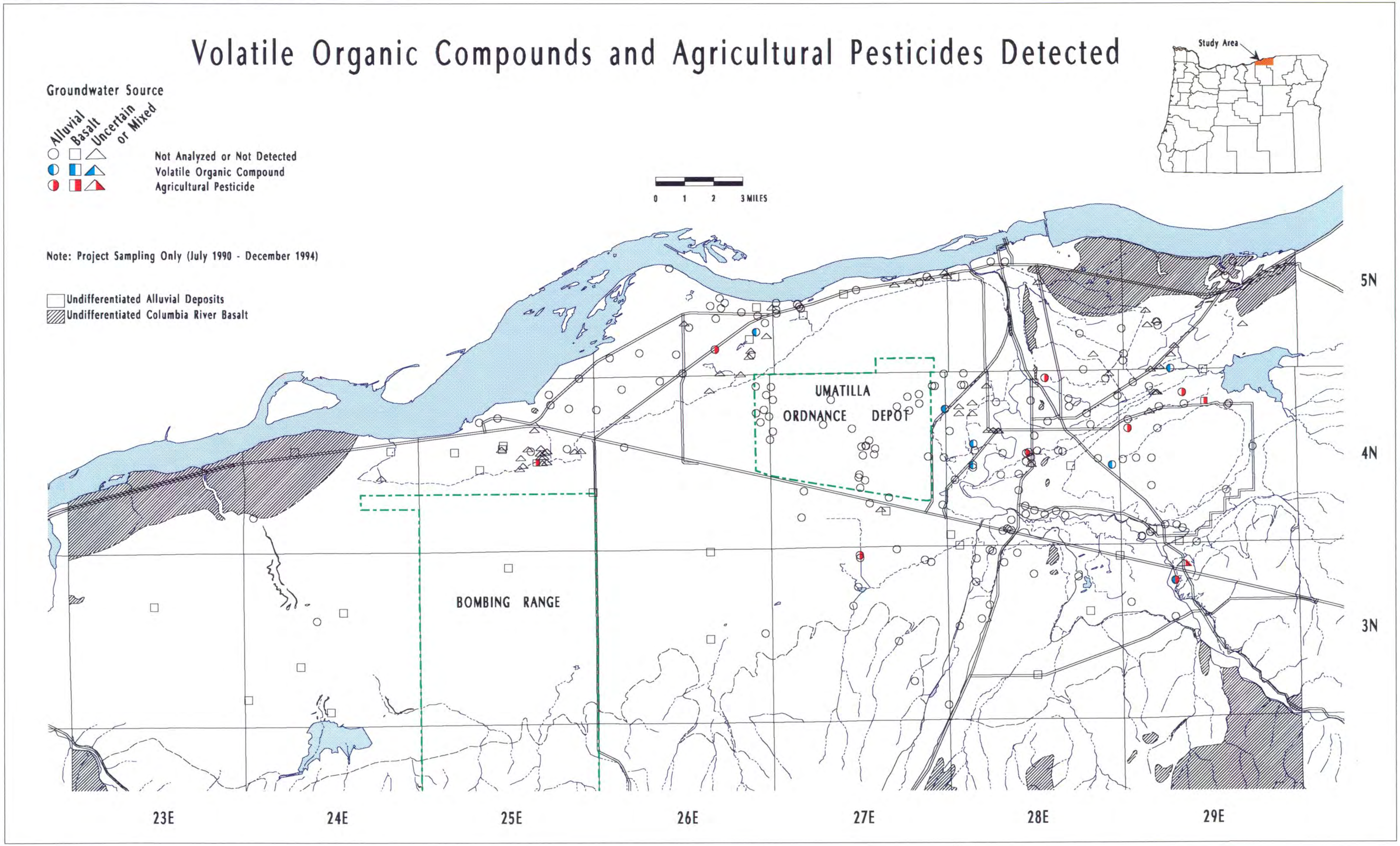
Maximum Bromide Concentrations Detected



Maximum Total Vanadium Concentrations Detected

PLATE 4.13
LOWER UMATILLA BASIN GROUNDWATER TECHNICAL REPORT

Volatile Organic Compounds and Agricultural Pesticides Detected



Appendix 1A

State Agency Groundwater Sampling
Selected 1984 to 1987 Data

Table:___ Nitrate and pesticides detected by 1984-1987 state agency groundwater sampling.

Sampling Site	Nitrate + Nitrite-Nitrogen		Pesticide		
	Minimum (mg/L)	Maximum (mg/L)	Constituent	Minimum (ug/L)	Maximum (ug/L)
UMA 001	-	20.00	ND	-	-
UMA 002	10.00	12.00	ND	-	-
UMA 003	25.00	80.00	Dacthal	ND	0.008
			Pentachlorophenol	-	0.004
			Tetrachlorophenol	-	0.002
UMA 004	-	0.46	ND	-	-
UMA 005	0.77	2.20	Pentachlorophenol	ND	0.220
			Tetrachlorophenol	-	0.070
			Dacthal	ND	0.005
			Dicamba	ND	0.003
UMA 006	-	0.10	ND	-	-
UMA 007	-	0.02	Pentachlorophenol	-	0.010
UMA 008	ND	0.02	Pentachlorophenol	-	0.006
			Tetrachlorophenol	-	0.003
			Dacthal	ND	0.002
UMA 009	-	23.00	ND	-	-
UMA 010	-	6.60	ND	-	-
UMA 011	-	10.00	ND	-	-
UMA 012	-	15.00	ND	-	-
UMA 013	21.00	28.00	NA		
UMA 014	11.00	15.00	NA		
UMA 015	-	20.00	NA		
UMA 016	11.00	16.00	NA		
UMA 017	-	23.00	NA		
UMA 018	-	0.23	NA		
UMA 019	-	46.00	NA		
UMA 020	-	38.00	NA		
UMA 021	-	2.90	NA		
UMA 022	-	7.60	NA		
UMA 023	-	ND	NA		
UMA 024	-	4.20	NA		
UMA 025	-	17.00	NA		

Note: ND = Not detected
NA = No laboratory analysis

Appendix 1B

Lower Umatilla Basin Groundwater Management Area Citizens Committee

Henry Lorenzen, Chairman
-Member, Environmental Quality Commission
P.O. Box 218
Pendleton, Oregon 97801
(503) 276-3331
FAX (503) 276-3148

Chester Prior
-Member, Governor's Task Force for Water Supply Issues
-Representing potato growers industry
Rt. 1, Box 1218
Power Line Road
Hermiston, Oregon 97838
(503) 567-5384
Ranch: (503) 376-8444
FAX (503) 376-8445

Stafford Hansell
-Former member of Oregon Legislature, active on several committees
Number 9 Eastregaard
Boardman, Oregon 97818
(503) 481-6040

Phil Walchli
-Member of the Umatilla Co. SWCD Board
Rt. 3, Box 3342
Hermiston, Oregon 97838
(503) 567-5842

Judge Louis Carlson
-Morrow County Commissioner
P.O. Box 788
Heppner, Oregon 97836
(503) 676-9061

Sheri Wadekamper
-Owner cow\calf operation and local farm
Rt. 2, Box 242
Irrigon, Oregon 97844
(503) 567-1985

Barry Beyeler
-Public Works Director, City of Boardman
P.O. Box 229
Boardman, Oregon 97818
(503) 481-9252

Lynn Webb
-Irrigation Manager for Pacific Northwest Farming Co.
P.O. Box 714
Irrigon, Oregon 97844
(503) 481-3549

Bob Levy
-Large farm owner, innovative
Rt. 1, Box 1230
Hermiston, Oregon 97838
(503) 567-9733

Jeff Lyon
-Environmental Manager for JR Simplot
- land application
P.O. Box 850
Hermiston, Oregon 97838
(503) 567-9733

Dennis Reisch
-Wiler-Ellis, fertilizer
/pesticide business
P.O. Box 609
Umatilla, Oregon 97882
(503) 922-3278

Frank Mader
-Morrow County & State
Conservation Farm of 1987-88
HC70 Box 318
Echo, Oregon 97826
(503) 376-8246

Tom Able, Jr.
-Organic vegetable farmer utilizing drip irrigation
1845 S. Hwy 395
Hermiston, Oregon 97838
(503) 567-5870

Brigitta Lamb
-President Eastern Oregon
Regional Arts Council
-Representing environmental issues
Rt. 1, Box 4180
Hermiston, Oregon 97838
(503) 567-3201

Don Eppenbach
-Irrigon City Administrator
-Previous connections with city planning and Army Depot
P.O. Box 428
Irrigon, Oregon 97844
(503) 922-3047

Gene Kerby
-Owns and operates "small"
farm near Umatilla Army Depot
P.O. Box 951
Umatilla, Oregon 97882
(503) 922-4237

Bob Kenny
-Melon Grower using controlled irrigation
Rt. 1, Box 145
Umatilla, Oregon 97882
(503) 922-4996

Ron Shoemaker
-Plant Engineer, Hermiston Foods -
- Representing food processing industry
- land application
301 Umatilla Avenue
Umatilla, Oregon 97882
(503) 922-5144

LTC William D. McCune
-Commanding officer
U.S. Army Depot Umatilla Activity
Hermiston, Oregon 97838
(503) 564-5200

Duane Neiffer
Rt. 1, Box 38A
Boardman, Oregon 97818
(503) 481-2076

Appendix 1C

Lower Umatilla Basin Groundwater Management Area Technical Advisory Committee

Don Wysocki, Committee Chairman
Columbia Basin Agricultural
Research Center
P.O. Box 370
Pendleton, Oregon 97801
(503) 278-4186

Jerald Rea
-Member, West Extension
Irrigation Board
-Port of Morrow, Farm and
Utility Supervisor
Rt. 1, Box 73B
Boardman, Oregon 97818
(503) 481-5922

Luther Fitch
-Senior OSU Agricultural
Extension Agent, (Retired)
P.O. Box 105
Hermiston, Oregon 97838
(503) 567-8321

Fred Zairi
-President of IRZ Consulting,
Water management
115 W. Hermiston Avenue,
Suite 210
Hermiston, Oregon 97838
(503) 567-0252

Tom Darnell
-OSU Horticultural Extension
Agent
P.O. Box E
Milton Freewater, Oregon 97862
(503) 567-8321

Skip Mathews
-ASCS Director for Morrow
County
P.O. Box 786
Heppner, Oregon 97836
(503) 676-9011

Charlie Newhouse
-ASCS Director for Umatilla
County
1229 SE 3rd
Pendleton, Oregon 97801
(503) 276-3811, Ext. 433

Loren Unruh
-SCS Representative for
Morrow County
Petty John Building
Heppner, Oregon 97836
(503) 676-9642

Bob Adleman
-SCS Representative for
Umatilla County
1229 SE 3rd
Pendleton, Oregon 97801
(503) 276-3811

Mike Henderson
Lamb-Weston, Inc.
2005 Saint Street
Richland, Washington 99352
(509) 375-5852

Appendix 2A
Inventory of Project Wells

Lower Umatilla Basin
Inventory of Project Wells for Hydrogeologic Assessment

Use Key:
DO = Domestic
DS = Domestic/Stock
FP = Fire Protection
ID = Irrigation/Domestic
IM = Industrial/Manufacturing
IN = Industrial
IR = Irrigation
LV = Livestock
MO = Monitoring
MU = Municipal
OB = Observation
TH = Thermal
TW = Test Well

Status Key:
AB = Abandoned
UN = Unused

Aquifer System Key:
(Producing Zone)
A = Alluvial
AB = Alluvial/Basalt, Alluvial primary
B = Basalt

Completion Zone Key:
Alluvial Aquifer
UF = Unconfined, fine-grained
UC = Unconfined, coarse-grained
CF = Confined, fine-grained
BF = Breccia/fracture zone
Basalt Aquifers
EM = Basal Elephant Mountain
PO = BasalPomona
UM = Basal Umatilla
UN = Undifferentiated

Completion Key:
1 = Monitoring well screened at or near water table
2 = Monitoring well screened below water table
3 = Perforated or screened
4 = Open casing at total depth
5 = Open hole
6 = Behind ungrouted casing or liner

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
02N/24E-02CAC	LUB	38		PORTLAND GENERAL ELECTRIC CO	CD-311		AB	81.3														
02N/24E-02DBC	LUB	25		PORTLAND GENERAL ELECTRIC CO	52	MO		70				x	x	A				2				
02N/24E-03DCA	LUB	26		PORTLAND GENERAL ELECTRIC CO	53	MO		78				x	x	A				2				
02N/24E-05BBB	LUB	33		PORTLAND GENERAL ELECTRIC CO	108	MO		49.6				x	x	B				6	3			
02N/24E-05DDA	LUB	219		PORTLAND GENERAL ELECTRIC CO	B-14	TW	AB	385														
02N/24E-07BAA	LUB	218		PORTLAND GENERAL ELECTRIC CO	B-13	TW	AB	120.2														
02N/24E-09ABA	LUB	215		PORTLAND GENERAL ELECTRIC CO	B-10	TW	AB	82.3														
02N/24E-09BDC	LUB	217		PORTLAND GENERAL ELECTRIC CO	B-12	TW	AB	83.3														
02N/24E-09DCD	LUB	216		PORTLAND GENERAL ELECTRIC CO	B-11	TW	AB	83.2														
02N/24E-11ABB	LUB	37		PORTLAND GENERAL ELECTRIC CO	CD-31	TW	AB	153														
02N/24E-11BAA	LUB	36		PORTLAND GENERAL ELECTRIC CO	122	MO		70					x	A	6			3				
02N/24E-11BAB	LUB	35		PORTLAND GENERAL ELECTRIC CO	120	MO		70.5				x	x	A	6			3				
02N/25E-05ACB	LUB	227		PORTLAND GENERAL ELECTRIC CO	CD-14	TW	AB	231														
02N/25E-06CBC	LUB	229		PORTLAND GENERAL ELECTRIC CO	CD-24	TW	AB	188.2														
02N/25E-07ACD	LUB	230		PORTLAND GENERAL ELECTRIC CO	CD-34	TW	AB	198														
02N/26E-05AAA	MORR	1548		TIDEWATER BARGE LINES	MW-4 FINLEY BUTTES LANDFILL	MO		374.9					x	A	1							
02N/26E-05AAA	MORR	1545		TIDEWATER BARGE LINES	MW-5 FINLEY BUTTES LANDFILL	MO		370					x	A	1							
02N/26E-05AAD	MORR	1546		TIDEWATER BARGE LINES	MW-2 FINLEY BUTTES LANDFILL	MO		316					x	A	1							
02N/26E-05ACC	MORR	1547		TIDEWATER BARGE LINES	BMW-1 FINLEY BUTTES LANDFILL	MO		330					x	A				3				
02N/26E-05ADC	MORR	1544		TIDEWATER BARGE LINES	MW-3 FINLEY BUTTES LANDFILL	MO		310					x	A	1							
02N/27E-01BAD	UMAT	5572		LAMB WESTON	MW-1 Madison Ranch	MO		17.08				x	x	A	1							
03N/23E-09DCA	MORR	572		TAGGARES FARMS		DO		700						B								5
03N/23E-09DDA	MORR	1528	169	TAGGARES FARMS		DO		650						B								5
03N/23E-25BDC	MORR	573		BOEING		IM		790						B	6			6	6	6		3
03N/24E-05CCC	LUB	214		PORTLAND GENERAL ELECTRIC CO	B-9	TW	AB	88.1														
03N/24E-05CDC	LUB	211		PORTLAND GENERAL ELECTRIC CO	B-6	TW	AB	128.5														
03N/24E-07BAD	LUB	212		PORTLAND GENERAL ELECTRIC CO	B-7	TW	AB	111.3														
03N/24E-09BBA	LUB	213		PORTLAND GENERAL ELECTRIC CO	B-8	TW	AB	110														
03N/24E-15BAB	MORR	576	171	BOEING AEROSPACE CO		IM		730						B								5
03N/24E-16BDC	LUB	28		PORTLAND GENERAL ELECTRIC CO	103	MO		67.1				x	x	A		2						
03N/24E-20DDD	LUB	29		PORTLAND GENERAL ELECTRIC CO	104	MO		55.1				x	x	B				6	3			
03N/24E-25DAC	LUB	220		PORTLAND GENERAL ELECTRIC CO	CD-2	TW	AB	88														
03N/24E-27CAD	LUB	222		PORTLAND GENERAL ELECTRIC CO	CD-6	TW	AB	93.8														

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aqui-fer Test Well	Recor-der Well	Drill Cut-tings Well	Synoptic Water Level Well	Water Level Well	Aqui-fer Sys-tem	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
03N/24E-31BBA	LUB	31		PORTLAND GENERAL ELECTRIC CO	106	MO		18.2				x	x	A	1							
03N/24E-31BBB	LUB	32		PORTLAND GENERAL ELECTRIC CO	107	MO		43.5				x	x	B				6	3			
03N/24E-33ADD	MORR	574		BOEING AEROSPACE CO		IM		564.5				x	x	B	6			6	6	6		5
03N/24E-33CAC	LUB	22		PORTLAND GENERAL ELECTRIC CO	8	MO		108				x	x	B					3			
03N/24E-33CAC	LUB	23		PORTLAND GENERAL ELECTRIC CO	9	MO		33					x	BA				3	3			
03N/24E-33CDA	LUB	210		PORTLAND GENERAL ELECTRIC CO	B-5	TW	AB	85.5														
03N/24E-33DCA	LUB	209		PORTLAND GENERAL ELECTRIC CO	B-4	TW	AB	114.5														
03N/24E-33DCB	LUB	225		PORTLAND GENERAL ELECTRIC CO	CD-10	TW	AB	111														
03N/24E-34DCA	LUB	208		PORTLAND GENERAL ELECTRIC CO	B-3	TW	AB	41.2														
03N/24E-35ADA	LUB	206		PORTLAND GENERAL ELECTRIC CO	B-1	TW	AB	100														
03N/24E-35ADA	LUB	226		PORTLAND GENERAL ELECTRIC CO	CD-13	TW	AB	109.9														
03N/24E-35DBC	LUB	207		PORTLAND GENERAL ELECTRIC CO	B-2	TW	AB	85.4														
03N/25E-04DAA	MORR	587	170	US NAVY, ATTN U.7.1 MONTEGNA	Tower #2 well.	DO		310						B					6			3
03N/25E-30DBB	LUB	224		PORTLAND GENERAL ELECTRIC CO	CD-9	TW	AB	159.4														
03N/25E-31CBA	LUB	228		PORTLAND GENERAL ELECTRIC CO	CD-16	TW	AB	182.5														
03N/25E-32ABB	LUB	223		PORTLAND GENERAL ELECTRIC CO	CD-7	TW	AB	264.6														
03N/25E-33BCC	LUB	221		PORTLAND GENERAL ELECTRIC CO	CD-4	TW	AB	275.3														
03N/26E-03AAA	MORR	589	194	BIG RIVER FARMS INC	Shop #4	DO		324					x	B					5	5		
03N/26E-04AAD	MORR	596		BULOW	#2	IR		680					x	B	6			6	6	6		5
03N/26E-04DBC	MORR	595		BULOW	#1	IR		835					x	B	5			6	5	5		5
03N/26E-05CBD	MORR	599		SABRE FARMS	#1	IR		950					x	B	6			6	6	6		5
03N/26E-10ACA	MORR	602		BREWER		IR		544					x	BA	5			5		5		5
03N/26E-10CAD	MORR	601		CRAMER		IR		666					x	BA	6			5		5		
03N/26E-13DDC	MORR	606	166	BIG RIVER FARMS, INC.		LV		200				x	x	A	3							
03N/26E-14DDB	MORR	607		JONES		IR		197						BA	5			5	5	5		
03N/26E-19CCC	MORR	608		BOARDMAN FARMS	Potato shed well	IM		383						B				6		5		5
03N/26E-22AAA	MORR	609	172	SABRE FARMS		DO		243						B					5			
03N/26E-32DBA	LUB	195		TIDEWATER BARGE LINES	MW-1 FINLEY BUTTES LANDFILL	MO		374.9					x	A				2				
03N/27E-01DBD	UMAT	5571		LAMB WESTON	MW-4 Madison Ranch	MO		61				x	x	A	1							
03N/27E-02BBD	UMAT	1162	167	HAMPTON		DS		110				x	x	A			4	5				
03N/27E-04ACA	MORR	611		KEY		IR		180				x	x	AB	3			5	5			
03N/27E-04ACC	MORR	614		KEY		IR	AB	88						A			3					
03N/27E-04ADA	MORR	613	133	KEY		IR		80				x	x	A			3					
03N/27E-04BCA	MORR	612		KEY		IR	AB	108						A			5					
03N/27E-04BCC	MORR	615		KEY		IR	AB	112						A			3					
03N/27E-04DDA	MORR	616		CARL KNIGHTEN		IR		185						AB			5	5	5			
03N/27E-05ADB	MORR	621		KEY		IR		400						BA			6	3		5		5
03N/27E-05BCA	MORR	620		KEY			AB	145						A			5	5				
03N/27E-05BDD	MORR	619		KEY			AB	200						A			3	3				
03N/27E-08AAC	MORR	626		MARTIN		IR		725					x	B			6	6	5	5		5
03N/27E-09ADD	MORR	628	199	HANSELL		IR		125				x	x	A			3	3				
03N/27E-16ABA	UMAT	5570		LAMB WESTON	MW-3 Madison Ranch	MO		39	x			x	x	A	3							
03N/27E-23BAC	UMAT	5594		LAMB WESTON	MW-2 Madison Ranch	MO		172				x	x	A	3							
03N/27E-25DCD	UMAT	1166		SAYLOR		IR		693						B			6	6		5		5
03N/27E-26DAC	UMAT	1168	186	MADISON RANCHES		DO		330						A			5					
03N/27E-36ADD	UMAT	1169	187	MADISON RANCHES		DO		100						A			5					
03N/28E-01ADA1	UMAT	5476	118	OREGON DEPT OF TRANSPORTATION		IR		95				x	x	B							5	
03N/28E-01ADA2	UMAT	1173		STATE HIGHWAY COMMISSION		UN		67		x		x	x	A		4						
03N/28E-01ADD	UMAT	1172		OREGON DEPT OF TRANSPORTATION	#1	DO		135				x	x	B				6			5	
03N/28E-02CCA	UMAT	1177		ANDREWS		IR		84						A			3					
03N/28E-02CDA	UMAT	1176		ANDREWS	Well #2	IR		625						BA			3	5			5	5

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aqui-fer Test Well	Recor-der Well	Drill Cut-tings Well	Synoptic Water Level Well	Water Level Well	Aqui-fer Sys-tem	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
03N/28E-03BBB	LUB	71		J.R. SIMPLOT CO	MW-38	MO		70.4					x	A	1							
03N/28E-03BCC	LUB	72		J.R. SIMPLOT CO	MW-39	MO		85.5					x	A	1							
03N/28E-03CCC	LUB	73		J.R. SIMPLOT CO	MW-40	MO		75.5					x	A	1							
03N/28E-04BDA	LUB	47		J.R. SIMPLOT CO	MW-14	MO		142				x	x	A	2							
03N/28E-04CBB	LUB	55		J.R. SIMPLOT CO	MW-22	MO		86				x	x	A	1							
03N/28E-04DBC	LUB	48		J.R. SIMPLOT CO	MW-15	MO		101				x	x	A	1							
03N/28E-05ABC	LUB	56		J.R. SIMPLOT CO	MW-23 (WELL B)	MO		25.5				x	x	A	1							
03N/28E-05BAD	LUB	57		J.R. SIMPLOT CO	MW-24 (WELL A)	MO		26.5				x	x	A	1							
03N/28E-05BCC	LUB	59		J.R. SIMPLOT CO	MW-26 (WELL E)	MO		31.5				x	x	A	1							
03N/28E-05BDD	LUB	58		J.R. SIMPLOT CO	MW-25 (WELL C)	MO		21.5				x	x	A	1							
03N/28E-05CAB	LUB	60		J.R. SIMPLOT CO	MW-27 (WELL D)	MO		21.5				x	x	A	1							
03N/28E-05CDC	LUB	62		J.R. SIMPLOT CO	MW-29 (WELL G)	MO		31.5				x	x	A	1							
03N/28E-05DAB	LUB	61		J.R. SIMPLOT CO	MW-28 (WELL F)	MO		31.5				x	x	A	1							
03N/28E-06ACB	LUB	74		J.R. SIMPLOT CO	MW-41	MO		75					x	A	1							
03N/28E-06DCC	UMAT	1183		BRENT HORN ENTERPRISES	Well #2	IR		1136						BA				5		5		5
03N/28E-07AAD	LUB	63	255	J.R. SIMPLOT CO	MW-30 (WELL H)	MO		34				x	x	A	1							
03N/28E-07ABB	LUB	75		J.R. SIMPLOT CO	MW-42	MO		95					x	A	1							
03N/28E-07DCC	LUB	76		J.R. SIMPLOT CO	MW-43	MO		44.5					x	A	1							
03N/28E-07DCD	LUB	70		J.R. SIMPLOT CO	MW-37	MO		25.85					x	A	1							
03N/28E-08ADB	UMAT	1186		WALKER			UN	47					x	A			5					
03N/28E-08CAC	LUB	67		J.R. SIMPLOT CO	MW-34	MO		29					x	A	1							
03N/28E-08DAC1	UMAT	1188		WALKER	Well #2		UN	437						BA			6	5		5		5
03N/28E-08DAC2	UMAT	1189		WALKER	Well #1		UN	216						A			5	5				
03N/28E-11AAB	UMAT	1193		CORREA		IR		50						A		3						
03N/28E-11ABB	UMAT	1194	193	CORREA		DS		50						A			4					
03N/28E-11CAC	UMAT	1192		EMERT RANCHES	Well #2	IR		87						A		3						
03N/28E-11CDA	UMAT	1191		EMERT RANCHES	Well #3	IR		605						BA				5			5	5
03N/28E-14ADA	UMAT	5373	196	DOUBLE M. RANCH		DO		100				x	x	A			5	5				
03N/28E-14CBA	UMAT	1198		PRIOR		UN		73				x	x	A			5	5				
03N/28E-17BAA	UMAT	1201	185	SAYLOR		DO		112				x	x	A			5					
03N/28E-17CAB	UMAT	5569		LAMB WESTON	MW-5 Madison Ranch	MO		18				x	x	A	3							
03N/28E-18AAD	LUB	68		J.R. SIMPLOT CO	MW-35	MO		26.2					x	A	1							
03N/28E-18ABD	UMAT	1203		BRENT HORN ENTERPRISES	Well #1	IR		1095						B			6	6		5		5
03N/28E-18CAD	LUB	77		J.R. SIMPLOT CO	MW-44	MO		27.5					x	A	1							
03N/28E-18DBC	LUB	69		J.R. SIMPLOT CO	MW-36	MO		29.25					x	A	1							
03N/28E-18DBD	UMAT	1204		BRENT HORN ENTERPRISES		IR		875						B						5		5
03N/28E-23BBA	UMAT	1214		L & L FARMS	L&L #3	IR		936						B								5
03N/28E-23DCB	UMAT	1216		L & L FARMS	L&L #1	IR		1012						B								5
03N/28E-26DCB	UMAT	1215		L & L FARMS	L&L #2	IR		911						B								5
03N/28E-27BCB	UMAT	1219		L&L FARMS		IR		984						B			6	6				5
03N/28E-27BCC	UMAT	1217	188	LEVY		DO		450					x	B								5
03N/28E-28CAB	UMAT	1220		L&L FARMS		IR		636						BA			3	5				5
03N/28E-34DBA	UMAT	1224		SPARKS	Maddox Well #1	IR		830						B								5
03N/28E-35ABC	UMAT	1232		PRIOR	Prior #5	IR		1255						B								5
03N/28E-35CAD	UMAT	1233		PRIOR	Prior #6	IR		1067						B								5
03N/28E-36BDA	UMAT	1235		PRIOR	Prior #2	IR		1005						B								5
03N/28E-36DBC	UMAT	1226		PRIOR	Prior #3	IR		689						B								5
03N/29E-02ADD	UMAT	1238		CIRCLE C FARMS, INC	Well #4	IR		1065						B								5
03N/29E-04BBC	UMAT	1243		MILLS MINT FARM	Well #2	IR		925						B								5
03N/29E-04DDD	UMAT	1279		KENNETH BATTY	#1	IR		1380						B								5
03N/29E-05ABC	UMAT	1259		HERRICK		IR		57						A			3					

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aqui-fer Test Well	Recor-der Well	Drill Cut-tings Well	Synoptic Water Level Well	Water Level Well	Aqui-fer Sys-tem	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
03N/29E-05ACD	UMAT	1255		HERRICK	Well #2	LV		145						AB			3					5
03N/29E-05BDA	UMAT	1253		FORREY		IR		240						BA			5	5				5
03N/29E-05CBC	UMAT	1249		CORREA		IR		30						A			3					
03N/29E-07CBD	UMAT	1270		PRIOR		IR		72						A		3						
03N/29E-07CDC	UMAT	1269	192	PRIOR	#10	IR		33				x	x	A		3						
03N/29E-08ACA	UMAT	1274	191	CITY OF ECHO	Lagoon Irrigation Well	DO		22.5				x	x	A			3					
03N/29E-09CDD	UMAT	1277		SIEBEL BROS SEED RANCH		IR		1117						B								5
03N/29E-10ABB	UMAT	1278		MILLS	well #2	IR		1380						B								5
03N/29E-11ACC	UMAT	1286		CIRCLE C RANCH	Well #6	IR		696						B			6	6				5
03N/29E-11DDD	UMAT	1282		CIRCLE C RANCH	Well #5	IR		1145						B								5
03N/29E-12BBC	UMAT	1294		CIRCLE C RANCH	Well #7	IR		1281						B								5
03N/29E-14BCA	UMAT	1300		CIRCLE C RANCH	Well #8	IR		1492						B								5
03N/29E-16AAD	UMAT	1314		CITY OF ECHO	Well #2	MU		820						B		6		6				5
03N/29E-16ACA	UMAT	1315		CITY OF ECHO	Well #3	MU		490						B		6		6				5
03N/29E-16DAB	UMAT	1311		CITY OF ECHO	Well #4	MU		600						B								5
03N/29E-17DBA	UMAT	1317	189	SPIKE	House well.	DO		30						A		5						
03N/29E-19BDD	UMAT	1318		TRAVELERS INS.	Brown well #4	IR		1125						B								5
03N/29E-20DCC	UMAT	1321	162	TRAVELERS INS.	Brown well #1	IR		1027						B								5
03N/29E-21BAD	UMAT	1325	190	SPIKE	Trailer house well	DO		25				x	x	A		3						
03N/29E-23ADB	UMAT	1326		COPPINGER	Well #3	IR		761						B								5
03N/29E-24ACD	UMAT	1328		COPPINGER	Well #1	IR		1012						B								5
03N/29E-24ADA	UMAT	1329		COPPINGER	Well #2	IR		318						B								5
03N/29E-30ADB	UMAT	1334		TRAVELERS INS.	Brown well #3	IR		1100						B								5
03N/29E-30DDD	UMAT	1335		TRAVELERS INS.	Brown well #2	IR		882						B								5
04N/24E-13BCC	MORR	647	179	WILSON		DO		100				x	x	B					3			
04N/24E-14CDA	MORR	665		HENDRIX		IR		541						B					6	6		5
04N/24E-14DAC	MORR	666		EADES		IR		725						B					6	6		5
04N/24E-17DAB	MORR	669	197	UNION PACIFIC RAILROAD		FP		216						B					5			
04N/24E-23BAB	MORR	1558		JOHNSON		DO		78			x			B					5			
04N/24E-30CDB	LUB	27		PORTLAND GENERAL ELECTRIC CO	101	MO		25				x	x	A		1						
04N/25E-01ACC	MORR	682		PORT OF MORROW	MW-1	MO		55				x	x	A		1						
04N/25E-01BAA	MORR	680		PORT OF MORROW	MW-5	MO		62				x	x	A		1						
04N/25E-01BAA	MORR	1555		PORT OF MORROW	CES 1-3	OB		235						B					5			
04N/25E-01BAA	MORR	679	176	PORT OF MORROW	POM Farm Well 4	OB		95						A		3						
04N/25E-01BAD	MORR	678		PORT OF MORROW	POM Farm Well 5	OB		101						A		3						
04N/25E-02ABA	MORR	1543		PORT OF MORROW	MW-11	MO		36				x	x	A		1						
04N/25E-02BDC	MORR	1542		PORT OF MORROW	MW-10	MO		33				x	x	A		1						
04N/25E-02CAA	MORR	684	178	PORT OF MORROW	POM Farm Well #3	OB		93	x					A		3						
04N/25E-02CBC	MORR	683		PORT OF MORROW	Cargill Well	OB		82	x			x	x	A		3						
04N/25E-02CDD	MORR	1551		PORT OF MORROW	MW-9	MO		57				x	x	A		1						
04N/25E-03CDD	MORR	686		PORT OF MORROW	Old Shop Well	OB		58				x	x	A		4						
04N/25E-08DAA	MORR	696	31	MATHEWSON		DO		55				x	x	A		4						
04N/25E-08DBB	MORR	698		CORPS OF ENGINEERS		IR		50						A		3						
04N/25E-09ACD	MORR	746		BOARDMAN CEMETERY ASSOC		IR		470								6		6	6	3		
04N/25E-09ADB	MORR	740	86	IRRIGATION RENTAL INC		DO		57				x	x	A		4						
04N/25E-09BAA	MORR	736		CITY OF BOARDMAN	TH1 (Test Hole 1)	TW	AB	54						A		3						
04N/25E-09BBD	MORR	732		CITY OF BOARDMAN	TH2 (Test Hole 2)	TW	AB	51.5						A		4						
04N/25E-09CBA	MORR	745		CITY OF BOARDMAN	Well 1-64	MU		585						B					6	6		
04N/25E-10AAC	MORR	1526		PORT OF MORROW	#4	IM		900						B								3
04N/25E-10BBD	MORR	757		PORT OF MORROW	#2	OB		48						A		3						
04N/25E-10BDC	MORR	753		PORT OF MORROW	CES 10-22	OB		40				x	x	A		4						

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/25E-10BDD	MORR	752		PORT OF MORROW	#1	OB		685						B					6	6		5
04N/25E-10CCB	MORR	755		PRICHARD	Well 2	IR		652						B				6	6	5		5
04N/25E-10DCB	MORR	748		KEITH TALLMAN & SONS		IR		210						B					3			
04N/25E-11ABB	MORR	761		PORT OF MORROW	CES ref. well 12	OB		60						A		3						
04N/25E-11BAA	MORR	762		TATONE	Rental House Well	DO		44						A		3						
04N/25E-11BAC	MORR	766		UMATILLA READY MIX	CES 11-13	IM		197						B					5			
04N/25E-11BCA	MORR	768		PORT OF MORROW	CES 5	OB		210						B					5			
04N/25E-11BCD	MORR	765		PORT OF MORROW	CES ref. well 8	OB		160						B	6			6	5			
04N/25E-11CDC	MORR	767		PORT OF MORROW	CES 6	OB		142						B					5			
04N/25E-11DCB	MORR	759		PORT OF MORROW	MW-6	MO		5				x	x	A		1						
04N/25E-11DCC	MORR	764		PORT OF MORROW	CES ref. well 9	OB		304						B						5		
04N/25E-11DDC	MORR	763		PORT OF MORROW	CES ref. well 10	OB		305						B					5	5		
04N/25E-12BBB	MORR	772	177	PORT OF MORROW	Farm Well #2	OB		88						A		3						
04N/25E-12BBC	MORR	769		PORT OF MORROW	Farm Well 1	OB		71				x	x	A		3						
04N/25E-12CAA	MORR	770		PORT OF MORROW	MW-3	MO		34				x	x	A		1						
04N/25E-12DBD	MORR	771		PORT OF MORROW	CES 4	OB		45						A		4						
04N/25E-13ADA	MORR	776		HILLVIEW DAIRY	#4	IR		555						B						5		5
04N/25E-13BCC	MORR	773	85	REEL		DO		74				x	x	A		4						
04N/25E-14BAA	MORR	795		FREDERICKSON	POM 14-2	DO		150						B					5			
04N/25E-14BCB	MORR	800		GEORGE SICARD & SON		IR		382						B		6		6	5	6		
04N/25E-14CCA	MORR	688		CALL		DO		105				x	x	B					5			
04N/25E-14CCC	MORR	790	3	NICHOLES		DO		104				x	x	B					5			
04N/25E-14CDD	MORR	668		CARLSON	POM 14-1	IR		145						B					3			
04N/25E-15ADD	MORR	793		J & B ELECTRIC	POM 15-2	DO		265						B					5	5		
04N/25E-16ADB	MORR	823	28	MOEN		DO		103				x	x	B					5			
04N/25E-17CBA	MORR	711		SHOEMAKE		DO		110				x	x	B					5			
04N/25E-17CDC	MORR	838		DESERT SPRINGS ESTATE	Well 1	DO		430						B					5	5		
04N/25E-17CDD	MORR	837		DESERT SPRINGS ESTATE	Well 2	DO		195						B					5			
04N/25E-20AAB	MORR	873	29	ALFRED		DO		100				x	x	B					5			
04N/25E-22ABB	MORR	904		WILLOW RUN GOLF COURSE	POM 22-1	DO		84						B					5			
04N/25E-22BBD	MORR	1563		PORT OF MORROW	MW-12 Carlson Site	MO		41				x	x	A				2				
04N/25E-22DCC	MORR	1557		PORT OF MORROW	MW-17 Carlson Site	MO		63				x	x	A				2				
04N/25E-23AAA	MORR	1561		PORT OF MORROW	MW-14 Carlson Site	MO		63				x	x	A				2				
04N/25E-23BBB	MORR	1556		PORT OF MORROW	MW-13 Carlson Site	MO		58				x	x	A				2				
04N/25E-23CDD	MORR	1560		PORT OF MORROW	MW-16 Carlson Site	MO		103				x	x	A				2				
04N/25E-24AAA	MORR	1562		PORT OF MORROW	MW-18 Carlson Site	MO		60				x	x	A				2				
04N/25E-24DDD	MORR	1559		PORT OF MORROW	MW-15 Carlson Site	MO		90				x	x	A				2				
04N/26E-01ABA	LUB	142		DEPARTMENT OF THE ARMY	45	MO		49					x	A				1				
04N/26E-01ACC	LUB	143		DEPARTMENT OF THE ARMY	46	MO		46					x	A			1					
04N/26E-01ADA	LUB	167		DEPARTMENT OF THE ARMY	31	MO		61					x	A			1					
04N/26E-01ADA	LUB	185		DEPARTMENT OF THE ARMY	SB-4	MO		75					x	A				1				
04N/26E-01ADC	LUB	141		DEPARTMENT OF THE ARMY	41-1	MO		69					x	A				1				
04N/26E-01DAA	LUB	114		DEPARTMENT OF THE ARMY	19-1	MO		83					x	A			1					
04N/26E-01DAA	LUB	116		DEPARTMENT OF THE ARMY	19-3	MO		81					x	A			1					
04N/26E-01DAB	LUB	179		DEPARTMENT OF THE ARMY	42	MO		73					x	A			1					
04N/26E-01DAD	LUB	153		DEPARTMENT OF THE ARMY	57-5	MO		76					x	A			1					
04N/26E-01DCB	LUB	85		DEPARTMENT OF THE ARMY	2	MO		76					x	A			1					
04N/26E-01DDB	LUB	107		DEPARTMENT OF THE ARMY	15-1	MO		82					x	A			1					
04N/26E-01DDC	LUB	108		DEPARTMENT OF THE ARMY	15-2	MO		89					x	A			1					
04N/26E-04BAB	MORR	914		WESTERN EMPIRE		UN		123						A		4						
04N/26E-04BAC	MORR	917	159	DESERT MAGIC INC		IR		92						A		3						

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/26E-05ABB	MORR	918		DESERT MAGIC INC		IR		148						A		3						
04N/26E-06ACC	MORR	681		PORT OF MORROW	MW-4, CES 6-1	MO		103				x	x	A		1						
04N/26E-06ADD	MORR	689		PORT OF MORROW	MW-2	MO		98				x	x	A		1		5				
04N/26E-06BBB	MORR	1550		PORT OF MORROW	MW-8	MO		82				x	x	A		1						
04N/26E-07AAC	MORR	921		WESTERN EMPIRE	Baker Well, POM ref. well 1.	UN		72						A		4		5				
04N/26E-07BBB	MORR	1549		PORT OF MORROW	MW-7	MO		84.5				x	x	A		1		1				
04N/26E-07DCA	MORR	920		JASA	POM ref. well 2	DO		150						B					5			
04N/26E-12AAC	LUB	121		DEPARTMENT OF THE ARMY	38-2	MO		87					x	A			1					
04N/26E-12ABA	LUB	149		DEPARTMENT OF THE ARMY	57-1	MO		86					x	A			1					
04N/26E-12ABD	LUB	120		DEPARTMENT OF THE ARMY	38-1	MO		75					x	A			1					
04N/26E-12ACB	LUB	122		DEPARTMENT OF THE ARMY	38-3	MO		101					x	A			1					
04N/26E-12ACC	LUB	86		DEPARTMENT OF THE ARMY	3	MO		94					x	A			1					
04N/26E-12ACC	LUB	176		DEPARTMENT OF THE ARMY	3R	MO		82					x	A			1					
04N/26E-12ADD	LUB	109		DEPARTMENT OF THE ARMY	16-1	MO		104					x	A			1					
04N/26E-12ADD	LUB	110		DEPARTMENT OF THE ARMY	16-2	MO		108					x	A			1					
04N/26E-12DBD	LUB	123		DEPARTMENT OF THE ARMY	38-4	MO		80					x	A			1					
04N/26E-12DDD	LUB	150		DEPARTMENT OF THE ARMY	57-2	MO		96					x	A			1					
04N/26E-13AAD	LUB	152		DEPARTMENT OF THE ARMY	57-4	MO		86					x	A			1					
04N/26E-15DBD	MORR	925		COMINCO AMERICAN		DO		250						B	6			6	5	5		
04N/26E-16DAA	LUB	12		EASTERN OREGON FARMS		IM		256						B						5		
04N/26E-17ADD	MORR	930		EASTERN OREGON FARMING CO		IR		52				x	x	A		3						
04N/26E-21DDD	MORR	932		EASTERN OREGON FARMING CO		DO		341						B	6			6	5			
04N/27E-01AAA	UMAT	1523		LAMB WESTON	MW-4 Original Site	MO		180				x	x	A			2					
04N/27E-01CBC	LUB	98		DEPARTMENT OF THE ARMY	11-4	MO		140					x	A			1					
04N/27E-01DBB1	UMAT	1524		LAMB WESTON	MW-3 Original Site	MO		180				x	x	A			2					
04N/27E-01DBB2	LUB	19		LAMB WESTON	MW-10 Original Site	MO		105				x	x	A	1							
04N/27E-01DCC	UMAT	1525		LAMB WESTON	MW-2 Original Site	MO		142				x	x	A			2					
04N/27E-02DCA	LUB	95		DEPARTMENT OF THE ARMY	11-1	MO		169					x	A			1					
04N/27E-02DCD	LUB	170		DEPARTMENT OF THE ARMY	34	MO		170					x	A			1					
04N/27E-02DCD	LUB	171		DEPARTMENT OF THE ARMY	35	MO		168					x	A			1					
04N/27E-02DDC	LUB	99		DEPARTMENT OF THE ARMY	11-5	MO		165					x	A			1					
04N/27E-02DDC	LUB	172		DEPARTMENT OF THE ARMY	36	MO		168					x	A			1					
04N/27E-04CCB	LUB	87		DEPARTMENT OF THE ARMY	4	MO		170					x	A			1					
04N/27E-05ABA	UMAT	1527		DEPARTMENT OF THE ARMY	Water Supply #6	IM		710				x	x	B	6			6	5			5
04N/27E-05BAA	UMAT	1526		DEPARTMENT OF THE ARMY	Water Supply # 7 (new); old 5	DO		682				x	x	B	6			6	6	5		5
04N/27E-06BBA	LUB	84		DEPARTMENT OF THE ARMY	1	MO		68.5					x	A			1					
04N/27E-06BBC	LUB	180		DEPARTMENT OF THE ARMY	43	MO		73					x	A				1				
04N/27E-06BCC	LUB	115		DEPARTMENT OF THE ARMY	19-2	MO		84					x	A				1				
04N/27E-06CBC	LUB	112		DEPARTMENT OF THE ARMY	18-1	MO		87					x	A			1					
04N/27E-06CCB	LUB	113		DEPARTMENT OF THE ARMY	18-2	MO		91					x	A			1					
04N/27E-07BAC	LUB	181		DEPARTMENT OF THE ARMY	44	MO		129.5					x	A			1					
04N/27E-07BBB	LUB	154		DEPARTMENT OF THE ARMY	59-1	MO		105					x	A			1					
04N/27E-07BBC	LUB	155		DEPARTMENT OF THE ARMY	59-2	MO		115					x	A			1					
04N/27E-07BCA	LUB	111		DEPARTMENT OF THE ARMY	16-3	MO		112					x	A			1					
04N/27E-07CBD	LUB	118		DEPARTMENT OF THE ARMY	31-2	MO		96					x	A			1					
04N/27E-07CCA	LUB	119		DEPARTMENT OF THE ARMY	31-3	MO		97					x	A			1					
04N/27E-07CCB	LUB	117		DEPARTMENT OF THE ARMY	31-1	MO		94					x	A			1					
04N/27E-07CCC	LUB	151		DEPARTMENT OF THE ARMY	57-3	MO		99					x	A			1					
04N/27E-07CCD	LUB	168		DEPARTMENT OF THE ARMY	32	MO		105.5					x	A			1					
04N/27E-08DAC	LUB	88		DEPARTMENT OF THE ARMY	5	MO		140					x	A			1					
04N/27E-08DAD	UMAT	1531		DEPARTMENT OF THE ARMY	Water Supply #3	FP		453				x	x	B	6			6	5	5		5

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/27E-09DDC	LUB	130		DEPARTMENT OF THE ARMY	4-16	MO		115					x	A			1					
04N/27E-11AAA	LUB	169		DEPARTMENT OF THE ARMY	33	MO		173					x	A			1					
04N/27E-11ADB	LUB	96		DEPARTMENT OF THE ARMY	11-2	MO		151					x	A			1					
04N/27E-11BAC	LUB	100		DEPARTMENT OF THE ARMY	11-6	MO		166					x	A			1					
04N/27E-12ADA	UMAT	1536	198	LAMB WESTON	MW-1 Original Site	MO		110				x	x	A			2	5				
04N/27E-12BBB	LUB	97		DEPARTMENT OF THE ARMY	11-3	MO		123					x	A			1					
04N/27E-13AAC	UMAT	1540		HUDDLESTON			AB	101					x	A		3						
04N/27E-13CDD	LUB	94		DEPARTMENT OF THE ARMY	11	MO		103		x			x	A		1						
04N/27E-13DBC	UMAT	1542		SKINNER		IR		97				x	x	A		3						
04N/27E-13DDD	UMAT	1539	136	SKINNER		DO		111						A		4						
04N/27E-15	UMAT	5860		DEPARTMENT OF THE ARMY	4-19	MO		168					x	B					1			
04N/27E-15	UMAT	5859		DEPARTMENT OF THE ARMY	4-20	MO		218					x	B					1			
04N/27E-15	UMAT	5858		DEPARTMENT OF THE ARMY	4-21	MO		215					x	B					1			
04N/27E-15	UMAT	5857		DEPARTMENT OF THE ARMY	4-22	MO		119					x	B					1			
04N/27E-15	UMAT	5855		DEPARTMENT OF THE ARMY	4-24	MO		113.5					x	A		1						
04N/27E-15BCA	LUB	89		DEPARTMENT OF THE ARMY	6	MO		70					x	A		1						
04N/27E-15BCC	LUB	90		DEPARTMENT OF THE ARMY	7	MO		106					x	A		1						
04N/27E-15BCD	LUB	124		DEPARTMENT OF THE ARMY	4-1	MO		97	x				x	A		1						
04N/27E-15BCD	LUB	128		DEPARTMENT OF THE ARMY	4-14	MO		91					x	A		2						
04N/27E-15BCD	LUB	132		DEPARTMENT OF THE ARMY	4-18	MO		73	x				x	A		1						
04N/27E-15BCD	LUB	139		DEPARTMENT OF THE ARMY	4-8	MO		285	x				x	B						1		
04N/27E-15BCD	LUB	165		DEPARTMENT OF THE ARMY	29	MO		80.5		x			x	A		1						
04N/27E-15BCD	LUB	182		DEPARTMENT OF THE ARMY	SB-1	MO		135					x	A				2				
04N/27E-15BCD	LUB	189		DEPARTMENT OF THE ARMY	24	MO							x									
04N/27E-15BCD	LUB	190		DEPARTMENT OF THE ARMY	25	MO							x									
04N/27E-15BD	LUB	92		DEPARTMENT OF THE ARMY	9	MO		90					x	A		1						
04N/27E-15BD	LUB	126		DEPARTMENT OF THE ARMY	4-12	MO		97					x	A		2						
04N/27E-15BD	LUB	133		DEPARTMENT OF THE ARMY	4-2	MO		80					x	A		1						
04N/27E-15BD	LUB	144		DEPARTMENT OF THE ARMY	47-1	MO		133					x	A		1						
04N/27E-15BD	LUB	145		DEPARTMENT OF THE ARMY	47-2	MO		131.5					x	A		1						
04N/27E-15BD	LUB	146		DEPARTMENT OF THE ARMY	47-3	MO		128					x	A		1						
04N/27E-15BD	LUB	147		DEPARTMENT OF THE ARMY	47-4	MO		128					x	A		1						
04N/27E-15BD	LUB	156		DEPARTMENT OF THE ARMY	67-1	MO		137					x	A		1						
04N/27E-15BD	LUB	188		DEPARTMENT OF THE ARMY	23	MO							x									
04N/27E-15CA	LUB	127		DEPARTMENT OF THE ARMY	4-13	MO		149.5	x				x	A		2						
04N/27E-15CA	LUB	138		DEPARTMENT OF THE ARMY	4-7	MO		117					x	A		1						
04N/27E-15CA	LUB	140		DEPARTMENT OF THE ARMY	4-9	MO		360	x				x	B						1		
04N/27E-15CA	LUB	164		DEPARTMENT OF THE ARMY	28	MO		136					x	A		1						
04N/27E-15CA	LUB	184		DEPARTMENT OF THE ARMY	SB-3	MO		184					x	A				2				
04N/27E-15CA	LUB	186		DEPARTMENT OF THE ARMY	21	MO							x									
04N/27E-15CB	LUB	91		DEPARTMENT OF THE ARMY	8	MO		34					x	A		1						
04N/27E-15CB	LUB	125		DEPARTMENT OF THE ARMY	4-10	MO		265	x				x	B						1		
04N/27E-15CB	LUB	129		DEPARTMENT OF THE ARMY	4-15	MO		86					x	A		2						
04N/27E-15CB	LUB	131		DEPARTMENT OF THE ARMY	4-17	MO		231	x				x	B						1		
04N/27E-15CB	LUB	162		DEPARTMENT OF THE ARMY	26	MO		60.5					x	A		1						
04N/27E-15CB	LUB	163		DEPARTMENT OF THE ARMY	27	MO		65					x	A		1						
04N/27E-15CB	LUB	166		DEPARTMENT OF THE ARMY	30	MO		60.5					x	A		1						
04N/27E-15CB	LUB	183		DEPARTMENT OF THE ARMY	SB-2	MO		78					x	A				2				
04N/27E-15CB	LUB	187		DEPARTMENT OF THE ARMY	22	MO							x									
04N/27E-15CC	LUB	134		DEPARTMENT OF THE ARMY	4-3	MO		58		x			x	A		1						
04N/27E-15DB	LUB	135		DEPARTMENT OF THE ARMY	4-4	MO		122					x	A		1						

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer			Basalt Aquifers				
															UF	UC	CF	BF	EM	PO	UM	UN
04N/27E-15DB	LUB	137		DEPARTMENT OF THE ARMY	4-6	MO		122		x			x	A		1						
04N/27E-15DC	LUB	136		DEPARTMENT OF THE ARMY	4-5	MO		118					x	A		1						
04N/27E-18CDB	MORR	667		DEPARTMENT OF THE ARMY	Water Supply #5	FP		618				x	x	B	6			6	6	6		5
04N/27E-19AB	LUB	191		DEPARTMENT OF THE ARMY	69-1	MO		83					x									
04N/27E-19ABB	MORR	938		DEPARTMENT OF THE ARMY	Water Supply #4	FP		581					x	B	6			6	6	6		5
04N/27E-19CCB	MORR	937		RUDDELL		IR		112				x	x	A		3						
04N/27E-20CBC	MORR	947		UNION PACIFIC RAIL ROAD		IM		457					x	B		6		5		5		5
04N/27E-20CCC	MORR	946	168	BRAAT		DO		173				x	x	A		3						
04N/27E-20DCA	MORR	942		DIEHL		DO		157						A		4						
04N/27E-21DA	LUB	103		DEPARTMENT OF THE ARMY	12-3	MO		110					x	A		1						
04N/27E-21DD	LUB	93		DEPARTMENT OF THE ARMY	10	MO		80		x			x	A		1						
04N/27E-21DD	LUB	105		DEPARTMENT OF THE ARMY	12-5	MO		100					x	A		1						
04N/27E-21DD	LUB	148		DEPARTMENT OF THE ARMY	50-1	MO		77					x	A		1						
04N/27E-22BA	UMAT	5856		DEPARTMENT OF THE ARMY	4-23	MO		111					x	A		1						
04N/27E-22BC	LUB	101		DEPARTMENT OF THE ARMY	12-1	MO		111					x	A		1						
04N/27E-22BD	LUB	161		DEPARTMENT OF THE ARMY	D	MO							x									
04N/27E-22CA	LUB	192		DEPARTMENT OF THE ARMY	70-1	MO		106.5					x	A		1						
04N/27E-22CA	LUB	194		DEPARTMENT OF THE ARMY	77-1	MO		105					x	A		1						
04N/27E-22CB	LUB	102		DEPARTMENT OF THE ARMY	12-2	MO		109					x	A		1						
04N/27E-22CB	LUB	104		DEPARTMENT OF THE ARMY	12-4	MO		104.5					x	A		1						
04N/27E-22CB	LUB	174		DEPARTMENT OF THE ARMY	38	MO		128					x	A		1						
04N/27E-22CB	LUB	177		DEPARTMENT OF THE ARMY	40	MO		112.5					x	A		1						
04N/27E-22CB	LUB	178		DEPARTMENT OF THE ARMY	41	MO		112					x	A		1						
04N/27E-22CC	LUB	106		DEPARTMENT OF THE ARMY	12-6	MO		97					x	A		1						
04N/27E-22CC	LUB	173		DEPARTMENT OF THE ARMY	37	MO		99					x	A		1						
04N/27E-22CC	LUB	175		DEPARTMENT OF THE ARMY	39	MO		110					x	A		1						
04N/27E-22CD	LUB	160		DEPARTMENT OF THE ARMY	C	MO							x									
04N/27E-22CDA	UMAT	1544		DEPARTMENT OF THE ARMY	Water Supply #1	UN		327				x	x	B	6			5	5	5		
04N/27E-22DB	LUB	193		DEPARTMENT OF THE ARMY	70-2	MO		106					x	A		1						
04N/27E-22DBD	UMAT	1543		DEPARTMENT OF THE ARMY	Water Supply #2	DO		360				x	x	B	6			6	5	5		
04N/27E-24ABD	UMAT	1546		JACKSON		IR		154					x	A		3						
04N/27E-24ACD	UMAT	1547		WEBB		AB		125					x	A		3		5				
04N/27E-25DAB1	UMAT	1557		JOHNSON		DO		191.5					x	B			6	6	5			
04N/27E-25DAB2	UMAT	1552	181	JOHNSON		IR		89				x	x	A			3					
04N/27E-26BCB1	UMAT	1568		HANSELL BROTHERS INC		IR		108				x	x	A		3						
04N/27E-26BCB2	UMAT	1560	182	NORTHERN PACIFIC RAILWAY		IR		105				x	x	A		3						
04N/27E-26BD	LUB	159		DEPARTMENT OF THE ARMY	B	MO							x									
04N/27E-27AB	LUB	157		DEPARTMENT OF THE ARMY	A1	MO							x									
04N/27E-27AB	LUB	158		DEPARTMENT OF THE ARMY	A2	MO							x									
04N/27E-27BCD	UMAT	1566	183	HANSELL BROTHERS INC		IR		121				x	x	A		3						
04N/27E-27BCD	UMAT	1565		HANSELL BROS INC		IR		127				x	x	A		3						
04N/27E-27BDA	UMAT	1569		HANSELL BROTHERS INC		IR		109					x	A		3						
04N/27E-27CBA	UMAT	1570		HANSELL BROTHERS INC		IR		135					x	A		4						
04N/27E-27CBC	MORR	955		BRAATT		IR		110		x			x	A		3						
04N/27E-27DAD	UMAT	1574	127	HANSELL		IR		547					x	B			6	6		6		5
04N/27E-27DAD1	UMAT	1572		HENSELL BROTHERS INC		IR		140				x	x	A		3						
04N/27E-28ACD	MORR	957		BRAAT		IR		161					x	A		3						
04N/27E-28BBA	MORR	951		AYLETT		IR		110					x	A		3						
04N/27E-28BDB	MORR	960		CHAPMAN		IR		119				x	x	A		4						
04N/27E-28CBD	LUB	2		AYLETT		UN		107				x	x	A		4						
04N/27E-28DCC	MORR	953		AYLETT		IR		124				x	x	A		3		5				

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/27E-28DCD	MORR	956		BRAAT		IR		127				x	x	A		3						
04N/27E-30AAC	MORR	968		RUDDELL		IR		85					x	A		3						
04N/27E-30BBD	MORR	966		RUDDELL		IR		79				x	x	A		3						
04N/27E-30CAA	MORR	1484		STARR-WOOD FARMS		IR		136								3						
04N/27E-30CAC	MORR	961		STARR-WOOD FARMS		IR		92				x	x	A		3						
04N/27E-30CCA	MORR	967		RUDDELL		IR		118				x	x	A		3						
04N/27E-30CDB	MORR	965		RUDDELL		IR		115					x	A		3						
04N/27E-30DDD1	MORR	964		MRS BERNICE KEY & SONS		IR		115				x	x	A		3						
04N/27E-30DDD2	MORR	962	184	KEY		IR		120				x	x	A		3						
04N/27E-30DDD3	MORR	963		KEY			UN	120	x	x		x	x	A		3						
04N/27E-31AAB	MORR	969		ANDREWS		UN		200				x	x	BA		3		3	5			
04N/27E-32AAB	MORR	973		HOZOPFEL		IR		106				x	x	A		3						
04N/27E-32ABA	MORR	974		GEORGIA BELLE HOZOPFEL		IR		104					x	A		3						
04N/27E-32ACA	MORR	975		GEORGIA BELL HALZAPFEL		IR		123					x	A		4						
04N/27E-32BAA	MORR	971		HOZOPFEL		IR		111				x	x	A		3						
04N/27E-32DAC	MORR	976		GEORIA BELLE HOLSAPFEL	Holzapfel #2		AB	310					x	B		6		6	5	5		
04N/27E-32DBB	MORR	970		CARROLL	House well	DO		300					x	B					5			
04N/27E-33ABD	MORR	981		MC DOLE		IR		120					x	A		3		4				
04N/27E-33ACD	MORR	987		MC DOLE		IR		96					x	A		4						
04N/27E-33CBA2	MORR	984		MC DOLE		IR		96					x	A		3						
04N/27E-33DBD	MORR	983		BRAAT		IR		113					x	A			3					
04N/27E-34BBC	UMAT	1577		MC DOLE			AB	97					x	A			3					
04N/27E-36AAB	UMAT	1579		INGRAM		IR		112				x	x	A			3	5				
04N/27E-36ADC	UMAT	1581		HULIT		IR		185					x	B				5	5			
04N/27E-36BBA	UMAT	1584		HANSELL	Redwine well 2. Also MORR 936.	IR		812						BA			6	5	5	5		5
04N/27E-36BDB	UMAT	1806		HANSELL	Redwine well 1. Also MORR 935.	IR		194					x	B			6	5	5			
04N/28E-01ACB	UMAT	1673	105	SCHNEIDER	Angell well.	DO		129						A		4						
04N/28E-01BAD	UMAT	1688		ALEX		ID		335						B						5	5	
04N/28E-01BBA	UMAT	1675		MEDELEZ	Issell well.	DO		155					x	A		4						
04N/28E-01CBC	UMAT	1671		BRYANT		ID		225						B						5		
04N/28E-01DCC	UMAT	5545	105	FAITH CHURCH OF GOD		DO		62						A		4						
04N/28E-01DDD	UMAT	1710	74	KANE		DO		51				x	x	A		1						
04N/28E-03ADC	UMAT	1752		FRAZIER		DO		75				x	x	A			4					
04N/28E-03BAC	UMAT	1776		DACK		DO		55						A			3					
04N/28E-03BAD	UMAT	1779	68	BROWN		DO		51						A		4						
04N/28E-03BCC	UMAT	1775	126	WALKER	Johnson well.	DO		339						B						5	5	
04N/28E-03DBA	UMAT	1772		CITY OF HERMISTON			AB	130				x	x	A		1						
04N/28E-03DBA	UMAT	1771		CITY OF HERMISTON	WELL #5	MU		103						A		3						
04N/28E-04ACD	UMAT	1810		AGNW INC		DO		202						B						5		
04N/28E-06ABA	UMAT	5365		LAMB WESTON	MW-5 Original Site	MO		152				x	x	A			2	2				
04N/28E-06ACD1	UMAT	5364		LAMB WESTON	MW-6 Original Site	MO		100				x	x	A			2	2				
04N/28E-06ACD2	UMAT	1854		LAMB WESTON	MW-8 Original Site	MO		30				x	x	A	1							
04N/28E-06CCC	UMAT	5363		LAMB WESTON	MW-7 Original Site	MO		110				x	x	A				2				
04N/28E-06CCD	UMAT	1855		LAMB WESTON	MW-9 Original Site	MO		40				x	x	A	1							
04N/28E-07AAA	UMAT	1867	138	REUTER	Reuter #1	DO		135						BA			6	5	5			
04N/28E-07ACC	UMAT	1875	140	WADEKAMPER		DO		286						BA			6	3	5	5		
04N/28E-07CDD	UMAT	1863		KETCHERSID	Olson well.	DO		283						B					5	3		
04N/28E-08CBC	UMAT	1864		LEWIS		DO		323						B			6	6	6	3		3
04N/28E-08CDA	UMAT	1953		RUHL		DO		135						A			6	5				
04N/28E-08DCB	UMAT	1959		KING	Well #1	ID		265						BA			6	5		5		
04N/28E-08DDB	UMAT	5589		RANDOL		DO		250			x			B						5		

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/28E-08DDD	UMAT	1958		BUSH	Rosenbaum well.	ID		215						B						5		
04N/28E-09CCB	UMAT	1992		MOLLENAK	Rogers well.	DO		200						B						5		
04N/28E-09DBD	UMAT	1974		CHURCH OF THE NAZARENE		DO		225				x	x	B			6	6		5		
04N/28E-10BAD	UMAT	2048		CITY OF HERMISTON	E. BASE OF HERM BUTTES	IR		160						B			6				5	
04N/28E-10CBC	UMAT	2019		CITY OF HERMISTON	CITY PARK WELL	IR		285						B			6			6		5
04N/28E-10CCA	UMAT	2015		HERMISTON GOOD SAM.CENTER		IR		225						B						5		
04N/28E-10CCB	UMAT	2045		HERMISTON SCHOOL DIST. #8		IR		597						BA		6		8		5	5	5
04N/28E-10CDD	UMAT	2049		CITY OF HERMISTON	WELL #1, MCMAY WELL	MU		500						B							5	5
04N/28E-10DBC	UMAT	2028	72	HELMS		DO		50				x	x	A			4					
04N/28E-11ACD	UMAT	2067		FOWLER		UN		110				x	x	B				6		5		
04N/28E-11ADD	UMAT	2068	76	WILLARD		DO		56				x	x	A		6		5				
04N/28E-11BAB	UMAT	2061		CITY OF HERMISTON	WELL #4	MU		1041						B								5
04N/28E-11CAC	UMAT	2077		CITY OF HERMISTON	#2 OLD, NEWPORT WELL	MO		1206						B		6					5	5
04N/28E-11CAC	UMAT	5735		CITY OF HERMISTON	#2 NEW, INJECTION WELL	IN		1206						B						3	6	5
04N/28E-11CCD	UMAT	2075		CITY OF HERMISTON	WELL #3, THIRD STREET WELL	MU		962						B						5	5	5
04N/28E-11DDA	UMAT	2055		HERMISTON SCHOOL DIST. 8R		IR		670						B						3	3	3
04N/28E-12BAD	UMAT	5546		HERMISTON BASEBALL COM.		DO		80				x	x	B						5		
04N/28E-12DDC	UMAT	2103		HERSHBERGER		IR		212						B						5		
04N/28E-13BAB	UMAT	2143		SAUNDERS		IM		92				x	x	A			5	5				
04N/28E-13CCC	UMAT	2130		ABLE		DO		120				x	x	A			4					
04N/28E-14CBC	UMAT	2151		RANKIN		DO		145				x	x	A			3					
04N/28E-14CDA	UMAT	2167		HERMISTON CEMETERY DIST. 8		IR		680						B						5	5	5
04N/28E-15BBC	UMAT	2188	70	GIANAKOPOULOS		DO		61				x	x	A			4					
04N/28E-15CBD	UMAT	5342		GRACE BAKER		DO		324				x	x	B						6		3
04N/28E-16CDA	UMAT	2286		SACH MIKAMI	New well.	IR		300						B			6	6		5		
04N/28E-16DDD	UMAT	2307	69	STEWART		DO		53				x	x	A			4					
04N/28E-17ABD	UMAT	2335		BOB GETTLE NURSERY		ID		225						B						5		
04N/28E-17BBC	UMAT	2317		BISCHKE		DO		123						B					3			
04N/28E-17CBB	UMAT	2338		GASS	New well	DO		125				x	x	A		3						
04N/28E-17CBC	UMAT	2331	78	HUSTON	Huffman well.	DO		97						A		4						
04N/28E-18BBA	UMAT	2373	63	MOLTMAN		DO		78						A			4					
04N/28E-18BCD	UMAT	2382		HUDDLESTON		IR		93				x	x	A		3		5				
04N/28E-18DBD	UMAT	2380		WALKER		IR		102					x	A		3						
04N/28E-19ADA	UMAT	2394		SWEEK	Earl well.	DO		400						B						5	5	5
04N/28E-19ADD	UMAT	2391	92	MARSH		DO		79						A		4						
04N/28E-19BCD	UMAT	2406		SKINNER		IR		126				x	x	A		3						
04N/28E-19CAA	UMAT	2403		LAMB WESTON		IM		130						AB		3		3	3			
04N/28E-19CAC	UMAT	2402		LAMB WESTON		IM		137					x	A		3		4				
04N/28E-19CAD	UMAT	2405		MARTIN	Martin well #1	IM		99					x	A		3						
04N/28E-19DBC	UMAT	5612		BLOOM		DO		75			x			A			4	5				
04N/28E-20BBC	UMAT	2414		POLLOCK & SON		IR		66				x	x	A		4						
04N/28E-20DAA	UMAT	2424	73	CHALLIS	Earl well.	DO		70						A		4						
04N/28E-21ABD	UMAT	5585		RODARTE		DO		115			x			A			3					
04N/28E-21CAA	UMAT	3380		SPINDEN		DO		80				x	x	A		4						
04N/28E-21CBC	UMAT	2477		UNION PACIFIC RAILROAD	Kamerrer well.	UN	UN	347						A		3						
04N/28E-22DBB	UMAT	2500		C & B LIVESTOCK INC	Well #3	IR		560						BA		6		5		5	5	5
04N/28E-23ACA	UMAT	2507		COOK	#3	IR		1180						B						5	5	5
04N/28E-23BDB	UMAT	2510	93	OREGON STATE UNIVERSITY		IR		875						B						5	5	5
04N/28E-23CBA	UMAT	2508		MIKAMI BROTHERS		IR		370						BA			6	5		5	5	
04N/28E-23DCA	UMAT	2509		CIRCLE C RANCHES	POD #1	IR		317						BA				5		5		
04N/28E-24ADA	UMAT	2515		CIRCLE C RANCHES	POD #4	IR		1145						B							5	5

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/28E-24BAA	UMAT	2524		ALBERT		DO		125				x	x	A			5					
04N/28E-24BBC	UMAT	2517		ELIASON		IM		250				x	x	B						5		
04N/28E-24BDC	UMAT	5450		CITY OF HERMISTON	WELL #6, NORPAC WELL	MU		1500						B								5
04N/28E-24DCA	UMAT	2519		CIRCLE C RANCHES	POD #2	IR		1137						B								5
04N/28E-26CCA	LUB	49		J.R. SIMPLOT CO	MW-16	MO		19				x	x	A	1							
04N/28E-26DCC	UMAT	2562		J.R. SIMPLOT CO	WELL 4	OB		1042													6	3
04N/28E-26DCC	UMAT	2561		J.R. SIMPLOT CO	WELL 6	OB		985						B								5
04N/28E-27AAB	UMAT	2585		J.R. SIMPLOT CO	UNION PACIFIC HINKLE WELL 2	IM		569						B							5	5
04N/28E-27BAB	UMAT	2575		C & B LIVESTOCK CO	#1; Gravel well	IR	AB	165						A			4					
04N/28E-27BAC	UMAT	2573		C & B LIVESTOCK CO	#2	IR		630						B								5
04N/28E-27BBC	UMAT	2580		J.R. SIMPLOT CO	Well 2	OB	AB	196									3					
04N/28E-27BCB	UMAT	2583		J.R. SIMPLOT CO	Well 1	OB		212						A			3					
04N/28E-27BCB	UMAT	2578		J.R. SIMPLOT CO	Well 3	OB		230					x	A			3					
04N/28E-27CC	LUB	79		J.R. SIMPLOT CO	MW-10R-S	MO							x	A	1							
04N/28E-27CC	LUB	80		J.R. SIMPLOT CO	MW-10R-D	MO							x	A			2					
04N/28E-27CCA	LUB	40		J.R. SIMPLOT CO	MW-10S	MO	AB	130				x	x	A	1							
04N/28E-27CCA	LUB	41		J.R. SIMPLOT CO	MW-10D	MO	AB	200				x	x	A			2					
04N/28E-27CCC	LUB	81		J.R. SIMPLOT CO	Parking Lot	OB							x	A								
04N/28E-27CDC	UMAT	2584		J.R. SIMPLOT CO	2A		AB	295						A			6	5				
04N/28E-27CDD	LUB	44		J.R. SIMPLOT CO	MW-12	MO		85				x	x	A	1							
04N/28E-27DCA	LUB	54		J.R. SIMPLOT CO	MW-21	MO		20				x	x	A	1							
04N/28E-27DDA	LUB	78		J.R. SIMPLOT CO	MW-45	MO		17.5					x	A	1							
04N/28E-27DDB	LUB	53		J.R. SIMPLOT CO	MW-20	MO		20				x	x	A	1							
04N/28E-27DDC	LUB	52		J.R. SIMPLOT CO	MW-19	MO		20				x	x	A	1							
04N/28E-27DDD	LUB	51		J.R. SIMPLOT CO	MW-18	MO		20				x	x	A	1							
04N/28E-28ABB	UMAT	2591	81	BLANC		DO		118				x	x	A		3						
04N/28E-28ACD	UMAT	2594		BUD RICH POTATO, INC	Betz well.	IM		750						BA			6	5		3		5
04N/28E-28DAB	LUB	42		J.R. SIMPLOT CO	MW-11S	MO		135				x	x	A	1							
04N/28E-28DAB	LUB	43		J.R. SIMPLOT CO	MW-11D	MO		200				x	x	A			2					
04N/28E-28DBC	UMAT	5593		J. R. SIMPLOT		IM		209			x			A		3		5				
04N/28E-28DCB	UMAT	2592		J.R. SIMPLOT CO	1A, WOODS WELL 2	OB		190						A			3	5				
04N/28E-28DCC	LUB	83		J.R. SIMPLOT CO	WOODS WELL 1	OB							x	A								
04N/28E-28DDC	LUB	45		J.R. SIMPLOT CO	MW-13S	MO		126				x	x	A	1							
04N/28E-28DDC	LUB	46		J.R. SIMPLOT CO	MW-13D	MO		178				x	x	A			2					
04N/28E-29BCC	UMAT	5763		UNIVERSAL FOODS	MW-2	MO		41.5					x	A	1							
04N/28E-29CAD	UMAT	5761		UNIVERSAL FOODS	MW-3	MO		55					x	A	1							
04N/28E-30BAD	UMAT	2601		LAMB-WESTON INC		IM		98				x	x	A		3		5				
04N/28E-30DDD	UMAT	2603		REID	Anderson well.	IR		721						B						5		5
04N/28E-31ACA	UMAT	2609		COX		IR		400						BA			3	3	5			5
04N/28E-31CBB	UMAT	2606	79	NOBLE		DO		150						B					5			
04N/28E-31CDD	UMAT	2607	165	CURTIS		DO		204						BA				5	5			
04N/28E-32ACB	UMAT	2614		MUELLER		IR		200						A			6	5				
04N/28E-32ADD	LUB	64		J.R. SIMPLOT CO	MW-31	MO		27.5					x	A	1							
04N/28E-32BBB	UMAT	5762		UNIVERSAL FOODS	MW-1	MO		56.5					x	A	1							
04N/28E-32CDC	LUB	66		J.R. SIMPLOT CO	MW-33	MO		27.5					x	A	1							
04N/28E-32DCC	LUB	65		J.R. SIMPLOT CO	MW-32	MO		28					x	A	1							
04N/28E-33BCC	UMAT	2628	80	ROAE		DO		94				x	x	A			5					
04N/28E-33CDB	UMAT	5565		HOPPER RANCH		LV		162			x			A			3	3				
04N/28E-34BAB	LUB	82		J.R. SIMPLOT CO	Iszler (Issler) well	OB							x	A								
04N/28E-34DBA	UMAT	2634		HOPPER		IR		461						B							5	5
04N/28E-35BBA	LUB	50		J.R. SIMPLOT CO	MW-17	MO		20				x	x	A	1							

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/29E-01ACD	UMAT	2643		POWELL-GOODIN FARMS		IR		1025						B							5	5
04N/29E-05AAD	UMAT	5587		CLARK		DO		175			x			B							5	
04N/29E-05CAA	UMAT	2696		THOMS		DO		65				x	x	A			5	5				
04N/29E-05CCB	UMAT	2708	151	BALDWIN		IR		200						B			6	6		5		
04N/29E-05DBD	UMAT	2711		HERSHEY		IR		772						B						5	5	5
04N/29E-06BAA	UMAT	2738		MOON		IR		480						B						5	5	5
04N/29E-06BDD	UMAT	2753	41	PHIPPS		DO		65				x	x	A		4						
04N/29E-07ACD	UMAT	2783		PERKINS	Well #3	IR		480						B						6	3	5
04N/29E-07ADC	UMAT	2774		PERKINS		DO		120				x	x	A			5					
04N/29E-07CAD	UMAT	2771		BROWN		IR		600						B			6	6		5	5	5
04N/29E-07CBD	UMAT	2796	42	BUWALDA		DO		105						A			5					
04N/29E-08ACA	UMAT	2802		DAVIDSON		IR		539						BA			5	5		5	5	5
04N/29E-08BDA	UMAT	2806		MEHREN		DO		157				x	x	A			5					
04N/29E-08BDB	UMAT	2807	43	WALCHLI		DO		105					x	A			5					
04N/29E-09ACB	UMAT	2811		WELLENBROCK		DO		107				x	x	A				5				
04N/29E-09BBD	UMAT	2813	195	KOPACZ		DO		103				x	x	A			5					
04N/29E-10ABA	UMAT	2824		PICKER		IR		365						BA			3	5			5	5
04N/29E-10ADB	UMAT	2830	45	WINEBARGER		DO		45				x	x	A			5					
04N/29E-10BCB	UMAT	2821		BURNS	Well #3	IR		1350						B			6	6			5	5
04N/29E-10DBC	UMAT	2825		BURNS	Well #2	IR		465						B			6	6			5	5
04N/29E-11CCC	UMAT	2836		BURNS	Ivan Cook well.	IR		640						B							5	5
04N/29E-11DDD	UMAT	2839		MILLS MINT FARM		IR		630						B								5
04N/29E-12DDA	UMAT	2843		MORSE	Well #3	IR		528						B								5
04N/29E-13CBA	UMAT	2844		PACIFIC GAS TRANSMISSION		DO		204				x	x	B								5
04N/29E-14CDA	UMAT	2855	56	HANSEN		DO		72					x	A			5					
04N/29E-14DCC	UMAT	2857		SPENCER		DO		64				x	x	A			5					
04N/29E-17ADD	UMAT	2862		WALCHLI		IR		1205						B							6	5
04N/29E-17BAB	UMAT	2863	46	BURNETT		DO		110				x	x	A			5					
04N/29E-17CCA	UMAT	2867		DREYER		IR		245				x	x	A			3	5				
04N/29E-17CCB	UMAT	2866		BE DREYER		DO		207	x			x	x	A			3					
04N/29E-18ACB	UMAT	2875		YORK		DO		140				x	x	A			5					
04N/29E-18ADC	UMAT	2869		MAYES		IR		125						A			5					
04N/29E-18CCD	UMAT	5307	111	WALCHI		UN		175				x	x	A			5					
04N/29E-18DAD	UMAT	2876		CHOWNING	Milton Culp well.	IR		262						A			3	5				
04N/29E-18DCB	UMAT	2872		CHOWNING	M. L. Koester well.	IR		643						B			6				5	5
04N/29E-19AAA	UMAT	5528		HERMISTON FOODS	MW-4	MO		108.2					x	A			2					
04N/29E-19ABB	UMAT	5526		HERMISTON FOODS	MW-2	MO		87					x	A			2					
04N/29E-19ADD	LUB	17		HERMISTON FOODS	SB-4	TH	AB	81						A								
04N/29E-19BAA	UMAT	2879		CHOWNING		IR		130						A			3					
04N/29E-19BAC	UMAT	5527		HERMISTON FOODS	MW-3	MO		113.5					x	A			2					
04N/29E-19BDA	LUB	15		HERMISTON FOODS	BH-1	TH	AB	51.5						A								
04N/29E-19BDD	UMAT	5341		HERMISTON FOODS	SB-5	TH	AB	206						A								
04N/29E-19CDC	UMAT	5328		HERMISTON FOODS	HF WW-1, SB-2	DO		231				x	x	A			3	3				
04N/29E-19CDC	LUB	18		HERMISTON FOODS	SB-7	TH	AB	112						A								
04N/29E-19CDD	UMAT	5344		HERMISTON FOODS	SB-6	TH	AB	201						A								
04N/29E-19DDD	UMAT	5525		HERMISTON FOODS	MW-1	MO		71.5					x	A			2					
04N/29E-20DCB	UMAT	2880		CIRCLE C RANCH		IR		655						B							5	5
04N/29E-23ADC	UMAT	2901		HASCALL		DO		60				x	x	A			5					
04N/29E-24ACA	UMAT	2907		PEARSON		IR		1102						B			6	6				5
04N/29E-24DCC	UMAT	2905		ZABRANSKY AND SONS INC.	#2	IR		1340						B								5
04N/29E-26DAB	UMAT	2918		MILLS MINT FARM INC.	#7	IR		745						B								5

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
04N/29E-27ABC	UMAT	2925	200	GIBSON		UN		80				x	x	A			3					
04N/29E-27BCA	UMAT	2924		BRANDT		DO		110				x	x	B				6			5	
04N/29E-27CAD	UMAT	2927		MILLS MINT FARM INC.	#2	IR		400						B								5
04N/29E-28CCC	UMAT	2984		ANDERSON LAND & LIVESTOCK		IR		195						BA			3				5	
04N/29E-29BDA	UMAT	2937		LOYALTA INC.		IR		1172						B							5	5
04N/29E-29DDC1	UMAT	2941		FRANKS		IR		70				x	x	A			3	5				
04N/29E-30ABB	UMAT	2944		LEHMAN		IR		1071						B							5	5
04N/29E-31DAA	UMAT	5287		A.E. STALEY MANUF. CO.	MW-1S	MO		25				x	x	A		1						
04N/29E-31DAA	UMAT	5292		A.E. STALEY MANUF. CO.	MW-1D	MO		65				x	x	A		2		2				
04N/29E-31DAD	UMAT	2949		A.E. STALEY MANUF. CO.	Production Well	IM		135						B							5	
04N/29E-31DBB	UMAT	5289		A.E. STALEY MANUF. CO.	MW-4S	MO		25				x	x	A		1						
04N/29E-31DBB	UMAT	5288		A.E. STALEY MANUF. CO.	MW-5S	MO		25				x	x	A		1						
04N/29E-31DCB	UMAT	5286		A.E. STALEY MANUF. CO.	MW-3S	MO		25				x	x	A		1						
04N/29E-31DCB	UMAT	5290		A.E. STALEY MANUF. CO.	MW-3D	MO		65				x	x	A		2		2				
04N/29E-31DCD	UMAT	5291		A.E. STALEY MANUF. CO.	MW-2S	MO		25				x	x	A		1						
04N/29E-32ADB	UMAT	2965		ALLEN		DO		43				x	x	A	4							
04N/29E-32BBC	UMAT	2962		CITY OF STANFIELD		MU		1161						B								5
04N/29E-32BCC	UMAT	2963	47	BURNETT		DO		145				x	x	B				1			5	
04N/29E-32CAC	UMAT	2976		CITY OF STANFIELD	#3	MU		778						B								5
04N/29E-33BCC	UMAT	2983	50	EMERSON		DO		50				x	x	A			5	5				
04N/29E-33CDD	UMAT	2986	52	BURKETT		DO		83						A				5				
04N/29E-36DAB	UMAT	2992		ZABRANSKY AND SONS INC.	#3	IR		1023						B			6	6				3
05N/26E-16ACA	MORR	1005	163	U.S FISH & WILDLIFE SERVICE		DO		77				x	x	A		4						
05N/26E-21BAC	LUB	13		US FISH & WILDLIFE	#2	IR						x	x	A		1						
05N/26E-22ADD	MORR	1021	34	FROBERS		DO		40				x	x	A		4						
05N/26E-23CBD	LUB	14	33	IRWIN		DO		83				x	x	A		5						
05N/26E-24CAD	MORR	1120	164	MURRAY		DO		175				x	x	B					5			
05N/26E-24DDA	LUB	7		CITY OF IRRIGON	Sand Point 2036	MO						x	x	A		4						
05N/26E-25AAD	LUB	6		CITY OF IRRIGON	Sand Point 2035	MO						x	x	A		4						
05N/26E-25ABD	LUB	4	53	COOLEY		DO		55				x	x	A		4						
05N/26E-25CDC	MORR	1216		TAYLOR		UN		173						B					5			
05N/26E-26BDA	MORR	1234		HELLBERG		IR		87						A		3						
05N/26E-26CBA	MORR	1532		BUCHANAN		DO		105				x	x	A		4						
05N/26E-26CDB	MORR	1238		WESTERN EMPIRE		IR		250						B					5			
05N/26E-27CBA	MORR	1250	161	DESERT MAGIC INC		IR		133	x			x	x	A		3						
05N/26E-27DBA	MORR	1251		DESERT MAGIC INC		IR		131						A		3						
05N/26E-31ACB	MORR	1252	175	MAGIC DESERT INC	Desert Magic D, POM ref. well 17.	IR		111	x					A		3		4				
05N/26E-31BDC	MORR	1253		WESTERN EMPIRE	Well 1S, Big Dad	IR		40				x	x	A		3						
05N/26E-32ABC	MORR	1254	174	DESERT MAGIC INC		IR		151						A		3						
05N/26E-33AAA	MORR	1260		WESTERN EMPIRE		IR		148					x	A		3		5				
05N/26E-33AAC	MORR	1264	173	WESTERN EMPIRE	Well #5	IR		124				x	x	A		3						
05N/26E-33ABB	MORR	1255		MIRACLE POTATO		IR		125				x	x	A		4						
05N/26E-33BAC	MORR	1261		WESTERN EMPIRE	Well #1C, Able Well	IR		145						A		3		4				
05N/26E-33CDB	MORR	1262		DESERT MAGIC INC		IR		95						A		3						
05N/26E-33DBD	MORR	1263		WESTERN EMPIRE	Well #7	IR		100						A		3						
05N/26E-34ABA	MORR	1274		WESTERN EMPIRE	Well #3	IR		110								3						
05N/26E-34ADB	MORR	1269		WESTERN EMPIRE	Well #12	IR		81						A		3						
05N/26E-34BBA	MORR	1273		WESTERN EMPIRE	Well #4	IR		131						A		3						
05N/26E-34BCD	MORR	1272		WESTERN EMPIRE	Well #6	IR		110						a		3						
05N/26E-34CCB	MORR	1267		WESTERN EMPIRE		IR		87				x	x	A				4				
05N/26E-34CCD	MORR	1270		WESTERN EMPIRE	Well #14	IR		44						A		3		4				

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones Alluvial Aquifer				Completion Zones Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
05N/26E-34DBD	MORR	1271		WESTERN EMPIRE	Well #10	IR		52						A		3						
05N/26E-35ABB	MORR	0		WESTERN EMPIRE	Well 2C, Charlie Well	IR		79						A		3		4				
05N/26E-35ABD	MORR	1323		WESTERN EMPIRE	Well 15	IR		36						A		3						
05N/26E-35BBB	MORR	1321	162	WESTERN EMPIRE	Well 11	IR		87				x	x	A		3						
05N/26E-35BBD	MORR	1322		WESTERN EMPIRE	Well 13	IR		38						A		3						
05N/26E-36BCA	MORR	1325	180	BOND		DO		47				x	x	A		4						
05N/27E-13CAC	UMAT	3271	96	ANDREWS		DO		57				x	x	A		4						
05N/27E-14DDA	UMAT	3294		B A MOORE COMPANY		DO		87				x	x	A		4						
05N/27E-14DDD	UMAT	3297		BUSHBY		DO		250				x	x	BA		6		5		5		
05N/27E-16DDD	UMAT	3307		SAMPSON		DO		123						B					3			
05N/27E-19CBA	MORR	1408		IRRIGON PARK & REC.		IR		60						A		3		4				
05N/27E-19CBB	MORR	1410	26	HURN		DO		65				x	x	A		4						
05N/27E-19CCB	MORR	1409		CITY OF IRRIGON	#1	MU		317						B					3			
05N/27E-19CDD	MORR	1411		WALKER		IR		65						A		6		4				
05N/27E-19DAB	LUB	1		CITY OF IRRIGON	DC	MO						x	x	A		1						
05N/27E-19DAC	LUB	16		CITY OF IRRIGON	DB2	MO						x	x	A		1						
05N/27E-19DAD	LUB	11		CITY OF IRRIGON	DB4	MO						x	x	A		1						
05N/27E-19DAD	LUB	9		CITY OF IRRIGON	UB	MO						x	x	A		1						
05N/27E-19DBC	LUB	5		CITY OF IRRIGON	Sand Point 2014	MO						x	x	A		1						
05N/27E-19DBD	LUB	10		CITY OF IRRIGON	DPB	MO						x	x	A		1						
05N/27E-20ADD	MORR	1418		EVANS		IR		300						B					5	5		
05N/27E-20CAD	LUB	8		CITY OF IRRIGON	Sand Point 2099	MO						x	x	A		1						
05N/27E-20CCB	MORR	1419		IRRIGON CEMETERY	Irrigon Cemetery Well	IR		52				x	x	A		6		4				
05N/27E-21ABD	MORR	1431	103	HOOVER		DO		40				x	x	A		4						
05N/27E-21BCA	MORR	1531		MCDANIEL		DO		100						B					5			
05N/27E-23BBC	UMAT	5820		WALTON		DO		255			x			B					6	5		
05N/27E-24BBA	UMAT	3333		MC CLANNAHAN	William McCannahan well	DO		403						B					5	5		
05N/27E-30CCC	MORR	1459		NEWQUIST		IR		194						B		6		6	5			
05N/27E-30CDB	MORR	1458		SCHNELL		IR		300						B					5	5		
05N/28E-10DDA	LUB	20		U.S. ARMY CORPS OF ENGINEERS	McNary Dam #3.	IM		779						B								5
05N/28E-11CAB	UMAT	3343		PORT OF UMATILLA	Port Well	MU		850						B								5
05N/28E-14ABC	UMAT	3347		CITY OF UMATILLA	Golf Course Well	MU		989						B								5
05N/28E-15CCB	UMAT	3358		POWER CITY WATER CO.		MU		455						B								5
05N/28E-16ADD	UMAT	3361		CITY OF UMATILLA	Intertie Well	MU		1134						B								5
05N/28E-16BBC	UMAT	3374	38	VIETH		DO		66				x	x	A		3						
05N/28E-17ABC	UMAT	3373	37	WAAS		DO		30				x	x	A		4						
05N/28E-18CAC	UMAT	5441	95	SHADY REST MOBILE HOME PARK	New well	DO		245						B								5
05N/28E-21DDA	UMAT	3384		WADEKAMPER		IR		250						B						5		5
05N/28E-21DDD	UMAT	3381		BLUE MOUNTAIN ASPHALT CO		IM		355						B						6	6	5
05N/28E-22BBA	UMAT	3397		POWER CITY WATER CO.		MU		397						B						5	5	5
05N/28E-25BDA	UMAT	5652		WOLFE	1 (South Well)	IR		20						A		3						
05N/28E-25BDA	UMAT	5653		WOLFE	2 (North Well)	IR		19		x		x	x	A		3						
05N/28E-25DAA	UMAT	3405	57	BLOODSWORTH		DO		69				x	x	A		4						
05N/28E-26CAA	UMAT	3415		PETTIGREW		DO		220				x	x	B						5		
05N/28E-26CAD	UMAT	3425		BAGGETT		IR		280						B						5		
05N/28E-26DDD	UMAT	3424	55	BILL WOLFF RANCHES		DS		60				x	x	A		4						
05N/28E-27CAB	UMAT	3434		CHARLES TRACTS WATER CO.	#3	DO		285						B						5		
05N/28E-28ABC	UMAT	5610		GREEN		DO		225			x			B						5		
05N/28E-32BDC	UMAT	3471		OREGON HIGHWAY DEPT	Old Chaves well.	UN		578						BA				5	5	5		5
05N/28E-32CAD	UMAT	3469		OREGON HIGHWAY DEPT	Old Chaves well.	UN		320						B					5	5		
05N/28E-33ADB	UMAT	3512		JACOBS	Hay well.	ID		315						B						5		5

Location	OWRD	ID	DEQ UMA #	Owner	Owner's Well Name	Use	Status	Total Depth	Aquifer Test Well	Recorder Well	Drill Cuttings Well	Synoptic Water Level Well	Water Level Well	Aquifer System	Completion Zones							
															Alluvial Aquifer				Basalt Aquifers			
															UF	UC	CF	BF	EM	PO	UM	UN
05N/28E-33DAB	UMAT	3474		ZUMWALT		DO		263						B						5		
05N/28E-34ADB	UMAT	3531		FUCHS		IR		300						B						5	5	
05N/28E-34CBD	UMAT	3530		WALLS		DO		123				x	x	A			4					
05N/28E-34DDB	UMAT	3537		BILL JEPSEN		DO		175				x	x	B						5		
05N/28E-35CCC	UMAT	3609		GODWIN		DO		120		x		x	x	A		4						
05N/28E-35CDD	UMAT	3621		WELCH		IR		178						A		4		5				
05N/28E-35DCD	UMAT	3607	39	POWELL		DO		162				x	x	A		4						
05N/28E-36ACC	UMAT	3633		CHRISTOPHERSON	Ness well	IR		305						B						5	5	
05N/28E-36CCB	UMAT	3638		WOLVERTON		DO		164				x	x	A		4						
05N/28E-36DAA	UMAT	3626	40	ZIEGENHIRT		DO		100				x	x	A		4						
05N/29E-15BBD	UMAT	5255		CHRISTENSEN		DO		323				x	x	B							6	3
05N/29E-15CBB	UMAT	3661		CONFORTH		IR		120				x	x	A		3		5				
05N/29E-16DDA	UMAT	3663		CONFORTH INC		DO		92				x	x	A		3						
05N/29E-17CAD	UMAT	3666		CONFORTH		IR		36				x	x	A		6		4				
05N/29E-19BDD	UMAT	3667		SCHWEIGERT		DO		48				x	x	A		3		5				
05N/29E-19CCB	UMAT	3673		WOLFE	Brown well.	IR		298						B						5	5	5
05N/29E-19DCC	UMAT	3670		THORNBURG		DO		230					x	B		6		6		5	5	
05N/29E-20DDB	UMAT	3676		CONFORTH		IR		27				x	x	A		4						
05N/29E-21AAA	UMAT	3679		CONFORTH		IR		95				x	x	A			4					
05N/29E-22CAB	UMAT	3686		GUTHERY		DO		100						A		6		5				
05N/29E-26CBD	UMAT	3691		MARKS	#1	IR		380						B						5	5	5
05N/29E-28AAB	UMAT	3717		GROSS		IR		175						B							5	5
05N/29E-28ADA	UMAT	3704		GROSS		DO		125				x	x	B						5	5	
05N/29E-28CBB	UMAT	3706		KOOP		IR		200						B							5	5
05N/29E-29BCD	UMAT	3727	109	BECK		DO		45				x	x	A		4						
05N/29E-29DDB	UMAT	3733		BAILEY	Wagner Well	IR		310						B							5	5
05N/29E-30ACA	UMAT	3755		THORNBURG		IR		40				x	x	A		3						
05N/29E-31ACC	UMAT	5769		SALLEE		DO		200			x			B							5	
05N/29E-31BAA	UMAT	3774		WILLIAMS		IR		67						A		6		3				
05N/29E-31DAA	UMAT	5300		MICHAEL		DO		110				x	x	A				5				
05N/29E-31DAA	UMAT	3809		SMITH		DO		81				x	x	A		4						
05N/29E-31DBD	UMAT	3783		VANDELL	Fourcade well	IR		201						B		6		6			5	
05N/29E-32CAB	UMAT	3813		HALLADAY		IR		200						B						5	5	5
05N/29E-32CCD	UMAT	3822		MALE		IR		72								4		5				
05N/29E-33BDD	UMAT	3826		GOODIER		DO		144				x	x	B						3		

Appendix 2B
Synoptic Water Level Data

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	1	12/5/90	Idle	E Tape	273.22	11.78			261.44	DEQ	
LUB	1	3/13/91	Idle	E Tape	273.22	11.89			261.33	DEQ	
LUB	1	6/10/91	Idle	E Tape	273.22	11.49			261.73	DEQ	
LUB	1	9/10/91	Idle	E Tape	273.22	9.26			263.96	DEQ	
LUB	1	12/10/91	Idle	E Tape	273.22	11.71			261.51	DEQ	
LUB	1	3/10/92	Idle	E Tape	273.22	13.75			259.47	DEQ	
LUB	10	12/5/90	Idle	E Tape	284.88	20.61			264.27	DEQ	
LUB	10	2/11/91	Idle	E Tape	284.88	18.22			266.66	DEQ	
LUB	10	3/13/91	Idle	E Tape	284.88	20.71			264.17	DEQ	
LUB	10	6/10/91	Idle	E Tape	284.88	20.24			264.64	DEQ	
LUB	10	8/16/91	Idle	E Tape	284.88	16.75			268.13	DEQ	
LUB	10	9/10/91	Idle	E Tape	284.88	18.58			266.30	DEQ	
LUB	10	12/10/91	Idle	E Tape	284.88	20.55			264.33	DEQ	
LUB	10	3/10/92	Idle	E Tape	284.88	21.15			263.73	DEQ	
LUB	100	12/18/90			655.8	154.68	657.98	156.86	501.12	USACE	
LUB	100	1/9/91			655.8	154.85	657.98	157.03	500.95	USACE	
LUB	100	2/11/91			655.8	154.6	657.98	156.78	501.20	USACE	
LUB	100	3/20/91			655.8	154.74	657.98	156.92	501.06	USACE	
LUB	100	4/18/91			655.8	154.72	657.98	156.9	501.08	USACE	
LUB	100	5/25/91			655.8	154.75	657.98	156.93	501.05	USACE	
LUB	100	6/26/91			655.8	154.72	657.98	156.9	501.08	USACE	
LUB	100	7/22/91			655.8	154.69	657.98	156.87	501.11	USACE	
LUB	100	8/19/91			655.8	154.68	657.98	156.86	501.12	USACE	
LUB	100	9/24/91			655.8	154.71	657.98	156.89	501.09	USACE	
LUB	100	10/17/91			655.8	154.78	657.98	156.96	501.02	USACE	
LUB	100	11/20/91			655.8	154.67	657.98	156.85	501.13	USACE	
LUB	100	12/18/91			655.8	154.41	657.98	156.59	501.39	USACE	
LUB	100	1/21/92			655.8	154.63	657.98	156.81	501.17	USACE	
LUB	100	2/17/92			655.8	154.68	657.98	156.86	501.12	USACE	
LUB	100	3/11/92			655.8	154.62	657.98	156.8	501.18	USACE	
LUB	100	4/20/92			655.8	154.6	657.98	156.78	501.20	USACE	
LUB	101	12/19/90			600.6	104.81	602.73	106.94	495.79	USACE	
LUB	101	1/12/91			600.6	104.56	602.73	106.69	496.04	USACE	
LUB	101	2/11/91			600.6	103.9	602.73	106.03	496.70	USACE	
LUB	101	3/20/91			600.6	102.44	602.73	104.57	498.16	USACE	
LUB	101	4/18/91			600.6	101.61	602.73	103.74	498.99	USACE	
LUB	101	5/24/91			600.6	101	602.73	103.13	499.60	USACE	
LUB	101	6/26/91			600.6	101.61	602.73	103.74	498.99	USACE	
LUB	101	7/22/91			600.6	102.52	602.73	104.65	498.08	USACE	
LUB	101	8/19/91			600.6	100.44	602.73	102.57	500.16	USACE	
LUB	101	9/24/91			600.6	103.61	602.73	105.74	496.99	USACE	
LUB	101	10/17/91			600.6	103.24	602.73	105.37	497.36	USACE	
LUB	101	11/20/91			600.6	103.05	602.73	105.18	497.55	USACE	
LUB	101	12/18/91			600.6	102.83	602.73	104.96	497.77	USACE	
LUB	101	1/21/92			600.6	102.68	602.73	104.81	497.92	USACE	
LUB	101	2/17/92			600.6	102.34	602.73	104.47	498.26	USACE	
LUB	101	3/11/92			600.6	101.44	602.73	103.57	499.16	USACE	
LUB	101	4/20/92			600.6	101.23	602.73	103.36	499.37	USACE	
LUB	102	12/19/90			597.8	101.98	599.9	104.08	495.82	USACE	
LUB	102	1/12/91			597.8	101.74	599.9	103.84	496.06	USACE	
LUB	102	2/11/91			597.8	101.08	599.9	103.18	496.72	USACE	
LUB	102	3/20/91			597.8	99.64	599.9	101.74	498.16	USACE	
LUB	102	4/18/91			597.8	98.83	599.9	100.93	498.97	USACE	
LUB	102	5/24/91			597.8	98.14	599.9	100.24	499.66	USACE	
LUB	102	6/26/91			597.8	98.79	599.9	100.89	499.01	USACE	
LUB	102	7/22/91			597.8	99.68	599.9	101.78	498.12	USACE	
LUB	102	8/19/91			597.8	100.32	599.9	102.42	497.48	USACE	
LUB	102	9/24/91			597.8	100.8	599.9	102.9	497.00	USACE	
LUB	102	10/17/91			597.8	100.42	599.9	102.52	497.38	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	102	11/20/91			597.8	100.24	599.9	102.34	497.56	USACE	
LUB	102	12/18/91			597.8	100.01	599.9	102.11	497.79	USACE	
LUB	102	1/21/92			597.8	99.87	599.9	101.97	497.93	USACE	
LUB	102	2/17/92			597.8	99.53	599.9	101.63	498.27	USACE	
LUB	102	3/11/92			597.8	98.62	599.9	100.72	499.18	USACE	
LUB	102	4/20/92			597.8	98.41	599.9	100.51	499.39	USACE	
LUB	103	12/19/90			598.9	103.05	601.02	105.17	495.85	USACE	
LUB	103	1/12/91			598.9	102.81	601.02	104.93	496.09	USACE	
LUB	103	2/11/91			598.9	102.12	601.02	104.24	496.78	USACE	
LUB	103	3/20/91			598.9	100.64	601.02	102.76	498.26	USACE	
LUB	103	4/18/91			598.9	99.85	601.02	101.97	499.05	USACE	
LUB	103	5/24/91			598.9	99.23	601.02	101.35	499.67	USACE	
LUB	103	6/26/91			598.9	99.88	601.02	102	499.02	USACE	
LUB	103	7/22/91			598.9	100.79	601.02	102.91	498.11	USACE	
LUB	103	8/19/91			598.9	101.43	601.02	103.55	497.47	USACE	
LUB	103	9/24/91			598.9	101.89	601.02	104.01	497.01	USACE	
LUB	103	10/17/91			598.9	101.5	601.02	103.62	497.40	USACE	
LUB	103	11/20/91			598.9	101.32	601.02	103.44	497.58	USACE	
LUB	103	12/18/91			598.9	101.07	601.02	103.19	497.83	USACE	
LUB	103	1/21/92			598.9	100.92	601.02	103.04	497.98	USACE	
LUB	103	2/17/92			598.9	100.57	601.02	102.69	498.33	USACE	
LUB	103	3/11/92			598.9	99.65	601.02	101.77	499.25	USACE	
LUB	103	4/20/92			598.9	99.46	601.02	101.58	499.44	USACE	
LUB	104	12/19/90			594.1	98.25	596.29	100.44	495.85	USACE	
LUB	104	1/12/91			594.1	98	596.29	100.19	496.10	USACE	
LUB	104	2/11/91			594.1	97.37	596.29	99.56	496.73	USACE	
LUB	104	3/20/91			594.1	95.97	596.29	98.16	498.13	USACE	
LUB	104	4/18/91			594.1	95.17	596.29	97.36	498.93	USACE	
LUB	104	5/24/91			594.1	94.51	596.29	96.7	499.59	USACE	
LUB	104	6/26/91			594.1	95.09	596.29	97.28	499.01	USACE	
LUB	104	7/22/91			594.1	95.99	596.29	98.18	498.11	USACE	
LUB	104	8/19/91			594.1	96.63	596.29	98.82	497.47	USACE	
LUB	104	9/24/91			594.1	97.09	596.29	99.28	497.01	USACE	
LUB	104	10/17/91			594.1	96.68	596.29	98.87	497.42	USACE	
LUB	104	11/20/91			594.1	96.49	596.29	98.68	497.61	USACE	
LUB	104	12/18/91			594.1	96.29	596.29	98.48	497.81	USACE	
LUB	104	1/21/92			594.1	96.13	596.29	98.32	497.97	USACE	
LUB	104	2/17/92			594.1	95.8	596.29	97.99	498.30	USACE	
LUB	104	3/11/92			594.1	94.93	596.29	97.12	499.17	USACE	
LUB	104	4/20/92			594.1	94.71	596.29	96.9	499.39	USACE	
LUB	105	12/19/90			588.2	92.55	590.38	94.73	495.65	USACE	
LUB	105	1/12/91			588.2	92.29	590.38	94.47	495.91	USACE	
LUB	105	2/11/91			588.2	91.58	590.38	93.76	496.62	USACE	
LUB	105	3/20/91			588.2	90.15	590.38	92.33	498.05	USACE	
LUB	105	4/18/91			588.2	89.27	590.38	91.45	498.93	USACE	
LUB	105	5/24/91			588.2	88.72	590.38	90.9	499.48	USACE	
LUB	105	6/26/91			588.2	89.42	590.38	91.6	498.78	USACE	
LUB	105	7/22/91			588.2	90.33	590.38	92.51	497.87	USACE	
LUB	105	8/19/91			588.2	90.99	590.38	93.17	497.21	USACE	
LUB	105	9/24/91			588.2	91.4	590.38	93.58	496.80	USACE	
LUB	105	10/17/91			588.2	91.1	590.38	93.28	497.10	USACE	
LUB	105	11/20/91			588.2	90.79	590.38	92.97	497.41	USACE	
LUB	105	12/18/91			588.2	90.56	590.38	92.74	497.64	USACE	
LUB	105	1/21/92			588.2	90.41	590.38	92.59	497.79	USACE	
LUB	105	2/17/92			588.2	89.97	590.38	92.15	498.23	USACE	
LUB	105	3/11/92			588.2	89.05	590.38	91.23	499.15	USACE	
LUB	105	4/20/92			588.2	88.87	590.38	91.05	499.33	USACE	
LUB	106	12/19/90			585.1	89.43	587.5	91.83	495.67	USACE	
LUB	106	1/12/91			585.1	89.13	587.5	91.53	495.97	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	106	2/11/91			585.1	88.44	587.5	90.84	496.66	USACE	
LUB	106	3/20/91			585.1	86.93	587.5	89.33	498.17	USACE	
LUB	106	4/18/91			585.1	86.16	587.5	88.56	498.94	USACE	
LUB	106	5/24/91			585.1	85.6	587.5	88	499.50	USACE	
LUB	106	6/26/91			585.1	86.32	587.5	88.72	498.78	USACE	
LUB	106	7/22/91			585.1	87.25	587.5	89.65	497.85	USACE	
LUB	106	8/19/91			585.1	87.9	587.5	90.3	497.20	USACE	
LUB	106	9/24/91			585.1	88.31	587.5	90.71	496.79	USACE	
LUB	106	10/17/91			585.1	87.94	587.5	90.34	497.16	USACE	
LUB	106	11/20/91			585.1	87.66	587.5	90.06	497.44	USACE	
LUB	106	12/18/91			585.1	87.44	587.5	89.84	497.66	USACE	
LUB	106	1/21/92			585.1	87.27	587.5	89.67	497.83	USACE	
LUB	106	2/17/92			585.1	86.89	587.5	89.29	498.21	USACE	
LUB	106	3/11/92			585.1	85.93	587.5	88.33	499.17	USACE	
LUB	106	4/20/92			585.1	85.79	587.5	88.19	499.31	USACE	
LUB	107	12/20/90			487.2	68.58	489.75	71.13	418.62	USACE	
LUB	107	1/10/91			487.2	68.47	489.75	71.02	418.73	USACE	
LUB	107	2/11/91			487.2	68.33	489.75	70.88	418.87	USACE	
LUB	107	3/20/91			487.2	68.22	489.75	70.77	418.98	USACE	
LUB	107	4/18/91			487.2	68.12	489.75	70.67	419.08	USACE	
LUB	107	5/25/91			487.2	67.96	489.75	70.51	419.24	USACE	
LUB	107	6/26/91			487.2	67.86	489.75	70.41	419.34	USACE	
LUB	107	7/23/91			487.2	67.78	489.75	70.33	419.42	USACE	
LUB	107	8/20/91			487.2	67.7	489.75	70.25	419.50	USACE	
LUB	107	9/25/91			487.2	67.66	489.75	70.21	419.54	USACE	
LUB	107	10/18/91			487.2	67.7	489.75	70.25	419.50	USACE	
LUB	107	11/21/91			487.2	67.53	489.75	70.08	419.67	USACE	
LUB	107	12/17/91			487.2	67.33	489.75	69.88	419.87	USACE	
LUB	107	1/22/92			487.2	67.27	489.75	69.82	419.93	USACE	
LUB	107	2/18/92			487.2	67.1	489.75	69.65	420.10	USACE	
LUB	107	3/12/92			487.2	67.06	489.75	69.61	420.14	USACE	
LUB	107	4/21/92			487.2	66.9	489.75	69.45	420.30	USACE	
LUB	108	12/20/90			503.9	78.7	506.17	80.97	425.20	USACE	
LUB	108	1/10/91			503.9	78.59	506.17	80.86	425.31	USACE	
LUB	108	2/11/91			503.9	78.46	506.17	80.73	425.44	USACE	
LUB	108	3/20/91			503.9	78.43	506.17	80.7	425.47	USACE	
LUB	108	4/18/91			503.9	78.63	506.17	80.9	425.27	USACE	
LUB	108	5/25/91			503.9	78.23	506.17	80.5	425.67	USACE	
LUB	108	6/26/91			503.9	78.13	506.17	80.4	425.77	USACE	
LUB	108	7/23/91			503.9	78.06	506.17	80.33	425.84	USACE	
LUB	108	8/20/91			503.9	77.97	506.17	80.24	425.93	USACE	
LUB	108	9/25/91			503.9	77.93	506.17	80.2	425.97	USACE	
LUB	108	10/18/91			503.9	77.93	506.17	80.2	425.97	USACE	
LUB	108	11/21/91			503.9	77.84	506.17	80.11	426.06	USACE	
LUB	108	12/17/91			503.9	77.65	506.17	79.92	426.25	USACE	
LUB	108	1/22/92			503.9	77.6	506.17	79.87	426.30	USACE	
LUB	108	2/18/92			503.9	77.43	506.17	79.7	426.47	USACE	
LUB	108	3/12/92			503.9	77.45	506.17	79.72	426.45	USACE	
LUB	108	4/21/92			503.9	77.31	506.17	79.58	426.59	USACE	
LUB	109	12/20/90			553.9	93.92	556.13	96.15	459.98	USACE	
LUB	109	1/10/91			553.9	93.69	556.13	95.92	460.21	USACE	
LUB	109	2/11/91			553.9	93.52	556.13	95.75	460.38	USACE	
LUB	109	3/20/91			553.9	93.52	556.13	95.75	460.38	USACE	
LUB	109	4/18/91			553.9	93.52	556.13	95.75	460.38	USACE	
LUB	109	5/25/91			553.9	93.42	556.13	95.65	460.48	USACE	
LUB	109	6/26/91			553.9	93.33	556.13	95.56	460.57	USACE	
LUB	109	7/23/91			553.9	93.1	556.13	95.33	460.80	USACE	
LUB	109	8/20/91			553.9	93.28	556.13	95.51	460.62	USACE	
LUB	109	9/25/91			553.9	93.19	556.13	95.42	460.71	USACE	

Lower Umatilla Basin
Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	109	10/18/91			553.9	93.38	556.13	95.61	460.52	USACE	
LUB	109	11/21/91			553.9	93.19	556.13	95.42	460.71	USACE	
LUB	109	12/17/91			553.9	92.95	556.13	95.18	460.95	USACE	
LUB	109	1/22/92			553.9	93.02	556.13	95.25	460.88	USACE	
LUB	109	2/18/92			553.9	92.85	556.13	95.08	461.05	USACE	
LUB	109	3/12/92			553.9	92.92	556.13	95.15	460.98	USACE	
LUB	109	4/21/92			553.9	92.81	556.13	95.04	461.09	USACE	
LUB	11	12/5/90	Idle	E Tape	282.17	20.97			261.20	DEQ	
LUB	11	2/11/91	Idle	E Tape	282.17	16.48			265.69	OWRD	
LUB	11	3/13/91	Idle	E Tape	282.17	21.29			260.88	DEQ	
LUB	11	6/10/91	Idle	E Tape	282.17	25.68			256.49	DEQ	
LUB	11	9/10/91	Idle	E Tape	282.17	23.89			258.28	DEQ	
LUB	11	12/10/91	Idle	E Tape	282.17	26.05			256.12	DEQ	
LUB	11	3/10/92	Idle	E Tape	282.17	26.38			255.79	DEQ	
LUB	110	12/20/90			556.3	96.94	558.82	99.46	459.36	USACE	
LUB	110	1/10/91			556.3	96.68	558.82	99.2	459.62	USACE	
LUB	110	2/11/91			556.3	96.48	558.82	99	459.82	USACE	
LUB	110	3/20/91			556.3	96.52	558.82	99.04	459.78	USACE	
LUB	110	4/18/91			556.3	96.56	558.82	99.08	459.74	USACE	
LUB	110	5/25/91			556.3	96.48	558.82	99	459.82	USACE	
LUB	110	6/26/91			556.3	96.41	558.82	98.93	459.89	USACE	
LUB	110	7/23/91			556.3	96.39	558.82	98.91	459.91	USACE	
LUB	110	8/20/91			556.3	96.39	558.82	98.91	459.91	USACE	
LUB	110	9/25/91			556.3	96.32	558.82	98.84	459.98	USACE	
LUB	110	10/18/91			556.3	96.54	558.82	99.06	459.76	USACE	
LUB	110	11/21/91			556.3	96.43	558.82	98.95	459.87	USACE	
LUB	110	12/17/91			556.3	96.16	558.82	98.68	460.14	USACE	
LUB	110	1/22/92			556.3	96.26	558.82	98.78	460.04	USACE	
LUB	110	2/18/92			556.3	96.13	558.82	98.65	460.17	USACE	
LUB	110	3/12/92			556.3	96.17	558.82	98.69	460.13	USACE	
LUB	110	4/21/92			556.3	96.09	558.82	98.61	460.21	USACE	
LUB	111	12/20/90			562.7	102.25	564.96	104.51	460.45	USACE	
LUB	111	1/10/91			562.7	102.2	564.96	104.46	460.50	USACE	
LUB	111	2/11/91			562.7	102.18	564.96	104.44	460.52	USACE	
LUB	111	3/20/91			562.7	102.17	564.96	104.43	460.53	USACE	
LUB	111	4/18/91			562.7	102.14	564.96	104.4	460.56	USACE	
LUB	111	5/25/91			562.7	102.11	564.96	104.37	460.59	USACE	
LUB	111	6/26/91			562.7	102.09	564.96	104.35	460.61	USACE	
LUB	111	7/23/91			562.7	102.08	564.96	104.34	460.62	USACE	
LUB	111	8/20/91			562.7	102.06	564.96	104.32	460.64	USACE	
LUB	111	9/25/91			562.7	102.09	564.96	104.35	460.61	USACE	
LUB	111	10/18/91			562.7	102.06	564.96	104.32	460.64	USACE	
LUB	111	11/21/91			562.7	102.11	564.96	104.37	460.59	USACE	
LUB	111	12/17/91			562.7	101.97	564.96	104.23	460.73	USACE	
LUB	111	1/22/92			562.7	102.05	564.96	104.31	460.65	USACE	
LUB	111	2/18/92			562.7	101.96	564.96	104.22	460.74	USACE	
LUB	111	3/12/92			562.7	102.01	564.96	104.27	460.69	USACE	
LUB	111	4/21/92			562.7	101.99	564.96	104.25	460.71	USACE	
LUB	112	12/20/90			490.5	73.33	492.88	75.71	417.17	USACE	
LUB	112	1/10/91			490.5	76.28	492.88	78.66	414.22	USACE	
LUB	112	2/11/91			490.5	76.18	492.88	78.56	414.32	USACE	
LUB	112	3/20/91			490.5	76.22	492.88	78.6	414.28	USACE	
LUB	112	4/18/91			490.5	76.18	492.88	78.56	414.32	USACE	
LUB	112	5/25/91			490.5	76.13	492.88	78.51	414.37	USACE	
LUB	112	6/26/91			490.5	76.14	492.88	78.52	414.36	USACE	
LUB	112	7/23/91			490.5	76.12	492.88	78.5	414.38	USACE	
LUB	112	8/20/91			490.5	76.1	492.88	78.48	414.40	USACE	
LUB	112	9/25/91			490.5	76.11	492.88	78.49	414.39	USACE	
LUB	112	10/18/91			490.5	76.12	492.88	78.5	414.38	USACE	

Lower Umatilla Basin
Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	112	11/21/91			490.5	76.11	492.88	78.49	414.39	USACE	
LUB	112	12/17/91			490.5	75.99	492.88	78.37	414.51	USACE	
LUB	112	1/22/92			490.5	76.05	492.88	78.43	414.45	USACE	
LUB	112	2/18/92			490.5	75.97	492.88	78.35	414.53	USACE	
LUB	112	3/12/92			490.5	76.02	492.88	78.4	414.48	USACE	
LUB	112	4/21/92			490.5	75.99	492.88	78.37	414.51	USACE	
LUB	113	12/20/90			500.5	78.98	502.94	81.42	421.52	USACE	
LUB	113	1/10/91			500.5	78.96	502.94	81.4	421.54	USACE	
LUB	113	2/11/91			500.5	78.9	502.94	81.34	421.60	USACE	
LUB	113	3/20/91			500.5	78.91	502.94	81.35	421.59	USACE	
LUB	113	4/18/91			500.5	78.91	502.94	81.35	421.59	USACE	
LUB	113	5/25/91			500.5	78.9	502.94	81.34	421.60	USACE	
LUB	113	6/26/91			500.5	78.89	502.94	81.33	421.61	USACE	
LUB	113	7/23/91			500.5	78.87	502.94	81.31	421.63	USACE	
LUB	113	8/20/91			500.5	78.86	502.94	81.3	421.64	USACE	
LUB	113	9/25/91			500.5	78.86	502.94	81.3	421.64	USACE	
LUB	113	10/18/91			500.5	78.88	502.94	81.32	421.62	USACE	
LUB	113	11/21/91			500.5	78.86	502.94	81.3	421.64	USACE	
LUB	113	12/17/91			500.5	78.8	502.94	81.24	421.70	USACE	
LUB	113	1/22/92			500.5	78.82	502.94	81.26	421.68	USACE	
LUB	113	2/18/92			500.5	78.78	502.94	81.22	421.72	USACE	
LUB	113	3/12/92			500.5	78.82	502.94	81.26	421.68	USACE	
LUB	113	4/21/92			500.5	78.77	502.94	81.21	421.73	USACE	
LUB	114	12/20/90			467.1	72.54	469.4	74.84	394.56	USACE	
LUB	114	1/10/91			467.1	72.49	469.4	74.79	394.61	USACE	
LUB	114	2/11/91			467.1	72.39	469.4	74.69	394.71	USACE	
LUB	114	3/20/91			467.1	72.37	469.4	74.67	394.73	USACE	
LUB	114	4/18/91			467.1	72.4	469.4	74.7	394.70	USACE	
LUB	114	5/25/91			467.1	72.35	469.4	74.65	394.75	USACE	
LUB	114	6/26/91			467.1	72.33	469.4	74.63	394.77	USACE	
LUB	114	7/23/91			467.1	72.3	469.4	74.6	394.80	USACE	
LUB	114	8/20/91			467.1	72.26	469.4	74.56	394.84	USACE	
LUB	114	9/25/91			467.1	72.29	469.4	74.59	394.81	USACE	
LUB	114	10/18/91			467.1	72.35	469.4	74.65	394.75	USACE	
LUB	114	11/21/91			467.1	72.32	469.4	74.62	394.78	USACE	
LUB	114	12/17/91			467.1	72.15	469.4	74.45	394.95	USACE	
LUB	114	1/22/92			467.1	72.28	469.4	74.58	394.82	USACE	
LUB	114	2/18/92			467.1	72.1	469.4	74.4	395.00	USACE	
LUB	114	3/12/92			467.1	72.18	469.4	74.48	394.92	USACE	
LUB	114	4/21/92			467.1	72.13	469.4	74.43	394.97	USACE	
LUB	115	12/20/90			460.2	76.98	462.56	79.34	383.22	USACE	
LUB	115	1/10/91			460.2	76.77	462.56	79.13	383.43	USACE	
LUB	115	2/11/91			460.2	76.53	462.56	78.89	383.67	USACE	
LUB	115	3/20/91			460.2	76.44	462.56	78.8	383.76	USACE	
LUB	115	4/18/91			460.2	76.3	462.56	78.66	383.90	USACE	
LUB	115	5/25/91			460.2	76.24	462.56	78.6	383.96	USACE	
LUB	115	6/26/91			460.2	76.27	462.56	78.63	383.93	USACE	
LUB	115	7/23/91			460.2	76.4	462.56	78.76	383.80	USACE	
LUB	115	8/20/91			460.2	76.55	462.56	78.91	383.65	USACE	
LUB	115	9/25/91			460.2	76.72	462.56	79.08	383.48	USACE	
LUB	115	10/18/91			460.2	76.85	462.56	79.21	383.35	USACE	
LUB	115	11/21/91			460.2	76.76	462.56	79.12	383.44	USACE	
LUB	115	12/17/91			460.2	76.46	462.56	78.82	383.74	USACE	
LUB	115	1/22/92			460.2	76.41	462.56	78.77	383.79	USACE	
LUB	115	2/18/92			460.2	76.19	462.56	78.55	384.01	USACE	
LUB	115	3/12/92			460.2	76.2	462.56	78.56	384.00	USACE	
LUB	115	4/21/92			460.2	76.04	462.56	78.4	384.16	USACE	
LUB	116	12/20/90			454.8	67.2	457.2	69.6	387.60	USACE	
LUB	116	1/10/91			454.8	67.09	457.2	69.49	387.71	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	116	2/11/91			454.8	87.02	457.2	89.42	367.78	USACE	
LUB	116	3/20/91			454.8	67.02	457.2	69.42	387.78	USACE	
LUB	116	4/18/91			454.8	67.03	457.2	69.43	387.77	USACE	
LUB	116	5/25/91			454.8	66.95	457.2	69.35	387.85	USACE	
LUB	116	6/26/91			454.8	66.96	457.2	69.36	387.84	USACE	
LUB	116	7/23/91			454.8	66.95	457.2	69.35	387.85	USACE	
LUB	116	8/20/91			454.8	66.96	457.2	69.36	387.84	USACE	
LUB	116	9/25/91			454.8	66.97	457.2	69.37	387.83	USACE	
LUB	116	10/18/91			454.8	67.11	457.2	69.51	387.69	USACE	
LUB	116	11/21/91			454.8	67.06	457.2	69.46	387.74	USACE	
LUB	116	12/17/91			454.8	66.94	457.2	69.34	387.86	USACE	
LUB	116	1/22/92			454.8	66.98	457.2	69.38	387.82	USACE	
LUB	116	2/18/92			454.8	66.85	457.2	69.25	387.95	USACE	
LUB	116	3/12/92			454.8	66.92	457.2	69.32	387.88	USACE	
LUB	116	4/21/92			454.8	66.87	457.2	69.27	387.93	USACE	
LUB	117	12/20/90			565.6	81.84	567.64	83.88	483.76	USACE	
LUB	117	1/10/91			565.6	81.65	567.64	83.69	483.95	USACE	
LUB	117	2/11/91			565.6	81.48	567.64	83.52	484.12	USACE	
LUB	117	3/20/91			565.6	81.44	567.64	83.48	484.16	USACE	
LUB	117	4/18/91			565.6	81.38	567.64	83.42	484.22	USACE	
LUB	117	5/25/91			565.6	81.3	567.64	83.34	484.30	USACE	
LUB	117	6/26/91			565.6	81.2	567.64	83.24	484.40	USACE	
LUB	117	7/23/91			565.6	81.17	567.64	83.21	484.43	USACE	
LUB	117	8/20/91			565.6	81.12	567.64	83.16	484.48	USACE	
LUB	117	9/25/91			565.6	81.09	567.64	83.13	484.51	USACE	
LUB	117	10/18/91			565.6	81.22	567.64	83.26	484.38	USACE	
LUB	117	11/21/91			565.6	81.16	567.64	83.2	484.44	USACE	
LUB	117	12/17/91			565.6	80.85	567.64	82.89	484.75	USACE	
LUB	117	1/22/92			565.6	80.91	567.64	82.95	484.69	USACE	
LUB	117	2/18/92			565.6	80.68	567.64	82.72	484.92	USACE	
LUB	117	3/12/92			565.6	80.77	567.64	82.81	484.83	USACE	
LUB	117	4/21/92			565.6	80.64	567.64	82.68	484.96	USACE	
LUB	118	12/20/90			567.9	84.28	570.11	86.49	483.62	USACE	
LUB	118	1/10/91			567.9	84.08	570.11	86.29	483.82	USACE	
LUB	118	2/11/91			567.9	83.94	570.11	86.15	483.96	USACE	
LUB	118	3/20/91			567.9	83.84	570.11	86.05	484.06	USACE	
LUB	118	4/18/91			567.9	83.84	570.11	86.05	484.06	USACE	
LUB	118	5/25/91			567.9	83.74	570.11	85.95	484.16	USACE	
LUB	118	6/26/91			567.9	83.64	570.11	85.85	484.26	USACE	
LUB	118	7/23/91			567.9	83.62	570.11	85.83	484.28	USACE	
LUB	118	8/20/91			567.9	83.59	570.11	85.8	484.31	USACE	
LUB	118	9/25/91			567.9	83.55	570.11	85.76	484.35	USACE	
LUB	118	10/18/91			567.9	83.73	570.11	85.94	484.17	USACE	
LUB	118	11/21/91			567.9	83.67	570.11	85.88	484.23	USACE	
LUB	118	12/17/91			567.9	83.26	570.11	85.47	484.64	USACE	
LUB	118	1/22/92			567.9	83.38	570.11	85.59	484.52	USACE	
LUB	118	2/18/92			567.9	83.12	570.11	85.33	484.78	USACE	
LUB	118	3/12/92			567.9	83.23	570.11	85.44	484.67	USACE	
LUB	118	4/21/92			567.9	83.12	570.11	85.33	484.78	USACE	
LUB	119	12/20/90			572.2	87.3	574.52	89.62	484.90	USACE	
LUB	119	1/10/91			572.2	87.11	574.52	89.43	485.09	USACE	
LUB	119	2/11/91			572.2	86.9	574.52	89.22	485.30	USACE	
LUB	119	3/20/91			572.2	86.92	574.52	89.24	485.28	USACE	
LUB	119	4/18/91			572.2	86.88	574.52	89.2	485.32	USACE	
LUB	119	5/25/91			572.2	86.81	574.52	89.13	485.39	USACE	
LUB	119	6/26/91			572.2	86.69	574.52	89.01	485.51	USACE	
LUB	119	7/23/91			572.2	86.68	574.52	89	485.52	USACE	
LUB	119	8/20/91			572.2	86.65	574.52	88.97	485.55	USACE	
LUB	119	9/25/91			572.2	86.6	574.52	88.92	485.60	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	119	10/18/91			572.2	86.73	574.52	89.05	485.47	USACE	
LUB	119	11/21/91			572.2	86.71	574.52	89.03	485.49	USACE	
LUB	119	12/17/91			572.2	86.37	574.52	88.69	485.83	USACE	
LUB	119	1/22/92			572.2	86.47	574.52	88.79	485.73	USACE	
LUB	119	2/18/92			572.2	86.23	574.52	88.55	485.97	USACE	
LUB	119	3/12/92			572.2	86.32	574.52	88.64	485.88	USACE	
LUB	119	4/21/92			572.2	86.22	574.52	88.54	485.98	USACE	
LUB	120	12/20/90			519.2	62.66	521.5	64.96	456.54	USACE	
LUB	120	1/10/91			519.2	62.5	521.5	64.8	456.70	USACE	
LUB	120	2/11/91			519.2	62.35	521.5	64.65	456.85	USACE	
LUB	120	3/20/91			519.2	62.22	521.5	64.52	456.98	USACE	
LUB	120	4/18/91			519.2	62.1	521.5	64.4	457.10	USACE	
LUB	120	5/25/91			519.2	61.94	521.5	64.24	457.26	USACE	
LUB	120	6/26/91			519.2	61.79	521.5	64.09	457.41	USACE	
LUB	120	7/23/91			519.2	61.68	521.5	63.98	457.52	USACE	
LUB	120	8/20/91			519.2	61.57	521.5	63.87	457.63	USACE	
LUB	120	9/25/91			519.2	61.46	521.5	63.76	457.74	USACE	
LUB	120	10/18/91			519.2	61.53	521.5	63.83	457.67	USACE	
LUB	120	11/21/91			519.2	61.32	521.5	63.62	457.88	USACE	
LUB	120	12/17/91			519.2	61.09	521.5	63.39	458.11	USACE	
LUB	120	1/22/92			519.2	60.96	521.5	63.26	458.24	USACE	
LUB	120	2/18/92			519.2	60.78	521.5	63.08	458.42	USACE	
LUB	120	3/12/92			519.2	60.72	521.5	63.02	458.48	USACE	
LUB	120	4/21/92			519.2	60.5	521.5	62.8	458.70	USACE	
LUB	121	12/20/90			521.9	75.49	524.39	77.98	446.41	USACE	
LUB	121	1/10/91			521.9	75.36	524.39	77.85	446.54	USACE	
LUB	121	2/11/91			521.9	75.16	524.39	77.65	446.74	USACE	
LUB	121	3/20/91			521.9	75.06	524.39	77.55	446.84	USACE	
LUB	121	4/18/91			521.9	74.94	524.39	77.43	446.96	USACE	
LUB	121	5/25/91			521.9	74.73	524.39	77.22	447.17	USACE	
LUB	121	6/26/91			521.9	74.62	524.39	77.11	447.28	USACE	
LUB	121	7/23/91			521.9	74.49	524.39	76.98	447.41	USACE	
LUB	121	8/20/91			521.9	74.36	524.39	76.85	447.54	USACE	
LUB	121	9/25/91			521.9	74.26	524.39	76.75	447.64	USACE	
LUB	121	10/18/91			521.9	74.23	524.39	76.72	447.67	USACE	
LUB	121	11/21/91			521.9	74.07	524.39	76.56	447.83	USACE	
LUB	121	12/17/91			521.9	73.85	524.39	76.34	448.05	USACE	
LUB	121	1/22/92			521.9	73.75	524.39	76.24	448.15	USACE	
LUB	121	2/18/92			521.9	73.54	524.39	76.03	448.36	USACE	
LUB	121	3/12/92			521.9	73.51	524.39	76	448.39	USACE	
LUB	121	4/21/92			521.9	73.32	524.39	75.81	448.58	USACE	
LUB	122	12/20/90			551.7	87.5	554.27	90.07	464.20	USACE	
LUB	122	1/10/91			551.7	87.28	554.27	89.85	464.42	USACE	
LUB	122	2/11/91			551.7	87.11	554.27	89.68	464.59	USACE	
LUB	122	3/20/91			551.7	86.96	554.27	89.53	464.74	USACE	
LUB	122	4/18/91			551.7	86.78	554.27	89.35	464.92	USACE	
LUB	122	5/25/91			551.7	86.58	554.27	89.15	465.12	USACE	
LUB	122	6/26/91			551.7	86.38	554.27	88.95	465.32	USACE	
LUB	122	7/23/91			551.7	86.26	554.27	88.83	465.44	USACE	
LUB	122	8/20/91			551.7	86.13	554.27	88.7	465.57	USACE	
LUB	122	9/25/91			551.7	86.02	554.27	88.59	465.68	USACE	
LUB	122	10/18/91			551.7	86.02	554.27	88.59	465.68	USACE	
LUB	122	11/21/91			551.7	85.86	554.27	88.43	465.84	USACE	
LUB	122	12/17/91			551.7	85.5	554.27	88.07	466.20	USACE	
LUB	122	1/22/92			551.7	85.36	554.27	87.93	466.34	USACE	
LUB	122	2/18/92			551.7	85.02	554.27	87.59	466.68	USACE	
LUB	122	3/12/92			551.7	84.94	554.27	87.51	466.76	USACE	
LUB	122	4/21/92			551.7	84.63	554.27	87.2	467.07	USACE	
LUB	123	12/20/90			544.2	65.61	546.42	67.83	478.59	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	123	1/10/91			544.2	65.39	546.42	67.61	478.81	USACE	
LUB	123	2/11/91			544.2	65.2	546.42	67.42	479.00	USACE	
LUB	123	3/20/91			544.2	65.02	546.42	67.24	479.18	USACE	
LUB	123	4/18/91			544.2	64.91	546.42	67.13	479.29	USACE	
LUB	123	5/25/91			544.2	64.73	546.42	66.95	479.47	USACE	
LUB	123	6/26/91			544.2	64.57	546.42	66.79	479.63	USACE	
LUB	123	7/23/91			544.2	64.46	546.42	66.68	479.74	USACE	
LUB	123	8/20/91			544.2	64.35	546.42	66.57	479.85	USACE	
LUB	123	9/25/91			544.2	64.25	546.42	66.47	479.95	USACE	
LUB	123	10/18/91			544.2	64.36	546.42	66.58	479.84	USACE	
LUB	123	11/21/91			544.2	64.15	546.42	66.37	480.05	USACE	
LUB	123	12/17/91			544.2	63.93	546.42	66.15	480.27	USACE	
LUB	123	1/22/92			544.2	63.83	546.42	66.05	480.37	USACE	
LUB	123	2/18/92			544.2	63.67	546.42	65.89	480.53	USACE	
LUB	123	3/12/92			544.2	63.63	546.42	65.85	480.57	USACE	
LUB	123	4/21/92			544.2	63.53	546.42	65.75	480.67	USACE	
LUB	124	12/19/90			562.9	67.19	564.76	69.05	495.71	USACE	
LUB	124	1/12/91			562.9	66.94	564.76	68.8	495.96	USACE	
LUB	124	2/11/91			562.9	66.66	564.76	68.52	496.24	USACE	
LUB	124	3/20/91			562.9	65.69	564.76	67.55	497.21	USACE	
LUB	124	4/18/91			562.9	64.67	564.76	66.53	498.23	USACE	
LUB	124	5/25/91			562.9	63.71	564.76	65.57	499.19	USACE	
LUB	124	6/26/91			562.9	63.55	564.76	65.41	499.35	USACE	
LUB	124	7/22/91			562.9	64.11	564.76	65.97	498.79	USACE	
LUB	124	8/20/91			562.9	64.81	564.76	66.67	498.09	USACE	
LUB	124	9/25/91			562.9	65.44	564.76	67.3	497.46	USACE	
LUB	124	10/17/91			562.9	65.41	564.76	67.27	497.49	USACE	
LUB	124	11/20/91			562.9	65.31	564.76	67.17	497.59	USACE	
LUB	124	12/18/91			562.9	65.14	564.76	67	497.76	USACE	
LUB	124	1/22/92			562.9	64.97	564.76	66.83	497.93	USACE	
LUB	124	2/17/92			562.9	64.93	564.76	66.79	497.97	USACE	
LUB	124	3/11/92			562.9	64.46	564.76	66.32	498.44	USACE	
LUB	124	4/20/92			562.9	63.78	564.76	65.64	499.12	USACE	
LUB	125	12/19/90			547.5	86.8	549.39	88.69	460.70	USACE	
LUB	125	1/12/91			547.5	87.98	549.39	89.87	459.52	USACE	
LUB	125	2/11/91			547.5	83.51	549.39	85.4	463.99	USACE	
LUB	125	3/20/91			547.5	80.96	549.39	82.85	466.54	USACE	
LUB	125	4/18/91			547.5	80.4	549.39	82.29	467.10	USACE	
LUB	125	5/25/91			547.5	81.03	549.39	82.92	466.47	USACE	
LUB	125	6/26/91			547.5	80.21	549.39	82.1	467.29	USACE	
LUB	125	7/22/91			547.5	85.92	549.39	87.81	461.58	USACE	
LUB	125	8/20/91			547.5	89.48	549.39	91.37	458.02	USACE	
LUB	125	9/25/91			547.5	91.08	549.39	92.97	456.42	USACE	
LUB	125	10/17/91			547.5	85.57	549.39	87.46	461.93	USACE	
LUB	125	11/20/91			547.5	86.73	549.39	88.62	460.77	USACE	
LUB	125	12/17/91			547.5	83.89	549.39	85.78	463.61	USACE	
LUB	125	1/21/92			547.5	82.86	549.39	84.75	464.64	USACE	
LUB	125	2/17/92			547.5	82.25	549.39	84.14	465.25	USACE	
LUB	125	3/11/92			547.5	81.43	549.39	83.32	466.07	USACE	
LUB	125	4/20/92			547.5	80.92	549.39	82.81	466.58	USACE	
LUB	126	12/19/90			562.5	66.81	564.46	68.77	495.69	USACE	
LUB	126	1/12/91			562.5	66.56	564.46	68.52	495.94	USACE	
LUB	126	2/11/91			562.5	66.29	564.46	68.25	496.21	USACE	
LUB	126	3/20/91			562.5	65.31	564.46	67.27	497.19	USACE	
LUB	126	4/18/91			562.5	64.28	564.46	66.24	498.22	USACE	
LUB	126	5/25/91			562.5	63.31	564.46	65.27	499.19	USACE	
LUB	126	6/26/91			562.5	63.16	564.46	65.12	499.34	USACE	
LUB	126	7/22/91			562.5	63.72	564.46	65.68	498.78	USACE	
LUB	126	8/20/91			562.5	64.41	564.46	66.37	498.09	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	126	9/25/91			562.5	65.03	564.46	66.99	497.47	USACE	
LUB	126	10/17/91			562.5	65.02	564.46	66.98	497.48	USACE	
LUB	126	11/20/91			562.5	64.93	564.46	66.89	497.57	USACE	
LUB	126	12/18/91			562.5	64.77	564.46	66.73	497.73	USACE	
LUB	126	1/22/92			562.5	64.64	564.46	66.6	497.86	USACE	
LUB	126	2/17/92			562.5	64.51	564.46	66.47	497.99	USACE	
LUB	126	3/11/92			562.5	64.06	564.46	66.02	498.44	USACE	
LUB	126	4/20/92			562.5	63.38	564.46	65.34	499.12	USACE	
LUB	127	12/19/90			614.3	118.6	616.51	120.81	495.70	USACE	
LUB	127	1/12/91			614.3	118.37	616.51	120.58	495.93	USACE	
LUB	127	2/11/91			614.3	118	616.51	120.21	496.30	USACE	
LUB	127	3/20/91			614.3	116.93	616.51	119.14	497.37	USACE	
LUB	127	4/18/91			614.3	115.87	616.51	118.08	498.43	USACE	
LUB	127	5/24/91			614.3	114.95	616.51	117.16	499.35	USACE	
LUB	127	6/26/91			614.3	115.03	616.51	117.24	499.27	USACE	
LUB	127	7/22/91			614.3	115.75	616.51	117.96	498.55	USACE	
LUB	127	8/20/91			614.3	116.44	616.51	118.65	497.86	USACE	
LUB	127	9/25/91			614.3	117.01	616.51	119.22	497.29	USACE	
LUB	127	10/17/91			614.3	116.67	616.51	118.88	497.63	USACE	
LUB	127	11/20/91			614.3	116.76	616.51	118.97	497.54	USACE	
LUB	127	12/18/91			614.3	116.6	616.51	118.81	497.70	USACE	
LUB	127	1/21/92			614.3	116.46	616.51	118.67	497.84	USACE	
LUB	127	2/17/92			614.3	116.33	616.51	118.54	497.97	USACE	
LUB	127	3/11/92			614.3	115.74	616.51	117.95	498.56	USACE	
LUB	127	4/20/92			614.3	115.15	616.51	117.36	499.15	USACE	
LUB	128	12/19/90			556.9	61.19	559.02	63.31	495.71	USACE	
LUB	128	1/12/91			556.9	60.98	559.02	63.1	495.92	USACE	
LUB	128	2/11/91			556.9	60.73	559.02	62.85	496.17	USACE	
LUB	128	3/20/91			556.9	59.86	559.02	61.98	497.04	USACE	
LUB	128	4/18/91			556.9	58.86	559.02	60.98	498.04	USACE	
LUB	128	5/25/91			556.9	57.88	559.02	60	499.02	USACE	
LUB	128	6/26/91			556.9	57.57	559.02	59.69	499.33	USACE	
LUB	128	7/22/91			556.9	58.04	559.02	60.16	498.86	USACE	
LUB	128	8/20/91			556.9	58.69	559.02	60.81	498.21	USACE	
LUB	128	9/24/91			556.9	59.28	559.02	61.4	497.62	USACE	
LUB	128	10/17/91			556.9	59.43	559.02	61.55	497.47	USACE	
LUB	128	11/20/91			556.9	59.34	559.02	61.46	497.56	USACE	
LUB	128	12/18/91			556.9	59.2	559.02	61.32	497.70	USACE	
LUB	128	1/22/92			556.9	59.06	559.02	61.18	497.84	USACE	
LUB	128	2/17/92			556.9	58.96	559.02	61.08	497.94	USACE	
LUB	128	3/11/92			556.9	58.58	559.02	60.7	498.32	USACE	
LUB	128	4/20/92			556.9	57.85	559.02	59.97	499.05	USACE	
LUB	129	12/19/90			547	51.29	549.13	53.42	495.71	USACE	
LUB	129	1/13/91			547	51.06	549.13	53.19	495.94	USACE	
LUB	129	2/11/91			547	50.74	549.13	52.87	496.26	USACE	
LUB	129	3/20/91			547	49.76	549.13	51.89	497.24	USACE	
LUB	129	4/18/91			547	48.77	549.13	50.9	498.23	USACE	
LUB	129	5/25/91			547	47.81	549.13	49.94	499.19	USACE	
LUB	129	6/26/91			547	47.65	549.13	49.78	499.35	USACE	
LUB	129	7/22/91			547	48.22	549.13	50.35	498.78	USACE	
LUB	129	8/20/91			547	48.88	549.13	51.01	498.12	USACE	
LUB	129	9/25/91			547	49.5	549.13	51.63	497.50	USACE	
LUB	129	10/17/91			547	49.49	549.13	51.62	497.51	USACE	
LUB	129	11/20/91			547	49.42	549.13	51.55	497.58	USACE	
LUB	129	12/18/91			547	49.3	549.13	51.43	497.70	USACE	
LUB	129	1/22/92			547	49.12	549.13	51.25	497.88	USACE	
LUB	129	2/17/92			547	49	549.13	51.13	498.00	USACE	
LUB	129	3/11/92			547	48.52	549.13	50.65	498.48	USACE	
LUB	129	4/20/92			547	47.85	549.13	49.98	499.15	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	13	2/11/91	Idle	E Tape	279	14.7			264.30	OWRD	
LUB	13	2/10/92	Idle	E Tape	279	16.81			262.19	OWRD	
LUB	130	12/19/90			604.4	103.61	606.56	105.77	500.79	USACE	
LUB	130	1/12/91			604.4	103.52	606.56	105.68	500.88	USACE	
LUB	130	2/11/91			604.4	103.49	606.56	105.65	500.91	USACE	
LUB	130	3/20/91			604.4	103.51	606.56	105.67	500.89	USACE	
LUB	130	4/18/91			604.4	103.64	606.56	105.8	500.76	USACE	
LUB	130	5/25/91			604.4	103.63	606.56	105.79	500.77	USACE	
LUB	130	6/26/91			604.4	103.61	606.56	105.77	500.79	USACE	
LUB	130	7/22/91			604.4	103.61	606.56	105.77	500.79	USACE	
LUB	130	8/19/91			604.4	103.57	606.56	105.73	500.83	USACE	
LUB	130	9/24/91			604.4	103.65	606.56	105.81	500.75	USACE	
LUB	130	10/17/91			604.4	103.68	606.56	105.84	500.72	USACE	
LUB	130	11/20/91			604.4	103.66	606.56	105.82	500.74	USACE	
LUB	130	12/17/91			604.4	103.62	606.56	105.78	500.78	USACE	
LUB	130	1/21/92			604.4	103.73	606.56	105.89	500.67	USACE	
LUB	130	2/17/92			604.4	103.69	606.56	105.85	500.71	USACE	
LUB	130	3/11/92			604.4	103.69	606.56	105.85	500.71	USACE	
LUB	130	4/20/92			604.4	103.69	606.56	105.85	500.71	USACE	
LUB	131	12/19/90			512.5	59.91	514.75	62.16	452.59	USACE	
LUB	131	1/13/91			512.5	60.3	514.75	62.55	452.20	USACE	
LUB	131	2/11/91			512.5	56.91	514.75	59.16	455.59	USACE	
LUB	131	3/20/91			512.5	54.56	514.75	56.81	457.94	USACE	
LUB	131	4/18/91			512.5	54.49	514.75	56.74	458.01	USACE	
LUB	131	5/25/91			512.5	54.12	514.75	56.37	458.38	USACE	
LUB	131	6/26/91			512.5	54.39	514.75	56.64	458.11	USACE	
LUB	131	7/22/91			512.5	58.61	514.75	60.86	453.89	USACE	
LUB	131	8/20/91			512.5	62.21	514.75	64.46	450.29	USACE	
LUB	131	9/25/91			512.5	64	514.75	66.25	448.50	USACE	
LUB	131	10/17/91			512.5	61.07	514.75	63.32	451.43	USACE	
LUB	131	11/20/91			512.5	59.65	514.75	61.9	452.85	USACE	
LUB	131	12/18/91			512.5	58.45	514.75	60.7	454.05	USACE	
LUB	131	1/22/92			512.5	57.3	514.75	59.55	455.20	USACE	
LUB	131	2/17/92			512.5	56.47	514.75	58.72	456.03	USACE	
LUB	131	3/11/92			512.5	55.65	514.75	57.9	456.85	USACE	
LUB	131	4/20/92			512.5	54.91	514.75	57.16	457.59	USACE	
LUB	132	12/19/90			554.5	58.79	557.58	61.87	495.71	USACE	
LUB	132	1/12/91			554.5	58.57	557.58	61.65	495.93	USACE	
LUB	132	2/11/91			554.5	58.27	557.58	61.35	496.23	USACE	
LUB	132	3/20/91			554.5	57.29	557.58	60.37	497.21	USACE	
LUB	132	4/18/91			554.5	56.27	557.58	59.35	498.23	USACE	
LUB	132	5/25/91			554.5	55.35	557.58	58.43	499.15	USACE	
LUB	132	6/26/91			554.5	55.15	557.58	58.23	499.35	USACE	
LUB	132	7/22/91			554.5	55.72	557.58	58.8	498.78	USACE	
LUB	132	8/20/91			554.5	56.41	557.58	59.49	498.09	USACE	
LUB	132	9/25/91			554.5	57.04	557.58	60.12	497.46	USACE	
LUB	132	10/17/91			554.5	57.03	557.58	60.11	497.47	USACE	
LUB	132	11/20/91			554.5	56.9	557.58	59.98	497.60	USACE	
LUB	132	12/18/91			554.5	56.76	557.58	59.84	497.74	USACE	
LUB	132	1/22/92			554.5	56.63	557.58	59.71	497.87	USACE	
LUB	132	2/17/92			554.5	56.51	557.58	59.59	497.99	USACE	
LUB	132	3/11/92			554.5	56.07	557.58	59.15	498.43	USACE	
LUB	132	4/20/92			554.5	55.37	557.58	58.45	499.13	USACE	
LUB	133	12/19/90			568.7	73.02	571.09	75.41	495.68	USACE	
LUB	133	1/12/91			568.7	72.84	571.09	75.23	495.86	USACE	
LUB	133	2/11/91			568.7	72.61	571.09	75	496.09	USACE	
LUB	133	3/20/91			568.7	71.84	571.09	74.23	496.86	USACE	
LUB	133	4/18/91			568.7	70.91	571.09	73.3	497.79	USACE	
LUB	133	5/25/91			568.7	69.91	571.09	72.3	498.79	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	133	6/29/91			568.7	69.46	571.09	71.85	499.24	USACE	
LUB	133	7/22/91			568.7	69.84	571.09	72.23	498.86	USACE	
LUB	133	8/20/91			568.7	70.36	571.09	72.75	498.34	USACE	
LUB	133	9/25/91			568.7	71.07	571.09	73.46	497.63	USACE	
LUB	133	10/17/91			568.7	71.18	571.09	73.57	497.52	USACE	
LUB	133	11/20/91			568.7	71.12	571.09	73.51	497.58	USACE	
LUB	133	12/18/91			568.7	71	571.09	73.39	497.70	USACE	
LUB	133	1/22/92			568.7	70.9	571.09	73.29	497.80	USACE	
LUB	133	2/17/92			568.7	70.75	571.09	73.14	497.95	USACE	
LUB	133	3/11/92			568.7	70.52	571.09	72.91	498.18	USACE	
LUB	133	4/20/92			568.7	69.79	571.09	72.18	498.91	USACE	
LUB	134	12/19/90			545.8	50.05	547.71	51.96	495.75	USACE	
LUB	134	1/10/91			545.8	49.83	547.71	51.74	495.97	USACE	
LUB	134	2/11/91			545.8	49.38	547.71	51.29	496.42	USACE	
LUB	134	3/20/91			545.8	48.12	547.71	50.03	497.68	USACE	
LUB	134	4/18/91			545.8	47.14	547.71	49.05	498.66	USACE	
LUB	134	5/24/91			545.8	46.31	547.71	48.22	499.49	USACE	
LUB	134	6/26/91			545.8	46.54	547.71	48.45	499.26	USACE	
LUB	134	7/22/91			545.8	47.34	547.71	49.25	498.46	USACE	
LUB	134	8/19/91			545.8	48.02	547.71	49.93	497.78	USACE	
LUB	134	9/24/91			545.8	48.59	547.71	50.5	497.21	USACE	
LUB	134	10/17/91			545.8	48.35	547.71	50.26	497.45	USACE	
LUB	134	11/19/91			545.8	48.08	547.71	49.99	497.72	USACE	
LUB	134	12/18/91			545.8	48.03	547.71	49.94	497.77	USACE	
LUB	134	1/22/92			545.8	47.89	547.71	49.8	497.91	USACE	
LUB	134	2/17/92			545.8	47.7	547.71	49.61	498.10	USACE	
LUB	134	3/11/92			545.8	47.02	547.71	48.93	498.78	USACE	
LUB	134	4/20/92			545.8	46.23	547.71	48.14	499.57	USACE	
LUB	135	12/18/90			612.7	117.07	615.21	119.58	495.63	USACE	
LUB	135	1/12/91			612.7	116.85	615.21	119.36	495.85	USACE	
LUB	135	2/11/91			612.7	116.48	615.21	118.99	496.22	USACE	
LUB	135	3/20/91			612.7	115.32	615.21	117.83	497.38	USACE	
LUB	135	4/18/91			612.7	114.27	615.21	116.78	498.43	USACE	
LUB	135	5/24/91			612.7	113.33	615.21	115.84	499.37	USACE	
LUB	135	6/26/91			612.7	113.51	615.21	116.02	499.19	USACE	
LUB	135	7/22/91			612.7	114.29	615.21	116.8	498.41	USACE	
LUB	135	8/20/91			612.7	114.97	615.21	117.48	497.73	USACE	
LUB	135	9/24/91			612.7	115.5	615.21	118.01	497.20	USACE	
LUB	135	10/17/91			612.7	115.1	615.21	117.61	497.60	USACE	
LUB	135	11/20/91			612.7	115.22	615.21	117.73	497.48	USACE	
LUB	135	12/18/91			612.7	115.03	615.21	117.54	497.67	USACE	
LUB	135	1/21/92			612.7	114.94	615.21	117.45	497.76	USACE	
LUB	135	2/17/92			612.7	114.8	615.21	117.31	497.90	USACE	
LUB	135	3/11/92			612.7	114.16	615.21	116.67	498.54	USACE	
LUB	135	4/20/92			612.7	113.62	615.21	116.13	499.08	USACE	
LUB	136	12/18/90			606.8	111.07	608.79	113.06	495.73	USACE	
LUB	136	1/12/91			606.8	110.86	608.79	112.85	495.94	USACE	
LUB	136	2/11/91			606.8	110.46	608.79	112.45	496.34	USACE	
LUB	136	3/20/91			606.8	109.22	608.79	111.21	497.58	USACE	
LUB	136	4/18/91			606.8	108.2	608.79	110.19	498.60	USACE	
LUB	136	5/24/91			606.8	107.27	608.79	109.26	499.53	USACE	
LUB	136	6/26/91			606.8	107.61	608.79	109.6	499.19	USACE	
LUB	136	7/22/91			606.8	108.41	608.79	110.4	498.39	USACE	
LUB	136	8/20/91			606.8	109.06	608.79	111.05	497.74	USACE	
LUB	136	9/25/91			606.8	109.57	608.79	111.56	497.23	USACE	
LUB	136	10/17/91			606.8	109.18	608.79	111.17	497.62	USACE	
LUB	136	11/20/91			606.8	109.26	608.79	111.25	497.54	USACE	
LUB	136	12/18/91			606.8	109.09	608.79	111.08	497.71	USACE	
LUB	136	1/21/92			606.8	108.96	608.79	110.95	497.84	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	136	2/17/92			606.8	108.79	608.79	110.78	498.01	USACE	
LUB	136	3/11/92			606.8	108.12	608.79	110.11	498.68	USACE	
LUB	136	4/20/92			606.8	107.62	608.79	109.61	499.18	USACE	
LUB	137	12/19/90			609.1	113.73	611.46	116.09	495.37	USACE	
LUB	137	1/10/91			609.1	113.54	611.46	115.9	495.56	USACE	
LUB	137	2/11/91			609.1	113.07	611.46	115.43	496.03	USACE	
LUB	137	3/20/91			609.1	111.95	611.46	114.31	497.15	USACE	
LUB	137	4/18/91			609.1	110.87	611.46	113.23	498.23	USACE	
LUB	137	5/24/91			609.1	109.88	611.46	112.24	499.22	USACE	
LUB	137	6/26/91			609.1	110.19	611.46	112.55	498.91	USACE	
LUB	137	7/22/91			609.1	111.01	611.46	113.37	498.09	USACE	
LUB	137	8/19/91			609.1	111.61	611.46	113.97	497.49	USACE	
LUB	137	9/24/91			609.1	112.14	611.46	114.5	496.96	USACE	
LUB	137	10/17/91			609.1	111.76	611.46	114.12	497.34	USACE	
LUB	137	11/20/91			609.1	111.93	611.46	114.29	497.17	USACE	
LUB	137	12/18/91			609.1	111.69	611.46	114.05	497.41	USACE	
LUB	137	1/21/92			609.1	111.57	611.46	113.93	497.53	USACE	
LUB	137	2/17/92			609.1	111.43	611.46	113.79	497.67	USACE	
LUB	137	3/11/92			609.1	110.78	611.46	113.14	498.32	USACE	
LUB	137	4/20/92			609.1	110.24	611.46	112.6	498.86	USACE	
LUB	138	12/19/90			606	110.56	608.1	112.66	495.44	USACE	
LUB	138	1/12/91			606	110.33	608.1	112.43	495.67	USACE	
LUB	138	2/11/91			606	109.99	608.1	112.09	496.01	USACE	
LUB	138	3/20/91			606	108.89	608.1	110.99	497.11	USACE	
LUB	138	4/18/91			606	107.85	608.1	109.95	498.15	USACE	
LUB	138	5/24/91			606	106.9	608.1	109	499.10	USACE	
LUB	138	6/26/91			606	106.94	608.1	109.04	499.06	USACE	
LUB	138	7/22/91			606	107.66	608.1	109.76	498.34	USACE	
LUB	138	8/20/91			606	108.3	608.1	110.4	497.70	USACE	
LUB	138	9/25/91			606	108.92	608.1	111.02	497.08	USACE	
LUB	138	10/17/91			606	108.64	608.1	110.74	497.36	USACE	
LUB	138	11/20/91			606	108.68	608.1	110.78	497.32	USACE	
LUB	138	12/18/91			606	108.51	608.1	110.61	497.49	USACE	
LUB	138	1/21/92			606	108.39	608.1	110.49	497.61	USACE	
LUB	138	2/17/92			606	108.26	608.1	110.36	497.74	USACE	
LUB	138	3/11/92			606	107.76	608.1	109.86	498.24	USACE	
LUB	138	4/20/92			606	107.07	608.1	109.17	498.93	USACE	
LUB	139	12/19/90			526.9	83.05	565.18	121.33	443.85	USACE	
LUB	139	1/12/91			526.9	83.08	565.18	121.36	443.82	USACE	
LUB	139	2/11/91			526.9	80.84	565.18	119.12	446.06	USACE	
LUB	139	3/20/91			526.9	77.82	565.18	116.1	449.08	USACE	
LUB	139	4/18/91			526.9	77.05	565.18	115.33	449.85	USACE	
LUB	139	6/26/91			526.9	78.05	565.18	116.33	448.85	USACE	
LUB	139	7/22/91			526.9	81.07	565.18	119.35	445.83	USACE	
LUB	139	8/20/91			526.9	84.74	565.18	123.02	442.16	USACE	
LUB	139	9/25/91			526.9	86.95	565.18	125.23	439.95	USACE	
LUB	139	10/17/91			526.9	85.77	565.18	124.05	441.13	USACE	
LUB	139	11/20/91			526.9	84.19	565.18	122.47	442.71	USACE	
LUB	139	12/17/91			526.9	82.94	565.18	121.22	443.96	USACE	
LUB	139	1/21/92			526.9	81.33	565.18	119.61	445.57	USACE	
LUB	139	2/17/92			526.9	80.31	565.18	118.59	446.59	USACE	
LUB	139	3/11/92			526.9	79.55	565.18	117.83	447.35	USACE	
LUB	139	4/20/92			526.9	78.62	565.18	116.9	448.28	USACE	
LUB	14	2/11/91	Idle	E Tape	286	20.92			265.08	OWRD	
LUB	14	8/23/91	Idle	E Tape	286	18.85			267.15	OWRD	
LUB	14	2/10/92	Idle	E Tape	286	21.71			264.29	OWRD	
LUB	140	12/19/90			614	153.31	616.12	155.43	460.69	USACE	
LUB	140	1/12/91			614	154.04	616.12	156.16	459.96	USACE	
LUB	140	2/11/91			614	150.65	616.12	152.77	463.35	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	140	3/20/91			614	148.68	616.12	150.8	465.32	USACE	
LUB	140	4/18/91			614	147.65	616.12	149.77	466.35	USACE	
LUB	140	5/24/91			614	147.57	616.12	149.69	466.43	USACE	
LUB	140	6/26/91			614	147.68	616.12	149.8	466.32	USACE	
LUB	140	7/22/91			614	151.8	616.12	153.92	462.20	USACE	
LUB	140	8/20/91			614	155.04	616.12	157.16	458.96	USACE	
LUB	140	9/25/91			614	156.71	616.12	158.83	457.29	USACE	
LUB	140	10/17/91			614	153.57	616.12	155.69	460.43	USACE	
LUB	140	11/20/91			614	152.9	616.12	155.02	461.10	USACE	
LUB	140	12/17/91			614	152.18	616.12	154.3	461.82	USACE	
LUB	140	1/21/92			614	151.1	616.12	153.22	462.90	USACE	
LUB	140	2/17/92			614	150.39	616.12	152.51	463.61	USACE	
LUB	140	3/11/92			614	149.63	616.12	151.75	464.37	USACE	
LUB	140	4/20/92			614	148.82	616.12	150.94	465.18	USACE	
LUB	141	12/20/90			443.6	59.67	445.89	61.96	383.93	USACE	
LUB	141	1/10/91			443.6	59.58	445.89	61.87	384.02	USACE	
LUB	141	2/11/91			443.6	59.47	445.89	61.76	384.13	USACE	
LUB	141	3/20/91			443.6	59.45	445.89	61.74	384.15	USACE	
LUB	141	4/18/91			443.6	59.41	445.89	61.7	384.19	USACE	
LUB	141	5/25/91			443.6	59.32	445.89	61.61	384.28	USACE	
LUB	141	6/26/91			443.6	59.28	445.89	61.57	384.32	USACE	
LUB	141	7/23/91			443.6	59.25	445.89	61.54	384.35	USACE	
LUB	141	8/20/91			443.6	59.23	445.89	61.52	384.37	USACE	
LUB	141	9/25/91			443.6	59.21	445.89	61.5	384.39	USACE	
LUB	141	10/18/91			443.6	59.32	445.89	61.61	384.28	USACE	
LUB	141	11/21/91			443.6	59.23	445.89	61.52	384.37	USACE	
LUB	141	12/17/91			443.6	59.01	445.89	61.3	384.59	USACE	
LUB	141	1/22/92			443.6	59.05	445.89	61.34	384.55	USACE	
LUB	141	2/18/92			443.6	58.73	445.89	61.02	384.87	USACE	
LUB	141	3/12/92			443.6	58.96	445.89	61.25	384.64	USACE	
LUB	141	4/21/92			443.6	58.89	445.89	61.18	384.71	USACE	
LUB	142	12/20/90			406.8	39.04	409.35	41.59	367.76	USACE	
LUB	142	1/10/91			406.8	39.1	409.35	41.65	367.70	USACE	
LUB	142	2/11/91			406.8	39.21	409.35	41.76	367.59	USACE	
LUB	142	3/20/91			406.8	39.36	409.35	41.91	367.44	USACE	
LUB	142	4/18/91			406.8	39.32	409.35	41.87	367.48	USACE	
LUB	142	5/25/91			406.8	38.9	409.35	41.45	367.90	USACE	
LUB	142	6/26/91			406.8	38.52	409.35	41.07	368.28	USACE	
LUB	142	7/23/91			406.8	38.46	409.35	41.01	368.34	USACE	
LUB	142	8/20/91			406.8	38.45	409.35	41	368.35	USACE	
LUB	142	9/25/91			406.8	38.48	409.35	41.03	368.32	USACE	
LUB	142	10/18/91			406.8	38.6	409.35	41.15	368.20	USACE	
LUB	142	11/21/91			406.8	38.65	409.35	41.2	368.15	USACE	
LUB	142	12/17/91			406.8	38.7	409.35	41.25	368.10	USACE	
LUB	142	1/22/92			406.8	38.87	409.35	41.42	367.93	USACE	
LUB	142	2/18/92			406.8	38.95	409.35	41.5	367.85	USACE	
LUB	142	3/12/92			406.8	39.07	409.35	41.62	367.73	USACE	
LUB	142	4/21/92			406.8	38.99	409.35	41.54	367.81	USACE	
LUB	143	12/20/90			425.1	33.82	427.68	36.4	391.28	USACE	
LUB	143	1/10/91			425.1	33.67	427.68	36.25	391.43	USACE	
LUB	143	2/11/91			425.1	33.61	427.68	36.19	391.49	USACE	
LUB	143	3/20/91			425.1	33.64	427.68	36.22	391.46	USACE	
LUB	143	4/18/91			425.1	33.76	427.68	36.34	391.34	USACE	
LUB	143	5/25/91			425.1	33.79	427.68	36.37	391.31	USACE	
LUB	143	6/26/91			425.1	33.55	427.68	36.13	391.55	USACE	
LUB	143	7/23/91			425.1	33.44	427.68	36.02	391.66	USACE	
LUB	143	8/20/91			425.1	36.27	427.68	38.85	388.83	USACE	
LUB	143	9/25/91			425.1	33.03	427.68	35.61	392.07	USACE	
LUB	143	10/18/91			425.1	32.96	427.68	35.54	392.14	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	143	11/21/91			425.1	32.67	427.68	35.25	392.43	USACE	
LUB	143	12/17/91			425.1	32.43	427.68	35.01	392.67	USACE	
LUB	143	1/22/92			425.1	32.4	427.68	34.98	392.70	USACE	
LUB	143	2/18/92			425.1	32.37	427.68	34.95	392.73	USACE	
LUB	143	3/12/92			425.1	32.44	427.68	35.02	392.66	USACE	
LUB	143	4/21/92			425.1	32.49	427.68	35.07	392.61	USACE	
LUB	144	12/18/90			621	125.27	623.23	127.5	495.73	USACE	
LUB	144	1/12/91			621	125.08	623.23	127.31	495.92	USACE	
LUB	144	2/11/91			621	124.78	623.23	127.01	496.22	USACE	
LUB	144	3/20/91			621	123.72	623.23	125.95	497.28	USACE	
LUB	144	4/18/91			621	123.72	623.23	125.95	497.28	USACE	
LUB	144	5/24/91			621	121.73	623.23	123.96	499.27	USACE	
LUB	144	6/26/91			621	121.7	623.23	123.93	499.30	USACE	
LUB	144	7/22/91			621	122.36	623.23	124.59	498.64	USACE	
LUB	144	8/20/91			621	123.03	623.23	125.26	497.97	USACE	
LUB	144	9/25/91			621	123.64	623.23	125.87	497.36	USACE	
LUB	144	10/17/91			621	123.3	623.23	125.53	497.70	USACE	
LUB	144	11/20/91			621	123.44	623.23	125.67	497.56	USACE	
LUB	144	12/18/91			621	123.25	623.23	125.48	497.75	USACE	
LUB	144	1/21/92			621	123.15	623.23	125.38	497.85	USACE	
LUB	144	2/17/92			621	123.04	623.23	125.27	497.96	USACE	
LUB	144	3/11/92			621	122.52	623.23	124.75	498.48	USACE	
LUB	144	4/20/92			621	121.89	623.23	124.12	499.11	USACE	
LUB	145	12/18/90			620.3	124.57	622.46	126.73	495.73	USACE	
LUB	145	1/12/91			620.3	124.38	622.46	126.54	495.92	USACE	
LUB	145	2/11/91			620.3	123.95	622.46	126.11	496.35	USACE	
LUB	145	3/20/91			620.3	122.98	622.46	125.14	497.32	USACE	
LUB	145	4/18/91			620.3	121.98	622.46	124.14	498.32	USACE	
LUB	145	5/24/91			620.3	121.04	622.46	123.2	499.26	USACE	
LUB	145	6/26/91			620.3	121.01	622.46	123.17	499.29	USACE	
LUB	145	7/22/91			620.3	121.68	622.46	123.84	498.62	USACE	
LUB	145	8/20/91			620.3	122.33	622.46	124.49	497.97	USACE	
LUB	145	9/25/91			620.3	122.94	622.46	125.1	497.36	USACE	
LUB	145	10/17/91			620.3	122.62	622.46	124.78	497.68	USACE	
LUB	145	11/20/91			620.3	122.71	622.46	124.87	497.59	USACE	
LUB	145	12/18/91			620.3	122.58	622.46	124.74	497.72	USACE	
LUB	145	1/21/92			620.3	122.46	622.46	124.62	497.84	USACE	
LUB	145	2/17/92			620.3	122.32	622.46	124.48	497.98	USACE	
LUB	145	3/11/92			620.3	121.82	622.46	123.98	498.48	USACE	
LUB	145	4/20/92			620.3	121.19	622.46	123.35	499.11	USACE	
LUB	146	12/18/90			616.9	121.25	619.3	123.65	495.65	USACE	
LUB	146	1/12/91			616.9	121.05	619.3	123.45	495.85	USACE	
LUB	146	2/11/91			616.9	120.7	619.3	123.1	496.20	USACE	
LUB	146	3/20/91			616.9	119.57	619.3	121.97	497.33	USACE	
LUB	146	4/18/91			616.9	118.55	619.3	120.95	498.35	USACE	
LUB	146	5/24/91			616.9	117.6	619.3	120	499.30	USACE	
LUB	146	6/26/91			616.9	117.68	619.3	120.08	499.22	USACE	
LUB	146	7/22/91			616.9	118.37	619.3	120.77	498.53	USACE	
LUB	146	9/25/91			616.9	119.65	619.3	122.05	497.25	USACE	
LUB	146	10/17/91			616.9	119.28	619.3	121.68	497.62	USACE	
LUB	146	11/20/91			616.9	119.39	619.3	121.79	497.51	USACE	
LUB	146	12/18/91			616.9	119.26	619.3	121.66	497.64	USACE	
LUB	146	1/21/92			616.9	119.09	619.3	121.49	497.81	USACE	
LUB	146	2/17/92			616.9	118.99	619.3	121.39	497.91	USACE	
LUB	146	3/11/92			616.9	118.42	619.3	120.82	498.48	USACE	
LUB	146	4/20/92			616.9	117.82	619.3	120.22	499.08	USACE	
LUB	147	12/18/90			617.1	121.38	619.13	123.41	495.72	USACE	
LUB	147	1/12/91			617.1	121.19	619.13	123.22	495.91	USACE	
LUB	147	2/11/91			617.1	120.83	619.13	122.86	496.27	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	147	3/20/91			617.1	119.72	619.13	121.75	497.38	USACE	
LUB	147	4/18/91			617.1	118.68	619.13	120.71	498.42	USACE	
LUB	147	5/24/91			617.1	117.77	619.13	119.8	499.33	USACE	
LUB	147	6/26/91			617.1	117.92	619.13	119.95	499.18	USACE	
LUB	147	7/22/91			617.1	118.54	619.13	120.57	498.56	USACE	
LUB	147	8/20/91			617.1	119.22	619.13	121.25	497.88	USACE	
LUB	147	9/25/91			617.1	119.79	619.13	121.82	497.31	USACE	
LUB	147	10/17/91			617.1	119.41	619.13	121.44	497.69	USACE	
LUB	147	11/20/91			617.1	119.53	619.13	121.56	497.57	USACE	
LUB	147	12/18/91			617.1	119.38	619.13	121.41	497.72	USACE	
LUB	147	1/21/92			617.1	119.26	619.13	121.29	497.84	USACE	
LUB	147	2/17/92			617.1	119.12	619.13	121.15	497.98	USACE	
LUB	147	3/11/92			617.1	118.54	619.13	120.57	498.56	USACE	
LUB	147	4/20/92			617.1	117.95	619.13	119.98	499.15	USACE	
LUB	148	12/19/90			563	67.12	563.58	67.7	495.88	USACE	
LUB	148	1/13/91			563	66.86	563.58	67.44	496.14	USACE	
LUB	148	2/11/91			563	66.07	563.58	66.65	496.93	USACE	
LUB	148	3/20/91			563	64.39	563.58	64.97	498.61	USACE	
LUB	148	4/18/91			563	63.7	563.58	64.28	499.30	USACE	
LUB	148	5/25/91			563	63.27	563.58	63.85	499.73	USACE	
LUB	148	6/26/91			563	64.07	563.58	64.65	498.93	USACE	
LUB	148	7/22/91			563	65.37	563.58	65.95	497.63	USACE	
LUB	148	8/20/91			563	65.67	563.58	66.25	497.33	USACE	
LUB	148	9/25/91			563	65.99	563.58	66.57	497.01	USACE	
LUB	148	10/18/91			563	65.78	563.58	66.36	497.22	USACE	
LUB	148	11/20/91			563	65.44	563.58	66.02	497.56	USACE	
LUB	148	12/18/91			563	65.17	563.58	65.75	497.83	USACE	
LUB	148	1/22/92			563	64.97	563.58	65.55	498.03	USACE	
LUB	148	2/17/92			563	64.46	563.58	65.04	498.54	USACE	
LUB	148	3/12/92			563	63.43	563.58	64.01	499.57	USACE	
LUB	148	4/21/92			563	63.48	563.58	64.06	499.52	USACE	
LUB	149	12/20/90			519.3	74.63	521.68	77.01	444.67	USACE	
LUB	149	1/13/91			519.3	74.45	521.68	76.83	444.85	USACE	
LUB	149	2/11/91			519.3	74.25	521.68	76.63	445.05	USACE	
LUB	149	3/20/91			519.3	74.14	521.68	76.52	445.16	USACE	
LUB	149	4/18/91			519.3	74	521.68	76.38	445.30	USACE	
LUB	149	5/25/91			519.3	73.83	521.68	76.21	445.47	USACE	
LUB	149	6/26/91			519.3	73.66	521.68	76.04	445.64	USACE	
LUB	149	7/23/91			519.3	73.54	521.68	75.92	445.76	USACE	
LUB	149	8/20/91			519.3	73.44	521.68	75.82	445.86	USACE	
LUB	149	9/25/91			519.3	73.32	521.68	75.7	445.98	USACE	
LUB	149	10/18/91			519.3	73.34	521.68	75.72	445.96	USACE	
LUB	149	11/21/91			519.3	73.17	521.68	75.55	446.13	USACE	
LUB	149	12/17/91			519.3	72.89	521.68	75.27	446.41	USACE	
LUB	149	1/22/92			519.3	72.82	521.68	75.2	446.48	USACE	
LUB	149	2/18/92			519.3	72.58	521.68	74.96	446.72	USACE	
LUB	149	3/12/92			519.3	72.55	521.68	74.93	446.75	USACE	
LUB	149	4/21/92			519.3	72.35	521.68	74.73	446.95	USACE	
LUB	150	12/20/90			571.1	85.52	573.32	87.74	485.58	USACE	
LUB	150	1/13/91			571.1	85.32	573.32	87.54	485.78	USACE	
LUB	150	2/11/91			571.1	85.08	573.32	87.3	486.02	USACE	
LUB	150	3/20/91			571.1	85.12	573.32	87.34	485.98	USACE	
LUB	150	4/18/91			571.1	85.1	573.32	87.32	486.00	USACE	
LUB	150	5/25/91			571.1	84.97	573.32	87.19	486.13	USACE	
LUB	150	6/26/91			571.1	84.86	573.32	87.08	486.24	USACE	
LUB	150	7/23/91			571.1	84.83	573.32	87.05	486.27	USACE	
LUB	150	8/20/91			571.1	84.8	573.32	87.02	486.30	USACE	
LUB	150	9/25/91			571.1	84.75	573.32	86.97	486.35	USACE	
LUB	150	10/18/91			571.1	84.86	573.32	87.08	486.24	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	150	11/21/91			571.1	84.81	573.32	87.03	486.29	USACE	
LUB	150	12/17/91			571.1	84.47	573.32	86.69	486.63	USACE	
LUB	150	1/22/92			571.1	84.57	573.32	86.79	486.53	USACE	
LUB	150	2/18/92			571.1	84.34	573.32	86.56	486.76	USACE	
LUB	150	3/12/92			571.1	84.41	573.32	86.63	486.69	USACE	
LUB	150	4/21/92			571.1	84.28	573.32	86.5	486.82	USACE	
LUB	151	12/20/90			573.6	88.44	575.86	90.7	485.16	USACE	
LUB	151	1/13/91			573.6	88.28	575.86	90.54	485.32	USACE	
LUB	151	2/11/91			573.6	88.14	575.86	90.4	485.46	USACE	
LUB	151	3/20/91			573.6	88.09	575.86	90.35	485.51	USACE	
LUB	151	4/18/91			573.6	88.09	575.86	90.35	485.51	USACE	
LUB	151	5/25/91			573.6	88.02	575.86	90.28	485.58	USACE	
LUB	151	6/26/91			573.6	87.89	575.86	90.15	485.71	USACE	
LUB	151	7/23/91			573.6	87.87	575.86	90.13	485.73	USACE	
LUB	151	8/20/91			573.6	87.81	575.86	90.07	485.79	USACE	
LUB	151	9/25/91			573.6	87.8	575.86	90.06	485.80	USACE	
LUB	151	10/18/91			573.6	87.89	575.86	90.15	485.71	USACE	
LUB	151	11/21/91			573.6	87.85	575.86	90.11	485.75	USACE	
LUB	151	12/17/91			573.6	87.59	575.86	89.85	486.01	USACE	
LUB	151	1/22/92			573.6	87.63	575.86	89.89	485.97	USACE	
LUB	151	2/18/92			573.6	87.43	575.86	89.69	486.17	USACE	
LUB	151	3/12/92			573.6	87.48	575.86	89.74	486.12	USACE	
LUB	151	4/21/92			573.6	87.38	575.86	89.64	486.22	USACE	
LUB	152	12/20/90			570.4	73.37	572.55	75.52	497.03	USACE	
LUB	152	1/15/91			570.4	73.29	572.55	75.44	497.11	USACE	
LUB	152	2/11/91			570.4	73.15	572.55	75.3	497.25	USACE	
LUB	152	3/20/91			570.4	73.09	572.55	75.24	497.31	USACE	
LUB	152	4/18/91			570.4	73.09	572.55	75.24	497.31	USACE	
LUB	152	5/25/91			570.4	73.1	572.55	75.25	497.30	USACE	
LUB	152	6/26/91			570.4	72.96	572.55	75.11	497.44	USACE	
LUB	152	7/23/91			570.4	72.97	572.55	75.12	497.43	USACE	
LUB	152	8/20/91			570.4	72.93	572.55	75.08	497.47	USACE	
LUB	152	9/25/91			570.4	72.98	572.55	75.13	497.42	USACE	
LUB	152	10/18/91			570.4	73.1	572.55	75.25	497.30	USACE	
LUB	152	11/21/91			570.4	73.07	572.55	75.22	497.33	USACE	
LUB	152	12/17/91			570.4	72.83	572.55	74.98	497.57	USACE	
LUB	152	1/22/92			570.4	72.91	572.55	75.06	497.49	USACE	
LUB	152	2/18/92			570.4	72.73	572.55	74.88	497.67	USACE	
LUB	152	3/12/92			570.4	72.8	572.55	74.95	497.60	USACE	
LUB	152	4/21/92			570.4	72.76	572.55	74.91	497.64	USACE	
LUB	153	12/20/90			472.7	64.94	475.03	67.27	407.76	USACE	
LUB	153	1/10/91			472.7	64.88	475.03	67.21	407.82	USACE	
LUB	153	2/11/91			472.7	64.75	475.03	67.08	407.95	USACE	
LUB	153	3/20/91			472.7	64.75	475.03	67.08	407.95	USACE	
LUB	153	4/18/91			472.7	64.69	475.03	67.02	408.01	USACE	
LUB	153	5/25/91			472.7	64.65	475.03	66.98	408.05	USACE	
LUB	153	6/26/91			472.7	64.55	475.03	66.88	408.15	USACE	
LUB	153	7/23/91			472.7	64.5	475.03	66.83	408.20	USACE	
LUB	153	8/20/91			472.7	64.45	475.03	66.78	408.25	USACE	
LUB	153	9/25/91			472.7	64.43	475.03	66.76	408.27	USACE	
LUB	153	10/18/91			472.7	64.48	475.03	66.81	408.22	USACE	
LUB	153	11/21/91			472.7	64.37	475.03	66.7	408.33	USACE	
LUB	153	12/17/91			472.7	64.21	475.03	66.54	408.49	USACE	
LUB	153	1/22/92			472.7	64.2	475.03	66.53	408.50	USACE	
LUB	153	2/18/92			472.7	64.08	475.03	66.41	408.62	USACE	
LUB	153	3/12/92			472.7	64.1	475.03	66.43	408.60	USACE	
LUB	153	4/21/92			472.7	64.01	475.03	66.34	408.69	USACE	
LUB	154	12/20/90			529.1	96.33	531.85	99.08	432.77	USACE	
LUB	154	1/10/91			529.1	96.27	531.85	99.02	432.83	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	154	2/11/91			529.1	96.24	531.85	98.99	432.86	USACE	
LUB	154	3/20/91			529.1	96.21	531.85	98.96	432.89	USACE	
LUB	154	4/18/91			529.1	96.23	531.85	98.98	432.87	USACE	
LUB	154	5/25/91			529.1	96.19	531.85	98.94	432.91	USACE	
LUB	154	6/26/91			529.1	96.19	531.85	98.94	432.91	USACE	
LUB	154	7/23/91			529.1	96.16	531.85	98.91	432.94	USACE	
LUB	154	8/20/91			529.1	96.13	531.85	98.88	432.97	USACE	
LUB	154	9/25/91			529.1	96.18	531.85	98.93	432.92	USACE	
LUB	154	10/18/91			529.1	96.18	531.85	98.93	432.92	USACE	
LUB	154	11/21/91			529.1	96.22	531.85	98.97	432.88	USACE	
LUB	154	12/17/91			529.1	96.09	531.85	98.84	433.01	USACE	
LUB	154	1/22/92			529.1	96.15	531.85	98.9	432.95	USACE	
LUB	154	2/18/92			529.1	96.04	531.85	98.79	433.06	USACE	
LUB	154	3/12/92			529.1	96.15	531.85	98.9	432.95	USACE	
LUB	154	4/21/92			529.1	96.11	531.85	98.86	432.99	USACE	
LUB	155	12/20/90			551	103.99	553.4	106.39	447.01	USACE	
LUB	155	1/10/91			551	103.95	553.4	106.35	447.05	USACE	
LUB	155	2/11/91			551	103.9	553.4	106.3	447.10	USACE	
LUB	155	3/20/91			551	103.9	553.4	106.3	447.10	USACE	
LUB	155	4/18/91			551	103.91	553.4	106.31	447.09	USACE	
LUB	155	5/25/91			551	103.88	553.4	106.28	447.12	USACE	
LUB	155	6/26/91			551	103.85	553.4	106.25	447.15	USACE	
LUB	155	7/23/91			551	103.85	553.4	106.25	447.15	USACE	
LUB	155	8/20/91			551	103.84	553.4	106.24	447.16	USACE	
LUB	155	9/25/91			551	103.84	553.4	106.24	447.16	USACE	
LUB	155	10/18/91			551	103.8	553.4	106.2	447.20	USACE	
LUB	155	11/21/91			551	103.83	553.4	106.23	447.17	USACE	
LUB	155	12/17/91			551	103.79	553.4	106.19	447.21	USACE	
LUB	155	1/22/92			551	103.81	553.4	106.21	447.19	USACE	
LUB	155	2/18/92			551	103.78	553.4	106.18	447.22	USACE	
LUB	155	3/12/92			551	103.8	553.4	106.2	447.20	USACE	
LUB	155	4/21/92			551	103.75	553.4	106.15	447.25	USACE	
LUB	156	12/18/90			625.2	129.43	627.44	131.67	495.77	USACE	
LUB	156	1/12/91			625.2	129.26	627.44	131.5	495.94	USACE	
LUB	156	2/11/91			625.2	128.95	627.44	131.19	496.25	USACE	
LUB	156	3/20/91			625.2	128.06	627.44	130.3	497.14	USACE	
LUB	156	4/18/91			625.2	127.06	627.44	129.3	498.14	USACE	
LUB	156	5/24/91			625.2	126.07	627.44	128.31	499.13	USACE	
LUB	156	6/26/91			625.2	125.86	627.44	128.1	499.34	USACE	
LUB	156	7/22/91			625.2	126.43	627.44	128.67	498.77	USACE	
LUB	156	8/20/91			625.2	127.05	627.44	129.29	498.15	USACE	
LUB	156	9/25/91			625.2	127.71	627.44	129.95	497.49	USACE	
LUB	156	10/17/91			625.2	127.47	627.44	129.71	497.73	USACE	
LUB	156	11/20/91			625.2	127.6	627.44	129.84	497.60	USACE	
LUB	156	12/18/91			625.2	127.45	627.44	129.69	497.75	USACE	
LUB	156	1/21/92			625.2	127.33	627.44	129.57	497.87	USACE	
LUB	156	2/17/92			625.2	127.24	627.44	129.48	497.96	USACE	
LUB	156	3/11/92			625.2	126.8	627.44	129.04	498.40	USACE	
LUB	156	4/20/92			625.2	126.08	627.44	128.32	499.12	USACE	
LUB	157	12/19/90			571.8	75.86	573.45	77.51	495.94	USACE	
LUB	157	1/15/91			571.8	75.61	573.45	77.26	496.19	USACE	
LUB	157	2/11/91			571.8	75.05	573.45	76.7	496.75	USACE	
LUB	157	3/20/91			571.8	73.75	573.45	75.4	498.05	USACE	
LUB	157	4/18/91			571.8	72.6	573.45	74.25	499.20	USACE	
LUB	157	5/25/91			571.8	72.38	573.45	74.03	499.42	USACE	
LUB	157	6/26/91			571.8	73.06	573.45	74.71	498.74	USACE	
LUB	157	7/22/91			571.8	73.73	573.45	75.38	498.07	USACE	
LUB	157	8/20/91			571.8	74.58	573.45	76.23	497.22	USACE	
LUB	157	9/25/91			571.8	74.85	573.45	76.5	496.95	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	157	10/17/91			571.8	74.43	573.45	76.08	497.37	USACE	
LUB	157	11/21/91			571.8	74.11	573.45	75.76	497.69	USACE	
LUB	157	12/18/91			571.8	73.86	573.45	75.51	497.94	USACE	
LUB	157	1/22/92			571.8	73.78	573.45	75.43	498.02	USACE	
LUB	157	2/17/92			571.8	73.53	573.45	75.18	498.27	USACE	
LUB	157	3/12/92			571.8	72.7	573.45	74.35	499.10	USACE	
LUB	157	4/21/92			571.8	72.46	573.45	74.11	499.34	USACE	
LUB	158	12/19/90			571.8	75.86	573.25	77.31	495.94	USACE	
LUB	158	1/15/91			571.8	75.6	573.25	77.05	496.20	USACE	
LUB	158	2/11/91			571.8	75.06	573.25	76.51	496.74	USACE	
LUB	158	3/20/91			571.8	73.75	573.25	75.2	498.05	USACE	
LUB	158	4/18/91			571.8	73.1	573.25	74.55	498.70	USACE	
LUB	158	5/25/91			571.8	72.4	573.25	73.85	499.40	USACE	
LUB	158	6/26/91			571.8	73.02	573.25	74.47	498.78	USACE	
LUB	158	7/22/91			571.8	74.19	573.25	75.64	497.61	USACE	
LUB	158	8/20/91			571.8	74.57	573.25	76.02	497.23	USACE	
LUB	158	9/25/91			571.8	74.82	573.25	76.27	496.98	USACE	
LUB	158	10/17/91			571.8	74.39	573.25	75.84	497.41	USACE	
LUB	158	11/21/91			571.8	74.09	573.25	75.54	497.71	USACE	
LUB	158	12/18/91			571.8	73.92	573.25	75.37	497.88	USACE	
LUB	158	1/22/92			571.8	73.75	573.25	75.2	498.05	USACE	
LUB	158	2/17/92			571.8	73.52	573.25	74.97	498.28	USACE	
LUB	158	3/12/92			571.8	73.41	573.25	74.86	498.39	USACE	
LUB	158	4/21/92			571.8	72.45	573.25	73.9	499.35	USACE	
LUB	159	12/19/90			587.2	87.86	589	89.66	499.34	USACE	
LUB	159	1/9/91			587.2	87.83	589	89.63	499.37	USACE	
LUB	159	2/11/91			587.2	87.74	589	89.54	499.46	USACE	
LUB	159	3/20/91			587.2	87.2	589	89	500.00	USACE	
LUB	159	4/18/91			587.2	87.23	589	89.03	499.97	USACE	
LUB	159	5/24/91			587.2	86.88	589	88.68	500.32	USACE	
LUB	159	6/26/91			587.2	87.06	589	88.86	500.14	USACE	
LUB	159	7/22/91			587.2	87.7	589	89.5	499.50	USACE	
LUB	159	8/19/91			587.2	87.95	589	89.75	499.25	USACE	
LUB	159	9/24/91			587.2	87.8	589	89.6	499.40	USACE	
LUB	159	10/17/91			587.2	86.91	589	88.71	500.29	USACE	
LUB	159	11/20/91			587.2	86.5	589	88.3	500.70	USACE	
LUB	159	12/18/91			587.2	86.48	589	88.28	500.72	USACE	
LUB	159	1/21/92			587.2	86.49	589	88.29	500.71	USACE	
LUB	159	2/17/92			587.2	86.54	589	88.34	500.66	USACE	
LUB	159	3/11/92			587.2	86.2	589	88	501.00	USACE	
LUB	159	4/20/92			587.2	86.19	589	87.99	501.01	USACE	
LUB	16	12/5/90	Idle	E Tape	284.58	20.92			263.66	OWRD	
LUB	16	3/13/91	Idle	E Tape	284.58	21.12			263.46	OWRD	
LUB	16	6/10/91	Idle	E Tape	284.58	20.61			263.97	OWRD	
LUB	16	9/10/91	Idle	E Tape	284.58	18.42			266.16	OWRD	
LUB	16	12/10/91	Idle	E Tape	284.58	20.79			263.79	OWRD	
LUB	16	3/10/92	Idle	E Tape	284.58	22.89			261.69	OWRD	
LUB	160	12/19/90			585.9	107.08	588.09	109.27	478.82	USACE	
LUB	160	1/15/91			585.9	89.83	588.09	92.02	496.07	USACE	
LUB	160	2/11/91			585.9	89.26	588.09	91.45	496.64	USACE	
LUB	160	3/20/91			585.9	87.92	588.09	90.11	497.98	USACE	
LUB	160	4/18/91			585.9	87.09	588.09	89.28	498.81	USACE	
LUB	160	5/25/91			585.9	86.31	588.09	88.5	499.59	USACE	
LUB	160	6/26/91			585.9	86.92	588.09	89.11	498.98	USACE	
LUB	160	7/22/91			585.9	87.81	588.09	90	498.09	USACE	
LUB	160	8/20/91			585.9	88.43	588.09	90.62	497.47	USACE	
LUB	160	9/25/91			585.9	88.83	588.09	91.02	497.07	USACE	
LUB	160	10/17/91			585.9	88.47	588.09	90.66	497.43	USACE	
LUB	160	11/21/91			585.9	88.31	588.09	90.5	497.59	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	160	12/18/91			585.9	88.12	588.09	90.31	497.78	USACE	
LUB	160	1/22/92			585.9	87.98	588.09	90.17	497.92	USACE	
LUB	160	2/17/92			585.9	87.68	588.09	89.87	498.22	USACE	
LUB	160	3/12/92			585.9	86.84	588.09	89.03	499.06	USACE	
LUB	160	4/21/92			585.9	86.57	588.09	88.76	499.33	USACE	
LUB	161	12/19/90			594.6	99.15	596.84	101.39	495.45	USACE	
LUB	161	1/12/91			594.6	98.9	596.84	101.14	495.70	USACE	
LUB	161	2/11/91			594.6	98.33	596.84	100.57	496.27	USACE	
LUB	161	3/20/91			594.6	96.96	596.84	99.2	497.64	USACE	
LUB	161	4/18/91			594.6	96.09	596.84	98.33	498.51	USACE	
LUB	161	5/24/91			594.6	95.32	596.84	97.56	499.28	USACE	
LUB	161	6/26/91			594.6	95.88	596.84	98.12	498.72	USACE	
LUB	161	7/22/91			594.6	88.98	596.84	91.22	505.62	USACE	
LUB	161	8/19/91			594.6	97.37	596.84	99.61	497.23	USACE	
LUB	161	9/24/91			594.6	97.82	596.84	100.06	496.78	USACE	
LUB	161	10/17/91			594.6	97.46	596.84	99.7	497.14	USACE	
LUB	161	11/20/91			594.6	97.36	596.84	99.6	497.24	USACE	
LUB	161	12/18/91			594.6	97.16	596.84	99.4	497.44	USACE	
LUB	161	1/21/92			594.6	97.03	596.84	99.27	497.57	USACE	
LUB	161	2/17/92			594.6	96.73	596.84	98.97	497.87	USACE	
LUB	161	3/11/92			594.6	95.94	596.84	98.18	498.66	USACE	
LUB	161	4/20/92			594.6	95.6	596.84	97.84	499.00	USACE	
LUB	162	12/19/90			547	51.3	548.57	52.87	495.70	USACE	
LUB	162	1/12/91			547	50.12	548.57	51.69	496.88	USACE	
LUB	162	2/11/91			547	50.81	548.57	52.38	496.19	USACE	
LUB	162	3/20/91			547	49.86	548.57	51.43	497.14	USACE	
LUB	162	4/18/91			547	48.82	548.57	50.39	498.18	USACE	
LUB	162	5/25/91			547	47.87	548.57	49.44	499.13	USACE	
LUB	162	6/26/91			547	47.61	548.57	49.18	499.39	USACE	
LUB	162	7/22/91			547	48.2	548.57	49.77	498.80	USACE	
LUB	162	8/20/91			547	48.83	548.57	50.4	498.17	USACE	
LUB	162	9/24/91			547	49.52	548.57	51.09	497.48	USACE	
LUB	162	10/17/91			547	49.52	548.57	51.09	497.48	USACE	
LUB	162	11/20/91			547	49.41	548.57	50.98	497.59	USACE	
LUB	162	12/18/91			547	49.28	548.57	50.85	497.72	USACE	
LUB	162	1/22/92			547	49.07	548.57	50.64	497.93	USACE	
LUB	162	2/17/92			547	49.01	548.57	50.58	497.99	USACE	
LUB	162	3/11/92			547	48.63	548.57	50.2	498.37	USACE	
LUB	162	4/20/92			547	47.84	548.57	49.41	499.16	USACE	
LUB	163	12/19/90			546.4	50.65	547.93	52.18	495.75	USACE	
LUB	163	1/12/91			546.4	50.41	547.93	51.94	495.99	USACE	
LUB	163	2/11/91			546.4	50.01	547.93	51.54	496.39	USACE	
LUB	163	3/20/91			546.4	48.79	547.93	50.32	497.61	USACE	
LUB	163	4/18/91			546.4	47.79	547.93	49.32	498.61	USACE	
LUB	163	5/25/91			546.4	46.9	547.93	48.43	499.50	USACE	
LUB	163	6/26/91			546.4	47.13	547.93	48.66	499.27	USACE	
LUB	163	7/22/91			546.4	47.91	547.93	49.44	498.49	USACE	
LUB	163	8/20/91			546.4	48.59	547.93	50.12	497.81	USACE	
LUB	163	9/24/91			546.4	49.14	547.93	50.67	497.26	USACE	
LUB	163	10/17/91			546.4	48.92	547.93	50.45	497.48	USACE	
LUB	163	11/20/91			546.4	48.82	547.93	50.35	497.58	USACE	
LUB	163	12/18/91			546.4	48.65	547.93	50.18	497.75	USACE	
LUB	163	1/21/92			546.4	48.48	547.93	50.01	497.92	USACE	
LUB	163	2/17/92			546.4	48.33	547.93	49.86	498.07	USACE	
LUB	163	3/11/92			546.4	47.66	547.93	49.19	498.74	USACE	
LUB	163	4/20/92			546.4	47.15	547.93	48.68	499.25	USACE	
LUB	164	12/19/90			614.3	118.57	615.8	120.07	495.73	USACE	
LUB	164	1/12/91			614.3	118.34	615.8	119.84	495.96	USACE	
LUB	164	2/11/91			614.3	118.01	615.8	119.51	496.29	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	164	3/20/91			614.3	116.87	615.8	118.37	497.43	USACE	
LUB	164	4/18/91			614.3	115.85	615.8	117.35	498.45	USACE	
LUB	164	5/24/91			614.3	114.92	615.8	116.42	499.38	USACE	
LUB	164	6/26/91			614.3	115.04	615.8	116.54	499.26	USACE	
LUB	164	7/22/91			614.3	115.78	615.8	117.28	498.52	USACE	
LUB	164	8/20/91			614.3	116.44	615.8	117.94	497.86	USACE	
LUB	164	9/24/91			614.3	117.01	615.8	118.51	497.29	USACE	
LUB	164	10/17/91			614.3	116.65	615.8	118.15	497.65	USACE	
LUB	164	11/20/91			614.3	116.74	615.8	118.24	497.56	USACE	
LUB	164	12/18/91			614.3	116.6	615.8	118.1	497.70	USACE	
LUB	164	1/21/92			614.3	116.45	615.8	117.95	497.85	USACE	
LUB	164	2/17/92			614.3	116.31	615.8	117.81	497.99	USACE	
LUB	164	3/11/92			614.3	115.77	615.8	117.27	498.53	USACE	
LUB	164	4/20/92			614.3	115.15	615.8	116.65	499.15	USACE	
LUB	165	12/19/90			570	74.28	571.43	75.71	495.72	USACE	
LUB	165	1/10/91			570	74.13	571.43	75.56	495.87	USACE	
LUB	165	2/11/91			570	73.9	571.43	75.33	496.10	USACE	
LUB	165	3/20/91			570	73.37	571.43	74.8	496.63	USACE	
LUB	165	4/18/91			570	72.45	571.43	73.88	497.55	USACE	
LUB	165	5/24/91			570	70.78	571.43	72.21	499.22	USACE	
LUB	165	6/26/91			570	70.63	571.43	72.06	499.37	USACE	
LUB	165	7/22/91			570	70.94	571.43	72.37	499.06	USACE	
LUB	165	8/19/91			570	71.48	571.43	72.91	498.52	USACE	
LUB	165	9/24/91			570	72.17	571.43	73.6	497.83	USACE	
LUB	165	10/17/91			570	72.43	571.43	73.86	497.57	USACE	
LUB	165	11/19/91			570	72.39	571.43	73.82	497.61	USACE	
LUB	165	12/18/91			570	72.27	571.43	73.7	497.73	USACE	
LUB	165	1/22/92			570	72.16	571.43	73.59	497.84	USACE	
LUB	165	2/17/92			570	72.06	571.43	73.49	497.94	USACE	
LUB	165	3/11/92			570	71.87	571.43	73.3	498.13	USACE	
LUB	165	4/20/92			570	71.04	571.43	72.47	498.96	USACE	
LUB	166	12/19/90			548.6	52.88	550.46	54.74	495.72	USACE	
LUB	166	1/13/91			548.6	52.66	550.46	54.52	495.94	USACE	
LUB	166	2/11/91			548.6	52.39	550.46	54.25	496.21	USACE	
LUB	166	3/20/91			548.6	51.48	550.46	53.34	497.12	USACE	
LUB	166	4/18/91			548.6	50.48	550.46	52.34	498.12	USACE	
LUB	166	5/25/91			548.6	49.53	550.46	51.39	499.07	USACE	
LUB	166	6/26/91			548.6	49.27	550.46	51.13	499.33	USACE	
LUB	166	7/22/91			548.6	49.79	550.46	51.65	498.81	USACE	
LUB	166	8/20/91			548.6	50.43	550.46	52.29	498.17	USACE	
LUB	166	9/24/91			548.6	51.07	550.46	52.93	497.53	USACE	
LUB	166	10/17/91			548.6	51.13	550.46	52.99	497.47	USACE	
LUB	166	11/20/91			548.6	51.01	550.46	52.87	497.59	USACE	
LUB	166	12/18/91			548.6	50.84	550.46	52.7	497.76	USACE	
LUB	166	1/22/92			548.6	50.71	550.46	52.57	497.89	USACE	
LUB	166	2/17/92			548.6	50.62	550.46	52.48	497.98	USACE	
LUB	166	3/11/92			548.6	50.17	550.46	52.03	498.43	USACE	
LUB	166	4/20/92			548.6	49.49	550.46	51.35	499.11	USACE	
LUB	168	12/19/90			571.3	87.59	572.8	89.09	483.71	USACE	
LUB	168	1/10/91			571.3	87.34	572.8	88.84	483.96	USACE	
LUB	168	2/11/91			571.3	87.09	572.8	88.59	484.21	USACE	
LUB	168	3/20/91			571.3	87.1	572.8	88.6	484.20	USACE	
LUB	168	4/18/91			571.3	87.08	572.8	88.58	484.22	USACE	
LUB	168	5/25/91			571.3	87.07	572.8	88.57	484.23	USACE	
LUB	168	6/26/91			571.3	86.85	572.8	88.35	484.45	USACE	
LUB	168	7/23/91			571.3	86.82	572.8	88.32	484.48	USACE	
LUB	168	8/20/91			571.3	86.82	572.8	88.32	484.48	USACE	
LUB	168	9/24/91			571.3	86.74	572.8	88.24	484.56	USACE	
LUB	168	10/17/91			571.3	86.93	572.8	88.43	484.37	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	168	11/21/91			571.3	86.9	572.8	88.4	484.40	USACE	
LUB	168	12/17/91			571.3	86.45	572.8	87.95	484.85	USACE	
LUB	168	1/22/92			571.3	86.6	572.8	88.1	484.70	USACE	
LUB	168	2/18/92			571.3	86.3	572.8	87.8	485.00	USACE	
LUB	168	3/12/92			571.3	86.43	572.8	87.93	484.87	USACE	
LUB	168	4/21/92			571.3	86.31	572.8	87.81	484.99	USACE	
LUB	169	12/18/90			645.2	140.11	647.26	142.17	505.09	USACE	
LUB	169	1/9/91			645.2	140.34	647.26	142.4	504.86	USACE	
LUB	169	2/11/91			645.2	140.16	647.26	142.22	505.04	USACE	
LUB	169	3/20/91			645.2	140.21	647.26	142.27	504.99	USACE	
LUB	169	4/18/91			645.2	140.36	647.26	142.42	504.84	USACE	
LUB	169	5/24/91			645.2	140.24	647.26	142.3	504.96	USACE	
LUB	169	6/26/91			645.2	140.11	647.26	142.17	505.09	USACE	
LUB	169	7/22/91			645.2	140.23	647.26	142.29	504.97	USACE	
LUB	169	8/19/91			645.2	140.06	647.26	142.12	505.14	USACE	
LUB	169	9/24/91			645.2	140.1	647.26	142.16	505.10	USACE	
LUB	169	10/17/91			645.2	140.33	647.26	142.39	504.87	USACE	
LUB	169	11/20/91			645.2	140.07	647.26	142.13	505.13	USACE	
LUB	169	12/18/91			645.2	139.41	647.26	141.47	505.79	USACE	
LUB	169	1/21/92			645.2	139.88	647.26	141.94	505.32	USACE	
LUB	169	2/17/92			645.2	140.01	647.26	142.07	505.19	USACE	
LUB	169	3/11/92			645.2	139.81	647.26	141.87	505.39	USACE	
LUB	169	4/20/92			645.2	139.67	647.26	141.73	505.53	USACE	
LUB	170	12/18/90			652.2	150.29	655.05	153.14	501.91	USACE	
LUB	170	1/9/91			652.2	150.47	655.05	153.32	501.73	USACE	
LUB	170	2/11/91			652.2	150.31	655.05	153.16	501.89	USACE	
LUB	170	3/20/91			652.2	150.42	655.05	153.27	501.78	USACE	
LUB	170	4/18/91			652.2	150.47	655.05	153.32	501.73	USACE	
LUB	170	5/24/91			652.2	150.4	655.05	153.25	501.80	USACE	
LUB	170	6/26/91			652.2	150.3	655.05	153.15	501.90	USACE	
LUB	170	7/22/91			652.2	150.34	655.05	153.19	501.86	USACE	
LUB	170	8/19/91			652.2	150.25	655.05	153.1	501.95	USACE	
LUB	170	9/24/91			652.2	150.3	655.05	153.15	501.90	USACE	
LUB	170	10/17/91			652.2	150.35	655.05	153.2	501.85	USACE	
LUB	170	11/20/91			652.2	150.31	655.05	153.16	501.89	USACE	
LUB	170	12/17/91			652.2	150.05	655.05	152.9	502.15	USACE	
LUB	170	1/21/92			652.2	150.21	655.05	153.06	501.99	USACE	
LUB	170	2/17/92			652.2	150.23	655.05	153.08	501.97	USACE	
LUB	170	3/11/92			652.2	150.11	655.05	152.96	502.09	USACE	
LUB	170	4/20/92			652.2	150.04	655.05	152.89	502.16	USACE	
LUB	171	12/18/90			654	150.88	655.78	152.66	503.12	USACE	
LUB	171	1/9/91			654	151.11	655.78	152.89	502.89	USACE	
LUB	171	2/11/91			654	150.95	655.78	152.73	503.05	USACE	
LUB	171	3/20/91			654	151.12	655.78	152.9	502.88	USACE	
LUB	171	4/18/91			654	151.14	655.78	152.92	502.86	USACE	
LUB	171	5/24/91			654	151.07	655.78	152.85	502.93	USACE	
LUB	171	6/26/91			654	150.95	655.78	152.73	503.05	USACE	
LUB	171	7/22/91			654	151.03	655.78	152.81	502.97	USACE	
LUB	171	8/19/91			654	150.95	655.78	152.73	503.05	USACE	
LUB	171	9/24/91			654	150.98	655.78	152.76	503.02	USACE	
LUB	171	10/17/91			654	151.09	655.78	152.87	502.91	USACE	
LUB	171	11/20/91			654	151.03	655.78	152.81	502.97	USACE	
LUB	171	12/17/91			654	150.75	655.78	152.53	503.25	USACE	
LUB	171	1/21/92			654	150.92	655.78	152.7	503.08	USACE	
LUB	171	2/17/92			654	150.96	655.78	152.74	503.04	USACE	
LUB	171	3/11/92			654	150.83	655.78	152.61	503.17	USACE	
LUB	171	4/20/92			654	150.77	655.78	152.55	503.23	USACE	
LUB	172	12/18/90			652.2	151.11	653.89	152.8	501.09	USACE	
LUB	172	1/9/91			652.2	151.33	653.89	153.02	500.87	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	172	2/11/91			652.2	151.14	653.89	152.83	501.06	USACE	
LUB	172	3/20/91			652.2	151.28	653.89	152.97	500.92	USACE	
LUB	172	4/18/91			652.2	151.31	653.89	153	500.89	USACE	
LUB	172	5/24/91			652.2	151.21	653.89	152.9	500.99	USACE	
LUB	172	6/26/91			652.2	151.11	653.89	152.8	501.09	USACE	
LUB	172	7/22/91			652.2	151.15	653.89	152.84	501.05	USACE	
LUB	172	8/19/91			652.2	151.06	653.89	152.75	501.14	USACE	
LUB	172	9/24/91			652.2	151.05	653.89	152.74	501.15	USACE	
LUB	172	10/17/91			652.2	151.15	653.89	152.84	501.05	USACE	
LUB	172	11/20/91			652.2	151.05	653.89	152.74	501.15	USACE	
LUB	172	1/21/92			652.2	150.92	653.89	152.61	501.28	USACE	
LUB	172	2/17/92			652.2	150.98	653.89	152.67	501.22	USACE	
LUB	172	3/11/92			652.2	150.75	653.89	152.44	501.45	USACE	
LUB	172	4/20/92			652.2	150.69	653.89	152.38	501.51	USACE	
LUB	173	12/19/90			583.9	88.03	585.18	89.31	495.87	USACE	
LUB	173	1/12/91			583.9	87.79	585.18	89.07	496.11	USACE	
LUB	173	2/11/91			583.9	87.12	585.18	88.4	496.78	USACE	
LUB	173	3/20/91			583.9	85.65	585.18	86.93	498.25	USACE	
LUB	173	4/18/91			583.9	84.88	585.18	86.16	499.02	USACE	
LUB	173	5/25/91			583.9	84.28	585.18	85.56	499.62	USACE	
LUB	173	6/26/91			583.9	84.93	585.18	86.21	498.97	USACE	
LUB	173	7/22/91			583.9	85.83	585.18	87.11	498.07	USACE	
LUB	173	8/19/91			583.9	86.46	585.18	87.74	497.44	USACE	
LUB	173	9/24/91			583.9	86.9	585.18	88.18	497.00	USACE	
LUB	173	10/17/91			583.9	86.5	585.18	87.78	497.40	USACE	
LUB	173	11/19/91			583.9	86.27	585.18	87.55	497.63	USACE	
LUB	173	12/18/91			583.9	86.05	585.18	87.33	497.85	USACE	
LUB	173	1/21/92			583.9	85.91	585.18	87.19	497.99	USACE	
LUB	173	2/17/92			583.9	85.54	585.18	86.82	498.36	USACE	
LUB	173	3/11/92			583.9	84.64	585.18	85.92	499.26	USACE	
LUB	173	4/20/92			583.9	84.46	585.18	85.74	499.44	USACE	
LUB	174	12/19/90			595.7	99.86	597	101.16	495.84	USACE	
LUB	174	1/12/91			595.7	99.61	597	100.91	496.09	USACE	
LUB	174	2/11/91			595.7	98.97	597	100.27	496.73	USACE	
LUB	174	3/20/91			595.7	97.45	597	98.75	498.25	USACE	
LUB	174	4/18/91			595.7	96.67	597	97.97	499.03	USACE	
LUB	174	5/24/91			595.7	96.07	597	97.37	499.63	USACE	
LUB	174	6/26/91			595.7	96.71	597	98.01	498.99	USACE	
LUB	174	7/22/91			595.7	97.62	597	98.92	498.08	USACE	
LUB	174	8/19/91			595.7	98.28	597	99.58	497.42	USACE	
LUB	174	9/24/91			595.7	98.72	597	100.02	496.98	USACE	
LUB	174	10/17/91			595.7	98.34	597	99.64	497.36	USACE	
LUB	174	11/20/91			595.7	98.11	597	99.41	497.59	USACE	
LUB	174	12/18/91			595.7	97.91	597	99.21	497.79	USACE	
LUB	174	1/21/92			595.7	97.76	597	99.06	497.94	USACE	
LUB	174	2/17/92			595.7	97.35	597	98.65	498.35	USACE	
LUB	174	3/11/92			595.7	96.44	597	97.74	499.26	USACE	
LUB	174	4/20/92			595.7	96.27	597	97.57	499.43	USACE	
LUB	175	12/19/90			592.2	96.36	593.68	97.84	495.84	USACE	
LUB	175	1/12/91			592.2	96.19	593.68	97.67	496.01	USACE	
LUB	175	2/11/91			592.2	95.42	593.68	96.9	496.78	USACE	
LUB	175	3/20/91			592.2	93.9	593.68	95.38	498.30	USACE	
LUB	175	4/18/91			592.2	93.13	593.68	94.61	499.07	USACE	
LUB	175	5/24/91			592.2	92.52	593.68	94	499.68	USACE	
LUB	175	6/26/91			592.2	93.23	593.68	94.71	498.97	USACE	
LUB	175	7/22/91			592.2	94.15	593.68	95.63	498.05	USACE	
LUB	175	8/19/91			592.2	94.8	593.68	96.28	497.40	USACE	
LUB	175	9/24/91			592.2	95.22	593.68	96.7	496.98	USACE	
LUB	175	10/17/91			592.2	94.85	593.68	96.33	497.35	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	175	11/20/91			592.2	94.58	593.68	96.06	497.62	USACE	
LUB	175	12/18/91			592.2	94.41	593.68	95.89	497.79	USACE	
LUB	175	1/21/92			592.2	94.24	593.68	95.72	497.96	USACE	
LUB	175	2/17/92			592.2	93.84	593.68	95.32	498.36	USACE	
LUB	175	3/11/92			592.2	92.91	593.68	94.39	499.29	USACE	
LUB	175	4/20/92			592.2	92.77	593.68	94.25	499.43	USACE	
LUB	176	12/20/90			529.1	58.32	530.82	60.04	470.78	USACE	
LUB	176	1/10/91			529.1	58.08	530.82	59.8	471.02	USACE	
LUB	176	2/11/91			529.1	57.89	530.82	59.61	471.21	USACE	
LUB	176	3/20/91			529.1	57.71	530.82	59.43	471.39	USACE	
LUB	176	4/18/91			529.1	57.58	530.82	59.3	471.52	USACE	
LUB	176	5/25/91			529.1	57.41	530.82	59.13	471.69	USACE	
LUB	176	6/26/91			529.1	57.24	530.82	58.96	471.86	USACE	
LUB	176	7/23/91			529.1	57.13	530.82	58.85	471.97	USACE	
LUB	176	8/20/91			529.1	57.04	530.82	58.76	472.06	USACE	
LUB	176	9/24/91			529.1	56.94	530.82	58.66	472.16	USACE	
LUB	176	10/18/91			529.1	57.11	530.82	58.83	471.99	USACE	
LUB	176	11/21/91			529.1	56.9	530.82	58.62	472.20	USACE	
LUB	176	12/17/91			529.1	56.55	530.82	58.27	472.55	USACE	
LUB	176	1/22/92			529.1	56.48	530.82	58.2	472.62	USACE	
LUB	176	2/18/92			529.1	56.23	530.82	57.95	472.87	USACE	
LUB	176	3/12/92			529.1	56.19	530.82	57.91	472.91	USACE	
LUB	176	4/21/92			529.1	55.96	530.82	57.68	473.14	USACE	
LUB	177	12/19/90			597.8	101.94	599.54	103.68	495.86	USACE	
LUB	177	1/12/91			597.8	101.68	599.54	103.42	496.12	USACE	
LUB	177	2/11/91			597.8	101.02	599.54	102.76	496.78	USACE	
LUB	177	3/20/91			597.8	99.54	599.54	101.28	498.26	USACE	
LUB	177	4/18/91			597.8	98.77	599.54	100.51	499.03	USACE	
LUB	177	5/24/91			597.8	98.13	599.54	99.87	499.67	USACE	
LUB	177	6/26/91			597.8	98.78	599.54	100.52	499.02	USACE	
LUB	177	7/22/91			597.8	99.69	599.54	101.43	498.11	USACE	
LUB	177	8/19/91			597.8	100.35	599.54	102.09	497.45	USACE	
LUB	177	9/24/91			597.8	100.78	599.54	102.52	497.02	USACE	
LUB	177	10/17/91			597.8	100.4	599.54	102.14	497.40	USACE	
LUB	177	11/20/91			597.8	100.18	599.54	101.92	497.62	USACE	
LUB	177	12/18/91			597.8	99.97	599.54	101.71	497.83	USACE	
LUB	177	1/21/92			597.8	99.81	599.54	101.55	497.99	USACE	
LUB	177	2/17/92			597.8	99.46	599.54	101.2	498.34	USACE	
LUB	177	3/11/92			597.8	98.55	599.54	100.29	499.25	USACE	
LUB	177	4/20/92			597.8	98.36	599.54	100.1	499.44	USACE	
LUB	178	12/19/90			596.7	100.89	598.36	102.55	495.81	USACE	
LUB	178	1/12/91			596.7	100.63	598.36	102.29	496.07	USACE	
LUB	178	2/11/91			596.7	99.98	598.36	101.64	496.72	USACE	
LUB	178	3/20/91			596.7	98.52	598.36	100.18	498.18	USACE	
LUB	178	4/18/91			596.7	97.71	598.36	99.37	498.99	USACE	
LUB	178	5/24/91			596.7	97.09	598.36	98.75	499.61	USACE	
LUB	178	6/26/91			596.7	97.73	598.36	99.39	498.97	USACE	
LUB	178	7/22/91			596.7	98.63	598.36	100.29	498.07	USACE	
LUB	178	8/19/91			596.7	99.27	598.36	100.93	497.43	USACE	
LUB	178	9/24/91			596.7	99.72	598.36	101.38	496.98	USACE	
LUB	178	10/17/91			596.7	99.36	598.36	101.02	497.34	USACE	
LUB	178	11/20/91			596.7	99.14	598.36	100.8	497.56	USACE	
LUB	178	12/18/91			596.7	98.93	598.36	100.59	497.77	USACE	
LUB	178	1/21/92			596.7	98.77	598.36	100.43	497.93	USACE	
LUB	178	2/17/92			596.7	98.4	598.36	100.06	498.30	USACE	
LUB	178	3/11/92			596.7	97.53	598.36	99.19	499.17	USACE	
LUB	178	4/20/92			596.7	97.33	598.36	98.99	499.37	USACE	
LUB	180	12/20/90			441.9	63.76	443.49	65.35	378.14	USACE	
LUB	180	1/10/91			441.9	63.61	443.49	65.2	378.29	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	180	2/11/91			441.9	63.49	443.49	65.08	378.41	USACE	
LUB	180	3/20/91			441.9	63.5	443.49	65.09	378.40	USACE	
LUB	180	4/18/91			441.9	63.47	443.49	65.06	378.43	USACE	
LUB	180	5/25/91			441.9	63.41	443.49	65	378.49	USACE	
LUB	180	6/26/91			441.9	63.36	443.49	64.95	378.54	USACE	
LUB	180	7/23/91			441.9	63.37	443.49	64.96	378.53	USACE	
LUB	180	8/20/91			441.9	63.35	443.49	64.94	378.55	USACE	
LUB	180	9/24/91			441.9	63.32	443.49	64.91	378.58	USACE	
LUB	180	10/18/91			441.9	63.5	443.49	65.09	378.40	USACE	
LUB	180	11/21/91			441.9	63.39	443.49	64.98	378.51	USACE	
LUB	180	12/17/91			441.9	63.18	443.49	64.77	378.72	USACE	
LUB	180	1/22/92			441.9	63.2	443.49	64.79	378.70	USACE	
LUB	180	2/18/92			441.9	63.02	443.49	64.61	378.88	USACE	
LUB	180	3/12/92			441.9	63.11	443.49	64.7	378.79	USACE	
LUB	180	4/21/92			441.9	63.02	443.49	64.61	378.88	USACE	
LUB	181	12/20/90			559.6	111.14	561.26	112.8	448.46	USACE	
LUB	181	1/10/91			559.6	111.23	561.26	112.89	448.37	USACE	
LUB	181	2/11/91			559.6	111.19	561.26	112.85	448.41	USACE	
LUB	181	3/20/91			559.6	111.17	561.26	112.83	448.43	USACE	
LUB	181	4/18/91			559.6	111.15	561.26	112.81	448.45	USACE	
LUB	181	5/25/91			559.6	111.21	561.26	112.87	448.39	USACE	
LUB	181	6/26/91			559.6	111.19	561.26	112.85	448.41	USACE	
LUB	181	7/23/91			559.6	111.09	561.26	112.75	448.51	USACE	
LUB	181	8/20/91			559.6	111.06	561.26	112.72	448.54	USACE	
LUB	181	9/24/91			559.6	111.19	561.26	112.85	448.41	USACE	
LUB	181	10/18/91			559.6	111.07	561.26	112.73	448.53	USACE	
LUB	181	11/21/91			559.6	111.08	561.26	112.74	448.52	USACE	
LUB	181	12/17/91			559.6	111.06	561.26	112.72	448.54	USACE	
LUB	181	1/22/92			559.6	111.04	561.26	112.7	448.56	USACE	
LUB	181	2/18/92			559.6	111.11	561.26	112.77	448.49	USACE	
LUB	181	3/12/92			559.6	111.17	561.26	112.83	448.43	USACE	
LUB	181	4/21/92			559.6	111.06	561.26	112.72	448.54	USACE	
LUB	182	12/19/90			567.3	71.52	569.55	73.77	495.78	USACE	
LUB	182	1/12/91			567.3	71.31	569.55	73.56	495.99	USACE	
LUB	182	2/11/91			567.3	71.11	569.55	73.36	496.19	USACE	
LUB	182	3/20/91			567.3	70.35	569.55	72.6	496.95	USACE	
LUB	182	4/18/91			567.3	69.41	569.55	71.66	497.89	USACE	
LUB	182	5/25/91			567.3	68.36	569.55	70.61	498.94	USACE	
LUB	182	6/26/91			567.3	67.97	569.55	70.22	499.33	USACE	
LUB	182	7/22/91			567.3	68.36	569.55	70.61	498.94	USACE	
LUB	182	8/20/91			567.3	68.98	569.55	71.23	498.32	USACE	
LUB	182	9/25/91			567.3	69.63	569.55	71.88	497.67	USACE	
LUB	182	10/17/91			567.3	69.77	569.55	72.02	497.53	USACE	
LUB	182	11/20/91			567.3	69.65	569.55	71.9	497.65	USACE	
LUB	182	12/18/91			567.3	69.56	569.55	71.81	497.74	USACE	
LUB	182	1/22/92			567.3	69.45	569.55	71.7	497.85	USACE	
LUB	182	2/17/92			567.3	69.35	569.55	71.6	497.95	USACE	
LUB	182	3/11/92			567.3	69.07	569.55	71.32	498.23	USACE	
LUB	182	4/20/92			567.3	68.3	569.55	70.55	499.00	USACE	
LUB	183	12/19/90			515.1	19.39	516.91	21.2	495.71	USACE	
LUB	183	1/13/91			515.1	19.16	516.91	20.97	495.94	USACE	
LUB	183	2/11/91			515.1	18.83	516.91	20.64	496.27	USACE	
LUB	183	3/20/91			515.1	17.78	516.91	19.59	497.32	USACE	
LUB	183	4/18/91			515.1	16.75	516.91	18.56	498.35	USACE	
LUB	183	6/26/91			515.1	15.77	516.91	17.58	499.33	USACE	
LUB	183	7/22/91			515.1	16.41	516.91	18.22	498.69	USACE	
LUB	183	8/20/91			515.1	17.09	516.91	18.9	498.01	USACE	
LUB	183	9/25/91			515.1	17.72	516.91	19.53	497.38	USACE	
LUB	183	10/17/91			515.1	17.65	516.91	19.46	497.45	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	183	11/20/91			515.1	17.53	516.91	19.34	497.57	USACE	
LUB	183	12/18/91			515.1	17.37	516.91	19.18	497.73	USACE	
LUB	183	1/22/92			515.1	17.22	516.91	19.03	497.88	USACE	
LUB	183	2/17/92			515.1	17.1	516.91	18.91	498.00	USACE	
LUB	183	3/11/92			515.1	16.59	516.91	18.4	498.51	USACE	
LUB	183	4/20/92			515.1	15.93	516.91	17.74	499.17	USACE	
LUB	184	12/19/90			614.2	118.56	615.98	120.34	495.64	USACE	
LUB	184	1/12/91			614.2	118.32	615.98	120.1	495.88	USACE	
LUB	184	2/11/91			614.2	117.97	615.98	119.75	496.23	USACE	
LUB	184	3/20/91			614.2	116.83	615.98	118.61	497.37	USACE	
LUB	184	4/18/91			614.2	115.77	615.98	117.55	498.43	USACE	
LUB	184	5/24/91			614.2	114.82	615.98	116.6	499.38	USACE	
LUB	184	6/26/91			614.2	115.02	615.98	116.8	499.18	USACE	
LUB	184	7/22/91			614.2	115.74	615.98	117.52	498.46	USACE	
LUB	184	8/20/91			614.2	116.42	615.98	118.2	497.78	USACE	
LUB	184	9/25/91			614.2	116.97	615.98	118.75	497.23	USACE	
LUB	184	10/17/91			614.2	116.61	615.98	118.39	497.59	USACE	
LUB	184	11/20/91			614.2	116.71	615.98	118.49	497.49	USACE	
LUB	184	12/18/91			614.2	116.54	615.98	118.32	497.66	USACE	
LUB	184	1/21/92			614.2	116.42	615.98	118.2	497.78	USACE	
LUB	184	2/17/92			614.2	116.27	615.98	118.05	497.93	USACE	
LUB	184	3/11/92			614.2	115.69	615.98	117.47	498.51	USACE	
LUB	184	4/20/92			614.2	115.09	615.98	116.87	499.11	USACE	
LUB	185	12/20/90			441.7	61.81	443.43	63.54	379.89	USACE	
LUB	185	1/10/91			441.7	61.85	443.43	63.58	379.85	USACE	
LUB	185	2/11/91			441.7	61.77	443.43	63.5	379.93	USACE	
LUB	185	3/20/91			441.7	61.81	443.43	63.54	379.89	USACE	
LUB	185	4/18/91			441.7	61.71	443.43	63.44	379.99	USACE	
LUB	185	5/25/91			441.7	61.71	443.43	63.44	379.99	USACE	
LUB	185	6/26/91			441.7	61.66	443.43	63.39	380.04	USACE	
LUB	185	7/23/91			441.7	61.62	443.43	63.35	380.08	USACE	
LUB	185	8/20/91			441.7	61.61	443.43	63.34	380.09	USACE	
LUB	185	9/24/91			441.7	61.58	443.43	63.31	380.12	USACE	
LUB	185	10/18/91			441.7	61.75	443.43	63.48	379.95	USACE	
LUB	185	11/21/91			441.7	61.67	443.43	63.4	380.03	USACE	
LUB	185	12/17/91			441.7	61.39	443.43	63.12	380.31	USACE	
LUB	185	1/22/92			441.7	61.48	443.43	63.21	380.22	USACE	
LUB	185	2/18/92			441.7	61.35	443.43	63.08	380.35	USACE	
LUB	185	3/12/92			441.7	61.41	443.43	63.14	380.29	USACE	
LUB	185	4/21/92			441.7	61.34	443.43	63.07	380.36	USACE	
LUB	186	12/19/90			613.9	118.27	615.69	120.06	495.63	USACE	
LUB	186	1/12/91			613.9	118.04	615.69	119.83	495.86	USACE	
LUB	186	2/11/91			613.9	117.66	615.69	119.45	496.24	USACE	
LUB	186	3/20/91			613.9	116.57	615.69	118.36	497.33	USACE	
LUB	186	4/18/91			613.9	115.56	615.69	117.35	498.34	USACE	
LUB	186	5/24/91			613.9	114.61	615.69	116.4	499.29	USACE	
LUB	186	6/26/91			613.9	114.71	615.69	116.5	499.19	USACE	
LUB	186	7/22/91			613.9	115.45	615.69	117.24	498.45	USACE	
LUB	186	8/20/91			613.9	116.11	615.69	117.9	497.79	USACE	
LUB	186	9/24/91			613.9	116.69	615.69	118.48	497.21	USACE	
LUB	186	10/17/91			613.9	116.34	615.69	118.13	497.56	USACE	
LUB	186	11/20/91			613.9	116.43	615.69	118.22	497.47	USACE	
LUB	186	12/18/91			613.9	116.25	615.69	118.04	497.65	USACE	
LUB	186	1/21/92			613.9	116.13	615.69	117.92	497.77	USACE	
LUB	186	2/17/92			613.9	115.99	615.69	117.78	497.91	USACE	
LUB	186	3/11/92			613.9	115.4	615.69	117.19	498.50	USACE	
LUB	186	4/20/92			613.9	114.81	615.69	116.6	499.09	USACE	
LUB	187	12/19/90			543.6	47.93	545.44	49.77	495.67	USACE	
LUB	187	1/12/91			543.6	47.72	545.44	49.56	495.88	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	187	2/11/91			543.6	47.42	545.44	49.26	496.18	USACE	
LUB	187	3/20/91			543.6	46.44	545.44	48.28	497.16	USACE	
LUB	187	4/18/91			543.6	45.41	545.44	47.25	498.19	USACE	
LUB	187	5/25/91			543.6	44.49	545.44	46.33	499.11	USACE	
LUB	187	6/26/91			543.6	44.27	545.44	46.11	499.33	USACE	
LUB	187	7/22/91			543.6	44.84	545.44	46.68	498.76	USACE	
LUB	187	8/20/91			543.6	45.53	545.44	47.37	498.07	USACE	
LUB	187	9/24/91			543.6	46.18	545.44	48.02	497.42	USACE	
LUB	187	10/17/91			543.6	46.14	545.44	47.98	497.46	USACE	
LUB	187	11/20/91			543.6	46.04	545.44	47.88	497.56	USACE	
LUB	187	12/18/91			543.6	45.89	545.44	47.73	497.71	USACE	
LUB	187	1/22/92			543.6	45.76	545.44	47.6	497.84	USACE	
LUB	187	2/17/92			543.6	45.65	545.44	47.49	497.95	USACE	
LUB	187	3/11/92			543.6	45.21	545.44	47.05	498.39	USACE	
LUB	187	4/20/92			543.6	44.5	545.44	46.34	499.10	USACE	
LUB	188	12/19/90			550.5	54.83	551.76	56.09	495.67	USACE	
LUB	188	1/12/91			550.5	54.62	551.76	55.88	495.88	USACE	
LUB	188	2/11/91			550.5	54.32	551.76	55.58	496.18	USACE	
LUB	188	3/20/91			550.5	53.39	551.76	54.65	497.11	USACE	
LUB	188	4/18/91			550.5	52.37	551.76	53.63	498.13	USACE	
LUB	188	5/25/91			550.5	51.42	551.76	52.68	499.08	USACE	
LUB	188	6/26/91			550.5	51.19	551.76	52.45	499.31	USACE	
LUB	188	7/22/91			550.5	51.73	551.76	52.99	498.77	USACE	
LUB	188	8/20/91			550.5	52.3	551.76	53.56	498.20	USACE	
LUB	188	9/24/91			550.5	53.03	551.76	54.29	497.47	USACE	
LUB	188	10/17/91			550.5	53.01	551.76	54.27	497.49	USACE	
LUB	188	11/20/91			550.5	52.94	551.76	54.2	497.56	USACE	
LUB	188	12/18/91			550.5	52.79	551.76	54.05	497.71	USACE	
LUB	188	1/22/92			550.5	52.67	551.76	53.93	497.83	USACE	
LUB	188	2/17/92			550.5	52.56	551.76	53.82	497.94	USACE	
LUB	188	3/11/92			550.5	52.15	551.76	53.41	498.35	USACE	
LUB	188	4/20/92			550.5	51.44	551.76	52.7	499.06	USACE	
LUB	189	12/19/90			557.4	62.03	558.67	63.3	495.37	USACE	
LUB	189	1/12/91			557.4	61.52	558.67	62.79	495.88	USACE	
LUB	189	2/11/91			557.4	61.29	558.67	62.56	496.11	USACE	
LUB	189	3/20/91			557.4	60.43	558.67	61.7	496.97	USACE	
LUB	189	4/18/91			557.4	59.43	558.67	60.7	497.97	USACE	
LUB	189	5/25/91			557.4	58.42	558.67	59.69	498.98	USACE	
LUB	189	6/26/91			557.4	58.07	558.67	59.34	499.33	USACE	
LUB	189	7/22/91			557.4	58.52	558.67	59.79	498.88	USACE	
LUB	189	8/20/91			557.4	59.13	558.67	60.4	498.27	USACE	
LUB	189	9/24/91			557.4	59.84	558.67	61.11	497.56	USACE	
LUB	189	10/17/91			557.4	59.82	558.67	61.09	497.58	USACE	
LUB	189	11/20/91			557.4	59.71	558.67	60.98	497.69	USACE	
LUB	189	12/18/91			557.4	59.68	558.67	60.95	497.72	USACE	
LUB	189	1/22/92			557.4	59.56	558.67	60.83	497.84	USACE	
LUB	189	2/17/92			557.4	59.47	558.67	60.74	497.93	USACE	
LUB	189	3/11/92			557.4	59.13	558.67	60.4	498.27	USACE	
LUB	189	4/20/92			557.4	58.38	558.67	59.65	499.02	USACE	
LUB	19	1/15/91	Idle		647.66	67.29			580.37	Lamb Weston	
LUB	19	2/12/91	Idle		647.66	68			579.67	Lamb Weston	
LUB	19	3/5/91	Idle		647.66	67.95			579.71	Lamb Weston	
LUB	19	4/16/91	Idle		647.66	68			579.67	Lamb Weston	
LUB	19	5/3/91	Idle		647.66	68.5			579.17	Lamb Weston	
LUB	19	6/18/91	Idle		647.66	68.04			579.62	Lamb Weston	
LUB	19	7/24/91	Idle		647.66	66.54			581.12	Lamb Weston	
LUB	19	9/20/91	Idle		647.66	67.12			580.54	Lamb Weston	
LUB	19	10/8/91	Idle		647.66	67.08			580.58	Lamb Weston	
LUB	19	1/21/92	Idle		647.66	65.44			582.22	Lamb Weston	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	19	2/12/92	Idle		647.66	65.43			582.23	Lamb Weston	
LUB	19	3/27/92	Idle		647.66	65.92			581.74	Lamb Weston	
LUB	190	12/19/90			555.4	59.74	557.28	61.62	495.66	USACE	
LUB	190	1/12/91			555.4	59.54	557.28	61.42	495.86	USACE	
LUB	190	2/11/91			555.4	59.27	557.28	61.15	496.13	USACE	
LUB	190	3/20/91			555.4	58.32	557.28	60.2	497.08	USACE	
LUB	190	4/18/91			555.4	57.29	557.28	59.17	498.11	USACE	
LUB	190	5/25/91			555.4	56.32	557.28	58.2	499.08	USACE	
LUB	190	6/26/91			555.4	56.07	557.28	57.95	499.33	USACE	
LUB	190	7/22/91			555.4	56.55	557.28	58.43	498.85	USACE	
LUB	190	8/20/91			555.4	57.27	557.28	59.15	498.13	USACE	
LUB	190	9/24/91			555.4	57.93	557.28	59.81	497.47	USACE	
LUB	190	10/17/91			555.4	57.94	557.28	59.82	497.46	USACE	
LUB	190	11/20/91			555.4	57.86	557.28	59.74	497.54	USACE	
LUB	190	12/18/91			555.4	57.71	557.28	59.59	497.69	USACE	
LUB	190	1/22/92			555.4	57.57	557.28	59.45	497.83	USACE	
LUB	190	2/17/92			555.4	57.47	557.28	59.35	497.93	USACE	
LUB	190	3/11/92			555.4	57.12	557.28	59	498.28	USACE	
LUB	190	4/20/92			555.4	56.33	557.28	58.21	499.07	USACE	
LUB	2	2/14/91	Idle	E Tape	555	57.22			497.78	OWRD	No pump
LUB	2	2/11/92	Idle	E Tape	555	56.17			498.83	OWRD	
LUB	22	3/1/91			662	20.62			641.38	PGE	
LUB	22	9/1/91			662	19.72			642.28	PGE	
LUB	22	3/1/92			662	17.92			644.08	PGE	
LUB	24	3/1/91				42.3				PGE	
LUB	24	9/1/91				41.8				PGE	
LUB	24	3/1/92				40.9				PGE	
LUB	25	3/1/91			680.4	43.8			636.60	PGE	
LUB	25	9/1/91			680.4	42.5			637.90	PGE	
LUB	25	3/1/92			680.4	42			638.40	PGE	
LUB	26	3/1/91			693.3	28.3			665.00	PGE	
LUB	26	9/1/91			693.3	28.2			665.10	PGE	
LUB	26	3/1/92			693.3	27			666.30	PGE	
LUB	27	3/1/91			383.6	1.4			382.20	PGE	
LUB	27	9/1/91			383.6	1.8			381.80	PGE	
LUB	27	3/1/92			383.6	1.7			381.90	PGE	
LUB	28	3/1/91			533.3	33.3			500.00	PGE	
LUB	28	9/1/91			533.3	35.5			497.80	PGE	
LUB	28	3/1/92			533.3	34			499.30	PGE	
LUB	29	3/1/91			589.5	17.2			572.30	PGE	
LUB	29	9/1/91			589.5	18.2			571.30	PGE	
LUB	29	3/1/92			589.5	17.3			572.20	PGE	
LUB	31	3/1/91			612	17.9			594.10	PGE	
LUB	31	9/1/91			612	17.9			594.10	PGE	
LUB	31	3/1/92			612	17.6			594.40	PGE	
LUB	32	3/1/91			612.1	28.4			583.70	PGE	
LUB	32	9/1/91			612.1	27.5			584.60	PGE	
LUB	32	3/1/92			612.1	27.3			584.80	PGE	
LUB	33	3/1/91			665.9	30.3			635.60	PGE	
LUB	33	9/1/91			665.9	28.2			637.70	PGE	
LUB	33	3/1/92			665.9	28.9			637.00	PGE	
LUB	35	3/1/91			700.4	47.8			652.60	PGE	
LUB	35	9/1/91			700.4	47.5			652.90	PGE	
LUB	35	3/1/92			700.4	47.2			653.20	PGE	
LUB	39	3/1/91				72.3				PGE	
LUB	39	9/1/91				72.3				PGE	
LUB	39	3/1/92				72.2				PGE	
LUB	4	2/11/91	Idle	E Tape	299	33.1			265.90	OWRD	
LUB	4	8/23/91	Idle	E Tape	299	31.31			267.69	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	4	2/10/92	Idle	E Tape	299	33.66			265.34	OWRD	
LUB	40	12/12/90					616.51	114.65	501.86	DEQ Report	
LUB	40	1/17/91					616.51	115.58	500.93	DEQ Report	
LUB	40	2/5/91					616.51	115.74	500.77	DEQ Report	
LUB	40	3/8/91					616.51	116	500.51	DEQ Report	
LUB	40	4/8/91					616.51	116.17	500.34	DEQ Report	
LUB	40	5/15/91					616.51	115.83	500.68	DEQ Report	
LUB	40	6/6/91					616.51	114.03	502.48	DEQ Report	
LUB	40	7/12/91					616.51	113.23	503.28	DEQ Report	
LUB	40	8/7/91					616.51	113.15	503.36	DEQ Report	
LUB	40	9/6/91					616.51	113.61	502.90	DEQ Report	
LUB	40	10/28/91								DEQ Report	Abandoned
LUB	41	12/12/90					616.5	123.33	493.17	DEQ Report	
LUB	41	1/17/91					616.5	122.43	494.07	DEQ Report	
LUB	41	2/6/91					616.5	121.29	495.21	DEQ Report	
LUB	41	3/11/91					616.5	130.84	485.66	DEQ Report	
LUB	41	4/8/91					616.5	133.97	482.53	DEQ Report	
LUB	41	6/6/91					616.5	122.97	493.53	DEQ Report	
LUB	41	7/12/91					616.5	127.43	489.07	DEQ Report	
LUB	41	8/7/91					616.5	134.43	482.07	DEQ Report	
LUB	41	9/6/91					616.5	121.87	494.63	DEQ Report	
LUB	41	10/28/91								DEQ Report	Abandoned
LUB	42	12/6/90					605.23	103.63	501.60	DEQ Report	
LUB	42	1/16/91					605.23	104.97	500.26	DEQ Report	
LUB	42	2/6/91					605.23	105.14	500.09	DEQ Report	
LUB	42	3/4/91					605.23	105.46	499.77	DEQ Report	
LUB	42	4/4/91					605.23	105.52	499.71	DEQ Report	
LUB	42	5/10/91					605.23	105.35	499.88	DEQ Report	
LUB	42	6/7/91					605.23	103.32	501.91	DEQ Report	
LUB	42	7/10/91					605.23	102.4	502.83	DEQ Report	
LUB	42	8/6/91					605.23	102.34	502.89	DEQ Report	
LUB	42	9/5/91					605.23	102.5	502.73	DEQ Report	
LUB	42	10/24/91					605.23	102.68	502.55	DEQ Report	
LUB	42	11/12/91					605.23	102.87	502.36	DEQ Report	
LUB	42	12/12/91					605.23	103.41	501.82	DEQ Report	
LUB	43	12/7/90					605.14	105.23	499.91	DEQ Report	
LUB	43	2/7/91					605.14	108.81	496.33	DEQ Report	
LUB	43	3/4/91					605.14	111.08	494.06	DEQ Report	
LUB	43	4/8/91					605.14	111.43	493.71	DEQ Report	
LUB	43	5/10/91					605.14	109.2	495.94	DEQ Report	
LUB	43	6/7/91					605.14	110.08	495.06	DEQ Report	
LUB	43	7/11/91					605.14	109.4	495.74	DEQ Report	
LUB	43	8/6/91					605.14	115.18	489.96	DEQ Report	
LUB	43	9/5/91					605.14	108.98	496.16	DEQ Report	
LUB	43	10/24/91					605.14	104.27	500.87	DEQ Report	
LUB	43	11/12/91					605.14	103.41	501.73	DEQ Report	
LUB	43	12/12/91					605.14	105.41	499.73	DEQ Report	
LUB	44	12/7/90					573.37	69.15	504.22	DEQ Report	
LUB	44	1/15/91					573.37	70.05	503.32	DEQ Report	
LUB	44	2/6/91					573.37	70	503.37	DEQ Report	
LUB	44	3/5/91					573.37	70.04	503.33	DEQ Report	
LUB	44	4/8/91					573.37	70	503.37	DEQ Report	
LUB	44	5/7/91					573.37	69.92	503.45	DEQ Report	
LUB	44	6/5/91					573.37	68.46	504.91	DEQ Report	
LUB	44	7/10/91					573.37	68.85	504.52	DEQ Report	
LUB	44	8/8/91					573.37	68.85	504.52	DEQ Report	
LUB	44	9/5/91					573.37	69.15	504.22	DEQ Report	
LUB	44	10/25/91					573.37	69.08	504.29	DEQ Report	
LUB	44	11/12/91					573.37	69.18	504.19	DEQ Report	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	44	12/12/91					573.37	69.39	503.98	DEQ Report	
LUB	45	12/6/90					615.83	114.53	501.30	DEQ Report	
LUB	45	1/13/91					615.83	116.02	499.81	DEQ Report	
LUB	45	2/7/91					615.83	116.3	499.53	DEQ Report	
LUB	45	3/4/91					615.83	116.49	499.34	DEQ Report	
LUB	45	4/4/91					615.83	116.62	499.21	DEQ Report	
LUB	45	5/10/91					615.83	116.35	499.48	DEQ Report	
LUB	45	6/7/91					615.83	114.26	501.57	DEQ Report	
LUB	45	7/10/91					615.83	113.76	502.07	DEQ Report	
LUB	45	8/6/91					615.83	113.67	502.16	DEQ Report	
LUB	45	9/4/91					615.83	117	498.83	DEQ Report	
LUB	45	10/24/91					615.83	113.85	501.98	DEQ Report	
LUB	45	11/8/91					615.83	113.95	501.88	DEQ Report	
LUB	45	12/13/91					615.83	114.69	501.14	DEQ Report	
LUB	46	12/6/90					615.92	110.54	505.38	DEQ Report	
LUB	46	1/16/91					615.92	114.64	501.28	DEQ Report	
LUB	46	2/7/91					615.92	114.2	501.72	DEQ Report	
LUB	46	3/4/91					615.92	116.24	499.68	DEQ Report	
LUB	46	4/4/91					615.92	116.3	499.62	DEQ Report	
LUB	46	5/20/91					615.92	119.9	496.02	DEQ Report	
LUB	46	6/7/91					615.92	116.32	499.60	DEQ Report	
LUB	46	7/10/91					615.92	121.25	494.67	DEQ Report	
LUB	46	8/6/91					615.92	123.13	492.79	DEQ Report	
LUB	46	9/4/91					615.92	116.42	499.50	DEQ Report	
LUB	46	10/24/91					615.92	110.4	505.52	DEQ Report	
LUB	46	11/8/91					615.92	109.36	506.56	DEQ Report	
LUB	46	12/13/91					615.92	110.2	505.72	DEQ Report	
LUB	47	12/7/90					643.51	84.33	559.18	DEQ Report	
LUB	47	1/16/91					643.51	85.78	557.73	DEQ Report	
LUB	47	2/5/91					643.51	86.23	557.28	DEQ Report	
LUB	47	3/6/91					643.51	86.8	556.71	DEQ Report	
LUB	47	4/3/91					643.51	85.65	557.86	DEQ Report	
LUB	47	5/14/91					643.51	84.65	558.86	DEQ Report	
LUB	47	6/11/91					643.51	85.53	559.98	DEQ Report	
LUB	47	7/11/91					643.51	82.87	560.64	DEQ Report	
LUB	47	8/8/91					643.51	82.57	560.94	DEQ Report	
LUB	47	9/6/91					643.51	82.41	561.10	DEQ Report	
LUB	47	10/25/91					643.51	82.38	561.13	DEQ Report	
LUB	47	11/12/91					643.51	82.46	561.05	DEQ Report	
LUB	47	12/12/91					643.51	82.81	560.70	DEQ Report	
LUB	48	12/12/90					659.45	81.59	577.86	DEQ Report	
LUB	48	1/16/91					659.45	81.9	577.55	DEQ Report	
LUB	48	2/5/91					659.45	82	577.45	DEQ Report	
LUB	48	3/8/91					659.45	81.58	577.87	DEQ Report	
LUB	48	4/3/91					659.45	81.67	577.78	DEQ Report	
LUB	48	5/14/91					659.45	81.4	578.05	DEQ Report	
LUB	48	6/4/91					659.45	81.16	578.29	DEQ Report	
LUB	48	7/11/91								DEQ Report	
LUB	49	12/4/90					551.59	11.47	540.12	DEQ Report	
LUB	49	1/15/91					551.59	11.34	540.25	DEQ Report	
LUB	49	2/8/91					551.59	10.68	540.91	DEQ Report	
LUB	49	3/5/91					551.59	8.87	542.72	DEQ Report	
LUB	49	4/1/91					551.59	10.14	541.45	DEQ Report	
LUB	49	5/9/91					551.59	10.52	541.07	DEQ Report	
LUB	49	6/5/91					551.59	7.66	543.93	DEQ Report	
LUB	49	7/3/91					551.59	9.77	541.82	DEQ Report	
LUB	49	7/30/91					551.59	10.56	541.03	DEQ Report	
LUB	49	9/6/91					551.59	11.49	540.10	DEQ Report	
LUB	49	10/22/91					551.59	11.61	539.98	DEQ Report	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	49	11/7/91					551.59	11.52	540.07	DEQ Report	
LUB	49	12/2/91					551.59	10.15	541.44	DEQ Report	
LUB	5	12/5/90	Idle	E Tape	283.45	17.46			265.99	DEQ	
LUB	5	2/11/91	Idle	E Tape	283.45	18.22			265.23	DEQ	
LUB	5	3/14/91	Idle	E Tape	283.45	17.46			265.99	DEQ	
LUB	5	6/10/91	Idle	E Tape	283.45	19.9			263.55	DEQ	
LUB	5	8/23/91	Idle	E Tape	283.45	15.75			267.70	DEQ	
LUB	5	9/10/91	Idle	E Tape	283.45	15.25			268.20	DEQ	
LUB	5	12/10/91	Idle	E Tape	283.45	17.83			265.62	DEQ	
LUB	5	2/10/92	Idle	E Tape	283.45	18.75			264.70	DEQ	
LUB	5	3/10/92	Idle	E Tape	283.45	17.85			265.60	DEQ	
LUB	50	12/5/90					551.91	10.54	541.37	DEQ Report	
LUB	50	1/15/91					551.91	10.18	541.73	DEQ Report	
LUB	50	2/8/91					551.91	10.16	541.75	DEQ Report	
LUB	50	3/5/91					551.91	9.45	542.46	DEQ Report	
LUB	50	4/1/91					551.91	9.53	542.38	DEQ Report	
LUB	50	5/8/91					551.91	9.75	542.16	DEQ Report	
LUB	50	6/5/91					551.91	7.68	544.23	DEQ Report	
LUB	50	7/3/91					551.91	8.7	543.21	DEQ Report	
LUB	50	7/30/91					551.91	10.31	541.60	DEQ Report	
LUB	50	9/6/91					551.91	10.74	541.17	DEQ Report	
LUB	50	10/22/91					551.91	10.66	541.25	DEQ Report	
LUB	50	11/7/91					551.91	10.34	541.57	DEQ Report	
LUB	50	12/2/91					551.91	9.03	542.88	DEQ Report	
LUB	51	12/5/90					551.01	11.83	539.18	DEQ Report	
LUB	51	1/15/91					551.01	11.15	539.86	DEQ Report	
LUB	51	2/8/91					551.01	11.23	539.78	DEQ Report	
LUB	51	3/5/91					551.01	10.65	540.36	DEQ Report	
LUB	51	4/1/91					551.01	10.65	540.36	DEQ Report	
LUB	51	5/8/91					551.01	10.8	540.21	DEQ Report	
LUB	51	6/5/91					551.01	8.16	542.85	DEQ Report	
LUB	51	7/3/91					551.01	10.63	540.38	DEQ Report	
LUB	51	7/30/91					551.01	11.35	539.66	DEQ Report	
LUB	51	9/16/91					551.01	12.17	538.84	DEQ Report	
LUB	51	10/22/91					551.01	12.12	538.89	DEQ Report	
LUB	51	11/7/91					551.01	11.49	539.52	DEQ Report	
LUB	51	12/2/91					551.01	10.61	540.40	DEQ Report	
LUB	52	12/5/90					548.1	9.71	538.39	DEQ Report	
LUB	52	1/15/91					548.1	8.55	539.55	DEQ Report	
LUB	52	2/7/91					548.1	9.27	538.83	DEQ Report	
LUB	52	3/5/91					548.1	8.2	539.90	DEQ Report	
LUB	52	4/1/91					548.1	8.68	539.42	DEQ Report	
LUB	52	5/9/91					548.1	8.37	539.73	DEQ Report	
LUB	52	6/5/91					548.1	8.02	540.08	DEQ Report	
LUB	52	7/9/91					548.1	9.78	538.32	DEQ Report	
LUB	52	8/7/91					548.1	9.82	538.28	DEQ Report	
LUB	52	9/25/91					548.1	9.98	538.12	DEQ Report	
LUB	52	10/23/91					548.1	9.72	538.38	DEQ Report	
LUB	52	11/7/91					548.1	9.66	538.44	DEQ Report	
LUB	52	12/2/91					548.1	8.05	540.05	DEQ Report	
LUB	53	12/5/90					550.17	11.07	539.10	DEQ Report	
LUB	53	1/15/91					550.17	10.61	539.56	DEQ Report	
LUB	53	2/8/91					550.17	10.39	539.78	DEQ Report	
LUB	53	3/5/91					550.17	10	540.17	DEQ Report	
LUB	53	4/1/91					550.17	10.03	540.14	DEQ Report	
LUB	53	5/9/91					550.17	10	540.17	DEQ Report	
LUB	53	6/5/91					550.17	7.63	542.54	DEQ Report	
LUB	53	7/9/91					550.17	10.17	540.00	DEQ Report	
LUB	53	7/31/91					550.17	10.78	539.39	DEQ Report	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	53	9/6/91					550.17	11.64	538.53	DEQ Report	
LUB	53	10/22/91					550.17	11.38	538.79	DEQ Report	
LUB	53	11/7/91					550.17	10.9	539.27	DEQ Report	
LUB	53	12/2/91					550.17	9.87	540.30	DEQ Report	
LUB	54	12/5/90					550.02	14.32	535.70	DEQ Report	
LUB	54	1/15/91					550.02	14.45	535.57	DEQ Report	
LUB	54	2/8/91					550.02	14.47	535.55	DEQ Report	
LUB	54	3/5/91					550.02	14.23	535.79	DEQ Report	
LUB	54	4/1/91					550.02	14.46	535.56	DEQ Report	
LUB	54	5/8/91					550.02	14.18	535.84	DEQ Report	
LUB	54	6/5/91					550.02	11.84	538.18	DEQ Report	
LUB	54	7/9/91					550.02	14.15	535.87	DEQ Report	
LUB	54	9/16/91					550.02	14.91	535.11	DEQ Report	
LUB	54	10/22/91					550.02	14.69	535.33	DEQ Report	
LUB	54	11/7/91					550.02	14.54	535.48	DEQ Report	
LUB	54	12/2/91					550.02	14.26	535.76	DEQ Report	
LUB	55	12/7/90					643.55	75.62	567.93	DEQ Report	
LUB	55	1/16/91					643.55	76.25	567.30	DEQ Report	
LUB	55	2/5/91					643.55	76.13	567.42	DEQ Report	
LUB	55	3/6/91					643.55	75.39	568.16	DEQ Report	
LUB	55	4/3/91					643.55	74.8	568.75	DEQ Report	
LUB	55	5/14/91					643.55	74.15	569.40	DEQ Report	
LUB	55	6/11/91					643.55	73.26	570.29	DEQ Report	
LUB	55	7/11/91					643.55	72.96	570.59	DEQ Report	
LUB	55	8/8/91					643.55	73.01	570.54	DEQ Report	
LUB	55	9/6/91					643.55	73.33	570.22	DEQ Report	
LUB	55	10/25/91					643.55	73.54	570.01	DEQ Report	
LUB	55	11/12/91					643.55	73.9	569.65	DEQ Report	
LUB	55	12/12/91					643.55	74.26	569.29	DEQ Report	
LUB	56	12/11/90					576.04	21.74	554.30	DEQ Report	
LUB	56	1/18/91					576.04	23.6	552.44	DEQ Report	
LUB	56	2/8/91					576.04	24.32	551.72	DEQ Report	
LUB	56	3/6/91					576.04	24.2	551.84	DEQ Report	
LUB	56	4/2/91					576.04	21.23	554.81	DEQ Report	
LUB	56	5/9/91					576.04	14.93	561.11	DEQ Report	
LUB	56	6/6/91					576.04	11.68	564.36	DEQ Report	
LUB	56	7/12/91					576.04	11.05	564.99	DEQ Report	
LUB	56	7/31/91					576.04	11.02	565.02	DEQ Report	
LUB	56	9/25/91					576.04	13.17	562.87	DEQ Report	
LUB	56	10/25/91					576.04	15.8	560.24	DEQ Report	
LUB	56	11/14/91					576.04	17.74	558.30	DEQ Report	
LUB	56	12/22/91					576.04	19.35	556.69	DEQ Report	
LUB	57	12/11/90					577.17			DEQ Report	Dry
LUB	57	1/18/91					577.17			DEQ Report	Dry
LUB	57	2/8/91					577.17			DEQ Report	Dry
LUB	57	3/6/91					577.17			DEQ Report	Dry
LUB	57	4/3/91					577.17	21.84	555.33	DEQ Report	
LUB	57	5/9/91					577.17	16.21	560.96	DEQ Report	
LUB	57	6/12/91					577.17	13.12	564.05	DEQ Report	
LUB	57	7/13/91					577.17	12.66	564.51	DEQ Report	
LUB	57	9/26/91					577.17	15.11	562.06	DEQ Report	
LUB	57	10/28/91					577.17	17.94	559.23	DEQ Report	
LUB	57	11/19/91					577.17	19.77	557.40	DEQ Report	
LUB	57	12/4/91					577.17	20.8	556.37	DEQ Report	
LUB	58	12/11/90					586.96			DEQ Report	Dry
LUB	58	1/18/91					586.96			DEQ Report	Dry
LUB	58	2/8/91					586.96			DEQ Report	Dry
LUB	58	3/6/91					586.96	17.88	569.08	DEQ Report	
LUB	58	4/2/91					586.96	15.88	571.08	DEQ Report	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	58	5/9/91					586.96	13.29	573.67	DEQ Report	
LUB	58	6/11/91					586.96	11.68	575.28	DEQ Report	
LUB	58	7/12/91					586.96	11.24	575.72	DEQ Report	
LUB	58	7/31/91					586.96	11.37	575.59	DEQ Report	
LUB	58	9/25/91					586.96	14.76	572.20	DEQ Report	
LUB	58	10/25/91					586.96	16.35	570.61	DEQ Report	
LUB	58	11/14/91					586.96	17.5	569.46	DEQ Report	
LUB	58	12/4/91					586.96	18.63	568.33	DEQ Report	
LUB	59	12/11/90					594.76			DEQ Report	Dry
LUB	59	1/18/91					594.76			DEQ Report	Dry
LUB	59	2/8/91					594.76			DEQ Report	Dry
LUB	59	3/8/91					594.76	27.3	567.46	DEQ Report	
LUB	59	4/3/91					594.76	24.97	569.79	DEQ Report	
LUB	59	5/9/91					594.76	22.35	572.41	DEQ Report	
LUB	59	6/11/91					594.76	20.91	573.85	DEQ Report	
LUB	59	7/12/91					594.76	20.3	574.46	DEQ Report	
LUB	59	7/31/91					594.76	20.44	574.32	DEQ Report	
LUB	59	9/26/91					594.76	25.1	569.66	DEQ Report	
LUB	59	10/25/91					594.76	27.13	567.63	DEQ Report	
LUB	59	11/14/91					594.76	28.18	566.58	DEQ Report	
LUB	59	12/3/91					594.76	29.26	565.50	DEQ Report	
LUB	6	2/13/91	Idle	E Tape	301	36.53			264.47	OWRD	
LUB	6	2/10/92	Idle	E Tape	301	37.17			263.83	OWRD	
LUB	60	12/11/90					588.37			DEQ Report	Dry
LUB	60	1/18/91					588.37			DEQ Report	Dry
LUB	60	2/8/91					588.37			DEQ Report	Dry
LUB	60	3/6/91					588.37	19.94	568.43	DEQ Report	
LUB	60	4/2/91					588.37	17.74	570.63	DEQ Report	
LUB	60	5/9/91					588.37	15.12	573.25	DEQ Report	
LUB	60	6/12/91					588.37	13.55	574.82	DEQ Report	
LUB	60	7/3/91					588.37	13.02	575.35	DEQ Report	
LUB	60	7/31/91					588.37	13.19	575.18	DEQ Report	
LUB	60	9/26/91					588.37	17.28	571.09	DEQ Report	
LUB	60	10/25/91					588.37	18.8	569.57	DEQ Report	
LUB	60	11/14/91					588.37	19.87	568.50	DEQ Report	
LUB	60	12/3/91					588.37			DEQ Report	Dry
LUB	61	12/12/90					597.81	27.83	569.98	DEQ Report	
LUB	61	1/18/91					597.81	29.08	568.73	DEQ Report	
LUB	61	2/8/91					597.81	29.06	568.75	DEQ Report	
LUB	61	3/7/91					597.81	27.83	569.98	DEQ Report	
LUB	61	4/3/91					597.81	26.54	571.27	DEQ Report	
LUB	61	5/15/91					597.81	23.77	574.04	DEQ Report	
LUB	61	6/12/91					597.81	22.02	575.79	DEQ Report	
LUB	61	7/13/91					597.81	21.14	576.67	DEQ Report	
LUB	61	7/31/91					597.81	21.14	576.67	DEQ Report	
LUB	61	9/26/91					597.81	23.1	574.71	DEQ Report	
LUB	61	10/29/91					597.81	24.31	573.50	DEQ Report	
LUB	61	11/19/91					597.81	25.29	572.52	DEQ Report	
LUB	61	12/9/91					597.81	26.25	571.56	DEQ Report	
LUB	62	12/11/90					608.05	28.19	579.86	DEQ Report	
LUB	62	1/18/91					608.05	28.04	580.01	DEQ Report	
LUB	62	2/8/91					608.05	25.5	582.55	DEQ Report	
LUB	62	3/6/91					608.05	23.49	584.56	DEQ Report	
LUB	62	4/2/91					608.05	22.25	585.80	DEQ Report	
LUB	62	5/14/91					608.05	18.8	589.25	DEQ Report	
LUB	62	6/12/91					608.05	19.93	588.12	DEQ Report	
LUB	62	7/12/91					608.05	18.45	589.60	DEQ Report	
LUB	62	7/30/91					608.05	19.57	588.48	DEQ Report	
LUB	62	9/26/91					608.05	23.55	584.50	DEQ Report	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	62	10/23/91					608.05	24.81	583.24	DEQ Report	
LUB	62	11/14/91					608.05	26.02	582.03	DEQ Report	
LUB	62	12/3/91					608.05	26.95	581.10	DEQ Report	
LUB	63	12/11/90					621.57	33.73	587.84	DEQ Report	
LUB	63	1/18/91					621.57	33.83	587.74	DEQ Report	
LUB	63	2/8/91					621.57	33.43	588.14	DEQ Report	
LUB	63	3/7/91					621.57	32.2	589.37	DEQ Report	
LUB	63	4/2/91					621.57	29.32	592.25	DEQ Report	
LUB	63	5/7/91					621.57	27.3	594.27	DEQ Report	
LUB	63	6/12/91					621.57	27.23	594.34	DEQ Report	
LUB	63	7/13/91					621.57	26.89	594.68	DEQ Report	
LUB	63	8/9/91					621.57	29.76	591.81	DEQ Report	
LUB	63	9/26/91					621.57	31.7	589.87	DEQ Report	
LUB	63	10/25/91					621.57	32.49	589.08	DEQ Report	
LUB	63	11/14/91					621.57	33.18	588.39	DEQ Report	
LUB	63	12/3/91					621.57	33.55	588.02	DEQ Report	
LUB	64	4/17/91					557.44	23.03	534.41	DEQ Report	
LUB	64	5/9/91					557.44	20.78	536.66	DEQ Report	
LUB	64	6/11/91					557.44	19.79	537.65	DEQ Report	
LUB	64	7/12/91					557.44	18.95	538.49	DEQ Report	
LUB	64	8/9/91					557.44	17.75	539.69	DEQ Report	
LUB	64	9/16/91					557.44	18.45	538.99	DEQ Report	
LUB	64	10/29/91					557.44	20.2	537.24	DEQ Report	
LUB	64	11/19/91					557.44	20.85	536.59	DEQ Report	
LUB	64	12/3/91					557.44	21.45	535.99	DEQ Report	
LUB	65	4/17/91					569.7	16.79	552.91	DEQ Report	
LUB	65	5/9/91					569.7	12.65	557.05	DEQ Report	
LUB	65	6/12/91					569.7	9.34	560.36	DEQ Report	
LUB	65	7/23/91					569.7	8.66	561.04	DEQ Report	
LUB	65	7/31/91					569.7	8.66	561.04	DEQ Report	
LUB	65	9/16/91					569.7	10.16	559.54	DEQ Report	
LUB	65	10/28/91					569.7	13.71	555.99	DEQ Report	
LUB	65	11/19/91					569.7	15.84	553.86	DEQ Report	
LUB	65	12/4/91					569.7	16.86	552.84	DEQ Report	
LUB	66	4/17/91					570.81	15.02	555.79	DEQ Report	
LUB	66	5/9/91					570.81	12.18	558.63	DEQ Report	
LUB	66	6/12/91					570.81	9.72	561.09	DEQ Report	
LUB	66	7/12/91					570.81	9.06	561.75	DEQ Report	
LUB	66	7/31/91					570.81	9.08	561.73	DEQ Report	
LUB	66	9/16/91					570.81	11	559.81	DEQ Report	
LUB	66	10/28/91					570.81	14.69	556.12	DEQ Report	
LUB	66	11/19/91					570.81	16.92	553.89	DEQ Report	
LUB	66	12/4/91					570.81	18.22	552.59	DEQ Report	
LUB	67	4/17/91					627.8	23.36	604.44	DEQ Report	
LUB	67	5/15/91					627.8	23.9	603.90	DEQ Report	
LUB	67	6/13/91					627.8	23.37	604.43	DEQ Report	
LUB	67	7/23/91					627.8	23.9	603.90	DEQ Report	
LUB	67	8/9/91					627.8	24.19	603.61	DEQ Report	
LUB	67	9/16/91					627.8	24.89	602.91	DEQ Report	
LUB	67	10/28/91					627.8	25.3	602.50	DEQ Report	
LUB	67	11/19/91					627.8	25.73	602.07	DEQ Report	
LUB	67	12/9/91					627.8	25.9	601.90	DEQ Report	
LUB	68	4/17/91					642.5	20.21	622.29	DEQ Report	
LUB	68	5/14/91					642.5	21	621.50	DEQ Report	
LUB	68	6/13/91					642.5	18.93	623.57	DEQ Report	
LUB	68	7/23/91					642.5	20.62	621.88	DEQ Report	
LUB	68	8/9/91					642.5	21.2	621.30	DEQ Report	
LUB	68	9/16/91					642.5	22.25	620.25	DEQ Report	
LUB	68	10/23/91					642.5	22.9	619.60	DEQ Report	

Lower Umatilla Basin
Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	68	11/14/91					642.5	23.28	619.22	DEQ Report	
LUB	68	12/9/91					642.5	23.39	619.11	DEQ Report	
LUB	69	4/18/91					655.37	16.3	639.07	DEQ Report	
LUB	69	5/14/91					655.37	16.53	638.84	DEQ Report	
LUB	69	6/13/91					655.37	16.48	638.89	DEQ Report	
LUB	69	7/23/91					655.37	16.95	638.42	DEQ Report	
LUB	69	8/9/91					655.37	16.8	638.57	DEQ Report	
LUB	69	9/16/91					655.37	17.43	637.94	DEQ Report	
LUB	69	10/23/91					655.37	17.45	637.92	DEQ Report	
LUB	69	11/14/91					655.37	17.66	637.71	DEQ Report	
LUB	69	12/3/91					655.37	17.73	637.64	DEQ Report	
LUB	7	2/13/91	Idle	E Tape	301	35.58			265.42	OWRD	
LUB	7	8/23/91	Idle	E Tape	301	32.64			268.36	OWRD	
LUB	7	2/10/92	Idle	E Tape	301	35.92			265.08	OWRD	
LUB	70	4/18/91					637.61	24.11	613.50	DEQ Report	
LUB	70	5/15/91					637.61	14.32	623.29	DEQ Report	
LUB	70	6/13/91					637.61	23.44	614.17	DEQ Report	
LUB	70	7/23/91					637.61	24.1	613.51	DEQ Report	
LUB	70	8/9/91					637.61	24.86	612.75	DEQ Report	
LUB	70	9/16/91					637.61	25.46	612.15	DEQ Report	
LUB	70	10/23/91					637.61	25.07	612.54	DEQ Report	
LUB	70	11/19/91					637.61			DEQ Report	Dry
LUB	70	12/4/91					637.61			DEQ Report	Dry
LUB	8	2/11/91	Idle	E Tape	304.35	33.45			270.90	OWRD	
LUB	8	8/23/91	Idle	E Tape	304.35	31.83			272.52	OWRD	
LUB	8	2/10/92	Idle	E Tape	304.35	33.35			271.00	OWRD	
LUB	84	12/20/90			431	45.11	433.89	48	385.89	USACE	
LUB	84	1/10/91			431	45.01	433.89	47.9	385.99	USACE	
LUB	84	2/11/91			431	45.03	433.89	47.92	385.97	USACE	
LUB	84	3/20/91			431	45.14	433.89	48.03	385.86	USACE	
LUB	84	4/18/91			431	45.43	433.89	48.32	385.57	USACE	
LUB	84	5/25/91			431	45.59	433.89	48.48	385.41	USACE	
LUB	84	6/26/91			431	45.63	433.89	48.52	385.37	USACE	
LUB	84	7/23/91			431	45.66	433.89	48.55	385.34	USACE	
LUB	84	8/20/91			431	45.33	433.89	48.22	385.67	USACE	
LUB	84	9/24/91			431	44.72	433.89	47.61	386.28	USACE	
LUB	84	10/18/91			431	44.49	433.89	47.38	386.51	USACE	
LUB	84	11/21/91			431	44.05	433.89	46.94	386.95	USACE	
LUB	84	12/17/91			431	43.68	433.89	46.57	387.32	USACE	
LUB	84	1/22/92			431	43.75	433.89	46.64	387.25	USACE	
LUB	84	2/18/92			431	43.62	433.89	46.51	387.38	USACE	
LUB	84	3/12/92			431	43.8	433.89	46.69	387.20	USACE	
LUB	84	4/21/92			431	43.83	433.89	46.72	387.17	USACE	
LUB	85	12/20/90			469.6	46.87	471.58	48.85	422.73	USACE	
LUB	85	1/10/91			469.6	46.69	471.58	48.67	422.91	USACE	
LUB	85	2/11/91			469.6	46.52	471.58	48.5	423.08	USACE	
LUB	85	3/20/91			469.6	46.37	471.58	48.35	423.23	USACE	
LUB	85	4/18/91			469.6	46.23	471.58	48.21	423.37	USACE	
LUB	85	5/25/91			469.6	46.02	471.58	48	423.58	USACE	
LUB	85	6/26/91			469.6	45.94	471.58	47.92	423.66	USACE	
LUB	85	7/23/91			469.6	45.84	471.58	47.82	423.76	USACE	
LUB	85	8/20/91			469.6	45.75	471.58	47.73	423.85	USACE	
LUB	85	9/24/91			469.6	45.64	471.58	47.62	423.96	USACE	
LUB	85	10/18/91			469.6	45.71	471.58	47.69	423.89	USACE	
LUB	85	11/21/91			469.6	45.49	471.58	47.47	424.11	USACE	
LUB	85	12/17/91			469.6	45.21	471.58	47.19	424.39	USACE	
LUB	85	1/22/92			469.6	45.08	471.58	47.06	424.52	USACE	
LUB	85	2/18/92			469.6	44.87	471.58	46.85	424.73	USACE	
LUB	85	3/12/92			469.6	44.79	471.58	46.77	424.81	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	85	4/21/92			469.6	44.6	471.58	46.58	425.00	USACE	
LUB	86	5/25/91			528.8	56.62	531.66	59.48	472.18	USACE	
LUB	87	12/20/90			616.5	144.58	619.52	147.6	471.92	USACE	
LUB	87	1/12/91			616.5	144.11	619.52	147.13	472.39	USACE	
LUB	87	2/11/91			616.5	144.05	619.52	147.07	472.45	USACE	
LUB	87	3/20/91			616.5	144.16	619.52	147.18	472.34	USACE	
LUB	87	4/18/91			616.5	144.24	619.52	147.26	472.26	USACE	
LUB	87	5/25/91			616.5	144.12	619.52	147.14	472.38	USACE	
LUB	87	6/26/91			616.5	144.01	619.52	147.03	472.49	USACE	
LUB	87	7/22/91			616.5	144.08	619.52	147.1	472.42	USACE	
LUB	87	8/19/91			616.5	144	619.52	147.02	472.50	USACE	
LUB	87	9/24/91			616.5	144.03	619.52	147.05	472.47	USACE	
LUB	87	10/17/91			616.5	144.27	619.52	147.29	472.23	USACE	
LUB	87	11/20/91			616.5	144.08	619.52	147.1	472.42	USACE	
LUB	87	12/17/91			616.5	143.82	619.52	146.84	472.68	USACE	
LUB	87	1/21/92			616.5	144.02	619.52	147.04	472.48	USACE	
LUB	87	2/17/92			616.5	144.05	619.52	147.07	472.45	USACE	
LUB	87	3/11/92			616.5	143.88	619.52	146.9	472.62	USACE	
LUB	87	4/20/92			616.5	143.82	619.52	146.84	472.68	USACE	
LUB	88	12/20/90			613.3	118.74	616.2	121.64	494.56	USACE	
LUB	88	1/12/91			613.3	118.17	616.2	121.07	495.13	USACE	
LUB	88	2/11/91			613.3	118.17	616.2	121.07	495.13	USACE	
LUB	88	3/20/91			613.3	118.21	616.2	121.11	495.09	USACE	
LUB	88	4/18/91			613.3	118.38	616.2	121.28	494.92	USACE	
LUB	88	5/25/91			613.3	118.34	616.2	121.24	494.96	USACE	
LUB	88	6/26/91			613.3	118.2	616.2	121.1	495.10	USACE	
LUB	88	7/22/91			613.3	118.38	616.2	121.28	494.92	USACE	
LUB	88	8/19/91			613.3	118.22	616.2	121.12	495.08	USACE	
LUB	88	9/24/91			613.3	118.39	616.2	121.29	494.91	USACE	
LUB	88	10/17/91			613.3	118.44	616.2	121.34	494.86	USACE	
LUB	88	11/20/91			613.3	118.37	616.2	121.27	494.93	USACE	
LUB	88	12/17/91			613.3	118.17	616.2	121.07	495.13	USACE	
LUB	88	1/21/92			613.3	118.3	616.2	121.2	495.00	USACE	
LUB	88	2/17/92			613.3	118.43	616.2	121.33	494.87	USACE	
LUB	88	3/11/92			613.3	118.3	616.2	121.2	495.00	USACE	
LUB	88	4/20/92			613.3	118.23	616.2	121.13	495.07	USACE	
LUB	89	12/19/90			551.7	56	553.75	58.05	495.70	USACE	
LUB	89	1/12/91			551.7	55.8	553.75	57.85	495.90	USACE	
LUB	89	2/11/91			551.7	55.58	553.75	57.63	496.12	USACE	
LUB	89	3/20/91			551.7	54.77	553.75	56.82	496.93	USACE	
LUB	89	4/18/91			551.7	53.77	553.75	55.82	497.93	USACE	
LUB	89	5/25/91			551.7	52.75	553.75	54.8	498.95	USACE	
LUB	89	6/26/91			551.7	52.38	553.75	54.43	499.32	USACE	
LUB	89	7/22/91			551.7	52.8	553.75	54.85	498.90	USACE	
LUB	89	8/20/91			551.7	53.44	553.75	55.49	498.26	USACE	
LUB	89	9/24/91			551.7	54.1	553.75	56.15	497.60	USACE	
LUB	89	10/17/91			551.7	54.2	553.75	56.25	497.50	USACE	
LUB	89	11/20/91			551.7	54.13	553.75	56.18	497.57	USACE	
LUB	89	12/18/91			551.7	54.45	553.75	56.5	497.25	USACE	
LUB	89	1/22/92			551.7	53.87	553.75	55.92	497.83	USACE	
LUB	89	2/17/92			551.7	53.76	553.75	55.81	497.94	USACE	
LUB	89	3/11/92			551.7	53.45	553.75	55.5	498.25	USACE	
LUB	89	4/20/92			551.7	52.56	553.75	54.61	499.14	USACE	
LUB	9	12/5/90	Idle	E Tape	301.37	38.69			262.68	DEQ	
LUB	9	2/11/91	Idle	E Tape	301.37	32.39			268.98	DEQ	
LUB	9	3/13/91	Idle	E Tape	301.37	39.52			261.85	DEQ	
LUB	9	6/10/91	Idle	E Tape	301.37	39.14			262.23	DEQ	
LUB	9	9/10/91	Idle	E Tape	301.37	37.27			264.10	DEQ	
LUB	9	12/10/91	Idle	E Tape	301.37	38.31			263.06	DEQ	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	9	3/10/92	Idle	E Tape	301.37	39.51			261.86	DEQ	
LUB	90	12/19/90			588.4	92.72	590.22	94.54	495.68	USACE	
LUB	90	1/12/91			588.4	92.52	590.22	94.34	495.88	USACE	
LUB	90	2/11/91			588.4	92.29	590.22	94.11	496.11	USACE	
LUB	90	3/20/91			588.4	91.51	590.22	93.33	496.89	USACE	
LUB	90	4/18/91			588.4	90.52	590.22	92.34	497.88	USACE	
LUB	90	5/25/91			588.4	90.45	590.22	92.27	497.95	USACE	
LUB	90	6/26/91			588.4	89.03	590.22	90.85	499.37	USACE	
LUB	90	7/22/91			588.4	89.4	590.22	91.22	499.00	USACE	
LUB	90	8/19/91			588.4	90.02	590.22	91.84	498.38	USACE	
LUB	90	9/24/91			588.4	90.75	590.22	92.57	497.65	USACE	
LUB	90	10/17/91			588.4	90.86	590.22	92.68	497.54	USACE	
LUB	90	11/20/91			588.4	90.81	590.22	92.63	497.59	USACE	
LUB	90	12/17/91			588.4	90.72	590.22	92.54	497.68	USACE	
LUB	90	1/21/92			588.4	90.52	590.22	92.34	497.88	USACE	
LUB	90	2/17/92			588.4	90.46	590.22	92.28	497.94	USACE	
LUB	90	3/11/92			588.4	90.18	590.22	92	498.22	USACE	
LUB	90	4/20/92			588.4	89.35	590.22	91.17	499.05	USACE	
LUB	91	12/19/90			513.3	17.58	515.6	19.88	495.72	USACE	
LUB	91	1/13/91			513.3	17.37	515.6	19.67	495.93	USACE	
LUB	91	2/11/91			513.3	17.05	515.6	19.35	496.25	USACE	
LUB	91	3/20/91			513.3	16.04	515.6	18.34	497.26	USACE	
LUB	91	4/18/91			513.3	15.03	515.6	17.33	498.27	USACE	
LUB	91	5/25/91			513.3	14.09	515.6	16.39	499.21	USACE	
LUB	91	6/26/91			513.3	13.95	515.6	16.25	499.35	USACE	
LUB	91	7/22/91			513.3	14.52	515.6	16.82	498.78	USACE	
LUB	91	8/20/91			513.3	15.17	515.6	17.47	498.13	USACE	
LUB	91	9/24/91			513.3	15.85	515.6	18.15	497.45	USACE	
LUB	91	10/17/91			513.3	15.83	515.6	18.13	497.47	USACE	
LUB	91	11/20/91			513.3	15.72	515.6	18.02	497.58	USACE	
LUB	91	12/18/91			513.3	15.55	515.6	17.85	497.75	USACE	
LUB	91	1/22/92			513.3	15.4	515.6	17.7	497.90	USACE	
LUB	91	2/17/92			513.3	15.28	515.6	17.58	498.02	USACE	
LUB	91	3/11/92			513.3	14.82	515.6	17.12	498.48	USACE	
LUB	91	4/20/92			513.3	14.12	515.6	16.42	499.18	USACE	
LUB	92	12/19/90			569.3	73.45	571.24	75.39	495.85	USACE	
LUB	92	1/12/91			569.3	73.71	571.24	75.65	495.59	USACE	
LUB	92	2/11/91			569.3	72.94	571.24	74.88	496.36	USACE	
LUB	92	3/20/91			569.3	71.93	571.24	73.87	497.37	USACE	
LUB	92	4/18/91			569.3	70.89	571.24	72.83	498.41	USACE	
LUB	92	5/25/91			569.3	69.93	571.24	71.87	499.37	USACE	
LUB	92	6/26/91			569.3	69.81	571.24	71.75	499.49	USACE	
LUB	92	7/22/91			569.3	70.38	571.24	72.32	498.92	USACE	
LUB	92	8/20/91			569.3	71.07	571.24	73.01	498.23	USACE	
LUB	92	9/24/91			569.3	71.7	571.24	73.64	497.60	USACE	
LUB	92	10/17/91			569.3	71.63	571.24	73.57	497.67	USACE	
LUB	92	11/20/91			569.3	71.56	571.24	73.5	497.74	USACE	
LUB	92	12/18/91			569.3	71.41	571.24	73.35	497.89	USACE	
LUB	92	1/22/92			569.3	71.27	571.24	73.21	498.03	USACE	
LUB	92	2/17/92			569.3	71.16	571.24	73.1	498.14	USACE	
LUB	92	3/11/92			569.3	70.7	571.24	72.64	498.60	USACE	
LUB	92	4/20/92			569.3	70.03	571.24	71.97	499.27	USACE	
LUB	93	12/19/90			556	60.15	558.68	62.83	495.85	USACE	
LUB	93	1/10/91			556	59.93	558.68	62.61	496.07	USACE	
LUB	93	2/11/91			556	59.11	558.68	61.79	496.89	USACE	
LUB	93	3/20/91			556	57.51	558.68	60.19	498.49	USACE	
LUB	93	4/18/91			556	56.79	558.68	59.47	499.21	USACE	
LUB	93	5/24/91			556	56.28	558.68	58.96	499.72	USACE	
LUB	93	6/26/91			556	57.07	558.68	59.75	498.93	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	93	7/22/91			556	58	558.68	60.68	498.00	USACE	
LUB	93	8/19/91			556	58.67	558.68	61.35	497.33	USACE	
LUB	93	9/24/91			556	59.07	558.68	61.75	496.93	USACE	
LUB	93	10/17/91			556	57.81	558.68	60.49	498.19	USACE	
LUB	93	11/19/91			556	58.45	558.68	61.13	497.55	USACE	
LUB	93	12/18/91			556	58.21	558.68	60.89	497.79	USACE	
LUB	93	1/21/92			556	58.03	558.68	60.71	497.97	USACE	
LUB	93	2/17/92			556	57.54	558.68	60.22	498.46	USACE	
LUB	93	3/11/92			556	56.56	558.68	59.24	499.44	USACE	
LUB	93	4/20/92			556	56.51	558.68	59.19	499.49	USACE	
LUB	94	12/19/90			581	85.15	582.48	86.63	495.85	USACE	
LUB	94	1/10/91			581	85.1	582.48	86.58	495.90	USACE	
LUB	94	2/11/91			581	84.83	582.48	86.31	496.17	USACE	
LUB	94	3/20/91			581	83.86	582.48	85.34	497.14	USACE	
LUB	94	4/18/91			581	82.22	582.48	83.7	498.78	USACE	
LUB	94	5/24/91			581	80.03	582.48	81.51	500.97	USACE	
LUB	94	6/26/91			581	81.09	582.48	82.57	499.91	USACE	
LUB	94	7/22/91			581	81.59	582.48	83.07	499.41	USACE	
LUB	94	8/19/91			581	82.07	582.48	83.55	498.93	USACE	
LUB	94	9/24/91			581	82.14	582.48	83.62	498.86	USACE	
LUB	94	10/17/91			581	82.63	582.48	84.11	498.37	USACE	
LUB	94	11/19/91			581	83.17	582.48	84.65	497.83	USACE	
LUB	94	12/18/91			581	83.04	582.48	84.52	497.96	USACE	
LUB	94	1/21/92			581	83.21	582.48	84.69	497.79	USACE	
LUB	94	2/17/92			581	83.24	582.48	84.72	497.76	USACE	
LUB	94	3/11/92			581	82.74	582.48	84.22	498.26	USACE	
LUB	94	4/20/92			581	81.67	582.48	83.15	499.33	USACE	
LUB	95	12/18/90			656.6	156.7	658.99	159.09	499.90	USACE	
LUB	95	1/9/91			656.6	156.91	658.99	159.3	499.69	USACE	
LUB	95	2/11/91			656.6	156.72	658.99	159.11	499.88	USACE	
LUB	95	3/20/91			656.6	156.85	658.99	159.24	499.75	USACE	
LUB	95	4/18/91			656.6	156.85	658.99	159.24	499.75	USACE	
LUB	95	5/24/91			656.6	156.75	658.99	159.14	499.85	USACE	
LUB	95	6/26/91			656.6	156.64	658.99	159.03	499.96	USACE	
LUB	95	7/22/91			656.6	156.68	658.99	159.07	499.92	USACE	
LUB	95	8/19/91			656.6	156.58	658.99	158.97	500.02	USACE	
LUB	95	9/24/91			656.6	156.57	658.99	158.96	500.03	USACE	
LUB	95	10/17/91			656.6	156.72	658.99	159.11	499.88	USACE	
LUB	95	11/20/91			656.6	156.56	658.99	158.95	500.04	USACE	
LUB	95	12/18/91			656.6	156.16	658.99	158.55	500.44	USACE	
LUB	95	1/21/92			656.6	156.41	658.99	158.8	500.19	USACE	
LUB	95	2/17/92			656.6	156.44	658.99	158.83	500.16	USACE	
LUB	95	3/11/92			656.6	156.27	658.99	158.66	500.33	USACE	
LUB	95	4/20/92			656.6	156.18	658.99	158.57	500.42	USACE	
LUB	96	12/18/90			639.8	134.8	641.84	136.84	505.00	USACE	
LUB	96	1/9/91			639.8	134.99	641.84	137.03	504.81	USACE	
LUB	96	2/11/91			639.8	134.97	641.84	137.01	504.83	USACE	
LUB	96	3/20/91			639.8	134.97	641.84	137.01	504.83	USACE	
LUB	96	4/18/91			639.8	135.28	641.84	137.32	504.52	USACE	
LUB	96	5/24/91			639.8	135.15	641.84	137.19	504.65	USACE	
LUB	96	6/26/91			639.8	134.97	641.84	137.01	504.83	USACE	
LUB	96	7/22/91			639.8	135.13	641.84	137.17	504.67	USACE	
LUB	96	8/19/91			639.8	134.9	641.84	136.94	504.90	USACE	
LUB	96	9/24/91			639.8	135.11	641.84	137.15	504.69	USACE	
LUB	96	10/17/91			639.8	135.16	641.84	137.2	504.64	USACE	
LUB	96	11/20/91			639.8	135.13	641.84	137.17	504.67	USACE	
LUB	96	12/18/91			639.8	134.52	641.84	136.56	505.28	USACE	
LUB	96	1/21/92			639.8	134.98	641.84	137.02	504.82	USACE	
LUB	96	2/17/92			639.8	135.09	641.84	137.13	504.71	USACE	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
LUB	96	3/11/92			639.8	134.93	641.84	136.97	504.87	USACE	
LUB	96	4/20/92			639.8	134.7	641.84	136.74	505.10	USACE	
LUB	97	12/18/90			634.3	113.2	636.64	115.54	521.10	USACE	
LUB	97	1/9/91			634.3	113.37	636.64	115.71	520.93	USACE	
LUB	97	2/11/91			634.3	113.15	636.64	115.49	521.15	USACE	
LUB	97	3/20/91			634.3	113.03	636.64	115.37	521.27	USACE	
LUB	97	4/18/91			634.3	113.08	636.64	115.42	521.22	USACE	
LUB	97	5/24/91			634.3	112.96	636.64	115.3	521.34	USACE	
LUB	97	6/26/91			634.3	112.68	636.64	115.02	521.62	USACE	
LUB	97	7/22/91			634.3	112.76	636.64	115.1	521.54	USACE	
LUB	97	8/19/91			634.3	112.54	636.64	114.88	521.76	USACE	
LUB	97	9/24/91			634.3	112.65	636.64	114.99	521.65	USACE	
LUB	97	10/17/91			634.3	112.55	636.64	114.89	521.75	USACE	
LUB	97	11/20/91			634.3	112.4	636.64	114.74	521.90	USACE	
LUB	97	12/18/91			634.3	111.93	636.64	114.27	522.37	USACE	
LUB	97	1/21/92			634.3	112.11	636.64	114.45	522.19	USACE	
LUB	97	2/17/92			634.3	111.99	636.64	114.33	522.31	USACE	
LUB	97	3/11/92			634.3	111.86	636.64	114.2	522.44	USACE	
LUB	97	4/20/92			634.3	111.63	636.64	113.97	522.67	USACE	
LUB	98	12/18/90			649.4	127.28	651.51	129.39	522.12	USACE	
LUB	98	1/9/91			649.4	127.44	651.51	129.55	521.96	USACE	
LUB	98	2/11/91			649.4	127.12	651.51	129.23	522.28	USACE	
LUB	98	3/20/91			649.4	126.22	651.51	128.33	523.18	USACE	
LUB	98	4/18/91			649.4	126.77	651.51	128.88	522.63	USACE	
LUB	98	5/25/91			649.4	126.6	651.51	128.71	522.80	USACE	
LUB	98	6/26/91			649.4	126.05	651.51	128.16	523.35	USACE	
LUB	98	7/22/91			649.4	126.13	651.51	128.24	523.27	USACE	
LUB	98	8/19/91			649.4	125.71	651.51	127.82	523.69	USACE	
LUB	98	9/24/91			649.4	125.77	651.51	127.88	523.63	USACE	
LUB	98	10/17/91			649.4	125.42	651.51	127.53	523.98	USACE	
LUB	98	11/20/91			649.4	125.09	651.51	127.2	524.31	USACE	
LUB	98	12/18/91			649.4	124.47	651.51	126.58	524.93	USACE	
LUB	98	1/21/92			649.4	124.68	651.51	126.79	524.72	USACE	
LUB	98	2/17/92			649.4	124.44	651.51	126.55	524.96	USACE	
LUB	98	3/11/92			649.4	124.33	651.51	126.44	525.07	USACE	
LUB	98	4/20/92			649.4	123.91	651.51	126.02	525.49	USACE	
LUB	99	12/18/90			651.9	150.72	654	152.82	501.18	USACE	
LUB	99	1/9/91			651.9	150.9	654	153	501.00	USACE	
LUB	99	2/11/91			651.9	150.73	654	152.83	501.17	USACE	
LUB	99	3/20/91			651.9	157.81	654	159.91	494.09	USACE	
LUB	99	4/18/91			651.9	150.83	654	152.93	501.07	USACE	
LUB	99	5/24/91			651.9	150.74	654	152.84	501.16	USACE	
LUB	99	6/26/91			651.9	150.62	654	152.72	501.28	USACE	
LUB	99	7/22/91			651.9	150.65	654	152.75	501.25	USACE	
LUB	99	8/19/91			651.9	150.53	654	152.63	501.37	USACE	
LUB	99	9/24/91			651.9	150.53	654	152.63	501.37	USACE	
LUB	99	10/17/91			651.9	150.56	654	152.66	501.34	USACE	
LUB	99	11/20/91			651.9	150.5	654	152.6	501.40	USACE	
LUB	99	12/17/91			651.9	150.2	654	152.3	501.70	USACE	
LUB	99	1/21/92			651.9	150.36	654	152.46	501.54	USACE	
LUB	99	2/17/92			651.9	150.36	654	152.46	501.54	USACE	
LUB	99	3/11/92			651.9	150.22	654	152.32	501.68	USACE	
LUB	99	4/20/92			651.9	150.09	654	152.19	501.81	USACE	
MORR	1005	2/11/91	Idle	E Tape	287	25.57			261.43	OWRD	
MORR	1005	8/22/91	Idle	E Tape	287	21.82			265.18	OWRD	
MORR	1005	2/10/92	Idle	E Tape	287	28.22			258.78	OWRD	
MORR	1021	2/11/91	Idle	E Tape	288	23.85			264.15	OWRD	
MORR	1021	8/23/91	Idle	E Tape	288	20.62			267.38	OWRD	
MORR	1021	2/10/92	Idle	E Tape	288	25.14			262.86	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
MORR	1120	2/15/91	Idle	E Tape	298	31.05			266.95	OWRD	
MORR	1120	8/23/91	Idle	E Tape	298	29.31			268.69	OWRD	Very slow recovery
MORR	1120	2/10/92	Idle	E Tape	298	31.97			266.03	OWRD	
MORR	1250	2/9/91	Idle	E Tape	334	70.95			263.05	OWRD	Very oily; bad cut
MORR	1253	2/1/91			280	10.79			269.21	Port of Morrow	
MORR	1264	2/9/91	Idle	E Tape	348	87.47			260.53	OWRD	
MORR	1264	8/22/91	Idle	E Tape	348	91.73			256.27	OWRD	C pivot on to south
MORR	1264	2/10/92	Idle	E Tape	348	86.93			261.07	OWRD	
MORR	1267	2/9/91	Idle	E Tape	320	73.26			246.74	OWRD	
MORR	1267	8/22/91	Idle	E Tape	320	78.31			241.69	OWRD	
MORR	1321	2/9/91	Idle	E Tape	315	43.92			271.08	OWRD	Some oil
MORR	1325	2/11/91	Idle	E Tape	351	21.46			329.54	OWRD	
MORR	1325	8/23/91	Idle	E Tape	351	21.4			329.60	OWRD	
MORR	1325	2/10/92	Idle	E Tape	351	21.31			329.69	OWRD	
MORR	1410	2/11/91	Idle	E Tape	283	18.45			264.55	OWRD	
MORR	1419	2/11/91	Idle	E Tape	305.2	35.14			270.06	OWRD	
MORR	1419	6/10/91	Idle	E Tape	305.2	35.2			270.00	DEQ	
MORR	1431	2/11/91	Idle	E Tape	302	6.35			295.65	OWRD	
MORR	1431	8/23/91	Idle	E Tape	302	4.65			297.35	OWRD	
MORR	1431	2/10/92	Idle	E Tape	302	6.78			295.22	OWRD	
MORR	1532	8/23/91	Idle	E Tape	335	66.86			268.14	OWRD	
MORR	1542	10/1/91			282.9	18.22			264.68	DEQ	
MORR	1542	12/1/91			282.9	18.22			264.68	DEQ	
MORR	1542	2/20/92			282.9	18.35			264.55	Port of Morrow	
MORR	1542	4/1/92			282.9	20.28			262.62	DEQ	
MORR	1543	10/1/91			280.5	14.3			266.20	DEQ	
MORR	1543	12/1/91			280.5	15.3			265.20	DEQ	
MORR	1543	2/20/92			280.5	15.56			264.94	Port of Morrow	
MORR	1543	4/1/92			280.5	15.64			264.86	DEQ	
MORR	1549	10/1/91			343.9	75.58			268.32	DEQ	
MORR	1549	12/1/91			343.9	74.41			269.49	DEQ	
MORR	1549	2/20/92			343.9	74.33			269.57	Port of Morrow	
MORR	1549	4/1/92			343.9	74.41			269.49	DEQ	
MORR	1550	10/1/91			328.8	62.42			266.38	DEQ	
MORR	1550	12/1/91			328.8	61.92			266.88	DEQ	
MORR	1550	2/20/92			328.8	62.06			266.74	Port of Morrow	
MORR	1550	4/1/92			328.8	62.55			266.25	DEQ	
MORR	1551	10/1/91			309.68	42.23			267.45	DEQ	
MORR	1551	12/1/91			309.68	42.29			267.39	DEQ	
MORR	1551	2/20/92			309.68	42.64			267.04	Port of Morrow	
MORR	1551	4/1/92			309.68	42.65			267.03	DEQ	
MORR	1556	11/7/91			389.08	34.71			354.37	Well log	
MORR	1556	1/9/92			389.08	34.71			354.37	OWRD	
MORR	1556	1/20/92			389.08	34.5			354.58	OWRD	
MORR	1556	2/20/92			389.08	34.5			354.58	Port of Morrow	
MORR	1556	4/1/92			389.08	34.45			354.63	DEQ	
MORR	1557	11/21/91			442.73	42.17			400.56	Well log	
MORR	1557	12/1/91			442.73	42.16			400.57	DEQ	
MORR	1557	1/9/92			442.73	42.17			400.56	OWRD	
MORR	1557	1/20/92			442.73	37.02			405.71	OWRD	
MORR	1557	2/20/92			442.73	36.95			405.78	Port of Morrow	
MORR	1557	4/1/92			442.73	36.87			405.86	DEQ	
MORR	1559	12/13/91			481.27	58.81			422.46	Well log	
MORR	1559	1/9/92			481.27	58.81			422.46	OWRD	
MORR	1559	1/20/92			481.27	58.69			422.58	OWRD	
MORR	1559	2/20/92			481.27	58.78			422.49	Port of Morrow	
MORR	1559	4/1/92			481.27	58.84			422.43	DEQ	
MORR	1560	12/10/91			464.51	57.25			407.26	Well log	
MORR	1560	1/9/92			464.51	57.25			407.26	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
MORR	1560	1/20/92			464.51	57.82			406.69	OWRD	
MORR	1560	2/20/92			464.51	57.6			406.91	Port of Morrow	
MORR	1560	4/1/92			464.51	57.27			407.24	DEQ	
MORR	1561	12/18/91			379.97	13.38			366.59	Well log	
MORR	1561	1/9/92			379.97	13.38			366.59	OWRD	
MORR	1561	1/20/92			379.97	13.33			366.64	OWRD	
MORR	1561	2/20/92			379.97	13.42			366.55	Port of Morrow	
MORR	1561	4/1/92			379.97	12.18			367.79	DEQ	
MORR	1562	12/21/91			416.55	22.6			393.95	Well log	
MORR	1562	1/9/92			416.55	22.6			393.95	OWRD	
MORR	1562	1/20/92			416.55	22.4			394.15	OWRD	
MORR	1562	2/20/92			416.55	22.47			394.08	Port of Morrow	
MORR	1562	4/1/92			416.55	22.53			394.02	DEQ	
MORR	1563	12/19/91			380.26	12.42			367.84	Well log	
MORR	1563	1/9/92			380.26	12.42			367.84	OWRD	
MORR	1563	1/20/92			380.26	12.44			367.82	OWRD	
MORR	1563	2/20/92			380.26	12.71			367.55	Port of Morrow	
MORR	1563	4/1/92			380.26	12.3			367.96	DEQ	
MORR	574	3/1/91			670	209			461.00	PGE	
MORR	574	9/1/91			670	210			460.00	PGE	
MORR	601	3/15/91			630	302.06			327.94	OWRD	
MORR	602	3/15/91			650	318.35			331.65	OWRD	
MORR	606	2/13/92	Idle	E Tape	678	160.36			517.64	OWRD	
MORR	613	2/8/91	Idle	E Tape	568	26.63			541.37	OWRD	
MORR	613	2/12/92	Idle	E Tape	568	26.29			541.71	OWRD	
MORR	628	1/25/91	Idle	E Tape	592	17.03			574.97	OWRD	Unused
MORR	628	2/8/91	Idle	E Tape	592	16.75			575.25	OWRD	Unused
MORR	628	8/23/91	Idle	E Tape	592	10.78			581.22	OWRD	Unused
MORR	628	2/12/92	Idle	E Tape	592	18.09			573.91	OWRD	Unused
MORR	647	2/13/92	Idle	E Tape	300	26.07			273.93	OWRD	
MORR	667	1/30/91			582	272			310.00	OWRD	
MORR	667	2/28/91			582	267			315.00	OWRD	
MORR	667	3/31/91			582	263			319.00	OWRD	
MORR	667	6/1/91			582	281			301.00	OWRD	
MORR	667	7/1/91			582	294			288.00	OWRD	
MORR	667	8/1/91			582	298			284.00	OWRD	
MORR	667	9/1/91			582	295			287.00	OWRD	
MORR	667	10/1/91			582	295			287.00	OWRD	
MORR	667	11/1/91			582	291			291.00	OWRD	
MORR	667	1/1/92			582	274			308.00	OWRD	
MORR	667	2/1/92			582	273			309.00	OWRD	
MORR	667	3/1/92			582	272			310.00	OWRD	
MORR	667	4/1/92			582	280			302.00	OWRD	
MORR	667	5/1/92			582	290			292.00	OWRD	
MORR	680	6/1/91			293.5	33.3			260.20	DEQ	
MORR	680	10/1/91			293.5	27.72			265.78	DEQ	
MORR	680	12/1/91			293.5	27.54			265.96	DEQ	
MORR	680	2/20/92			293.5	27.49			266.01	Port of Morrow	
MORR	681	12/1/90			352	83.91			268.09	DEQ	
MORR	681	2/1/91			352	83.37			268.63	Port of Morrow	
MORR	681	3/1/91			352	83.91			268.09	DEQ	
MORR	681	6/1/91			352	85.32			266.68	DEQ	
MORR	681	10/1/91			352	82.74			269.26	DEQ	
MORR	681	12/1/91			352	83.74			268.26	DEQ	
MORR	681	2/20/92			352	83.52			268.48	Port of Morrow	
MORR	681	4/1/92			352	83.75			268.25	DEQ	
MORR	682	12/1/90			310.8	42.61			268.19	DEQ	
MORR	682	2/1/91			310.8	42.24			268.56	Port of Morrow	
MORR	682	3/1/91			310.8	42.61			268.19	Port of Morrow	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
MORR	682	6/1/91			310.8	44.24			266.56	DEQ	
MORR	682	10/1/91			310.8	43.36			267.44	DEQ	
MORR	682	12/1/91			310.8	42.61			268.19	DEQ	
MORR	682	2/20/92			310.8	42.64			268.16	Port of Morrow	
MORR	682	4/1/92			310.8	42.89			267.91	DEQ	
MORR	683	2/1/91			312.8	49.7			263.10	Port of Morrow	
MORR	683	3/1/91			312.8	49.7			263.10	DEQ	
MORR	686	12/1/90			288	27.03			260.97	DEQ	
MORR	686	2/1/91			288	24.45			263.55	Port of Morrow	
MORR	686	3/1/91			288	24.2			263.80	DEQ	
MORR	686	6/1/91			288	25.45			262.55	DEQ	
MORR	686	10/1/91			288	22.2			265.80	DEQ	
MORR	688	2/9/91	Int. Pmpg	E Tape	359	5.59			353.41	OWRD	Not fully recovered
MORR	688	8/22/91	Idle	E Tape	359	24.53			334.47	OWRD	
MORR	688	2/11/92	Idle	E Tape	359	16.42			342.58	OWRD	
MORR	689	12/1/90			357.1	88.41			268.69	DEQ	
MORR	689	2/1/91			357.1	88.04			269.06	Port of Morrow	
MORR	689	3/1/91			357.1	88.41			268.69	DEQ	
MORR	689	6/1/91			357.1	90.41			266.69	DEQ	
MORR	689	10/1/91			357.1	90.41			266.69	DEQ	
MORR	689	12/1/91			357.1	88.33			268.77	DEQ	
MORR	689	2/20/92			357.1	88.04			269.06	Port of Morrow	
MORR	689	4/1/92			357.1	88.49			268.61	DEQ	
MORR	696	2/9/91	Idle	E Tape	290	23.12			266.88	OWRD	
MORR	696	8/22/91	Int. Pmpg	E Tape	290	21			269.00	OWRD	
MORR	696	2/11/92	Idle	E Tape	290	23.37			266.63	OWRD	
MORR	711	2/13/91	Idle		311	0			311.00	OWRD	Flowing artesian
MORR	740	2/7/91	Idle	E Tape	289	18.76			270.24	OWRD	
MORR	740	8/22/91	Idle	E Tape	289	19.08			269.92	OWRD	
MORR	740	2/11/92	Idle	E Tape	289	19.3			269.70	OWRD	
MORR	753	2/1/91			274	13.31			260.69	Port of Morrow	
MORR	759	12/1/90			302.6	1.9			300.70	DEQ	
MORR	759	2/1/91			302.6	2.82			299.78	Port of Morrow	
MORR	759	3/1/91			302.6	2.9			299.70	DEQ	
MORR	759	6/1/91			302.6	0.65			301.95	DEQ	
MORR	759	10/1/91			302.6	-0.35			302.95	DEQ	
MORR	759	12/1/91			302.6	0.53			302.07	DEQ	
MORR	759	2/20/92			302.6	2.02			300.58	Port of Morrow	
MORR	759	4/1/92			302.6	-0.49			303.09	DEQ	
MORR	769	2/1/91			314	42.93			271.07	Port of Morrow	
MORR	769	6/1/91			314	45.39			268.61	DEQ	
MORR	770	12/1/90			324.5	14.87			309.63	DEQ	
MORR	770	2/1/91			324.5	15.79			308.71	Port of Morrow	
MORR	770	3/1/91			324.5	14.87			309.63	DEQ	
MORR	770	6/1/91			324.5	10.57			313.93	DEQ	
MORR	770	10/1/91			324.5	12.03			312.47	DEQ	
MORR	770	12/1/91			324.5	10.87			313.63	DEQ	
MORR	770	2/20/92			324.5	15.02			309.48	Port of Morrow	
MORR	770	4/1/92			324.5	15.28			309.22	DEQ	
MORR	773	2/7/91	Idle	E Tape	337	5.12			331.88	OWRD	
MORR	773	8/22/91	Idle	E Tape	337	2.93			334.07	OWRD	
MORR	773	2/11/92	Idle	E Tape	337	3.85			333.15	OWRD	
MORR	790	2/9/91	Idle	E Tape	381	37.79			343.21	OWRD	
MORR	790	2/11/92	Idle	E Tape	381	36.78			344.22	OWRD	
MORR	823	8/22/91	Rec Pumped	E Tape	342	26.24			315.76	OWRD	Slow recovery
MORR	823	2/11/92	Rec Pumped	E Tape	342	33.72			308.28	OWRD	Slow recovery
MORR	873	2/13/91	Idle	E Tape	360	16.81			343.19	OWRD	
MORR	873	2/11/92	Idle	E Tape	360	16.69			343.31	OWRD	
MORR	930	2/7/91	Idle	E Tape	422	11.02			410.98	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
MORR	937	2/9/91	Idle	E Tape	539	50.04			488.96	OWRD	Very oily; bad cut.
MORR	946	2/14/91			540	42.96			497.04	OWRD	Very oily
MORR	951	3/21/92			563	66.24			496.76	OWRD	
MORR	953	2/14/91	Idle	E Tape	570	70.7			499.30	OWRD	Some oil
MORR	953	2/12/92	Idle	E Tape	570	69.58			500.42	OWRD	Very little oil.
MORR	956	2/8/91	Idle	E Tape	565	65.57			499.43	OWRD	
MORR	956	2/11/92	Idle	E Tape	565	64.6			500.40	OWRD	Recharge canal full
MORR	960	2/14/91	Idle	E Tape	571.86	73.68			498.18	OWRD	
MORR	960	2/11/92	Idle	E Tape	571.86	73.22			498.64	OWRD	
MORR	961	2/14/91	Idle	E Tape	580	83.09			496.91	OWRD	
MORR	961	2/12/92	Idle	E Tape	580	83.45			496.55	OWRD	
MORR	961	3/20/92	Idle	E Tape	580	82.78			497.22	OWRD	
MORR	962	2/9/91	Idle	E Tape	579	79.94			499.06	OWRD	
MORR	962	2/14/92	Idle	E Tape	579	78.38			500.62	OWRD	
MORR	964	2/9/91			579	80.58			498.42	OWRD	
MORR	964	2/14/92	Idle	E Tape	579	79.32			499.68	OWRD	Some oil.
MORR	965	3/20/92			580	78.04			501.96	OWRD	
MORR	966	2/14/91	Idle	E Tape	548	48.52			499.48	OWRD	Very oily
MORR	966	2/12/92	Idle	E Tape	548	48.9			499.10	OWRD	
MORR	966	3/20/92	Idle	E Tape	548	48.7			499.30	OWRD	Very oily; bad cut.
MORR	967	2/14/91			580	82.91			497.09	OWRD	
MORR	970	12/11/90	Rec Pumped	E Tape	598	110.87			487.13	OWRD	Slow recovery
MORR	971	2/9/91			570	71.47			498.53	OWRD	
MORR	971	3/21/92			570	66.12			503.88	OWRD	
MORR	973	2/8/91	Idle	E Tape	569	72.79			496.21	OWRD	
MORR	973	2/12/92	Idle	E Tape	569	69.93			499.07	OWRD	
MORR	981	2/14/91			569				569.00	OWRD	
MORR	984	3/21/92			582	78.41			503.59	OWRD	
MORR	987	3/15/91			571	69.85			501.15	OWRD	
MORR	987	3/21/92			571	69.03			501.97	OWRD	
UMAT	1162	12/13/90	Int. Pmpg	E Tape	557	28.73			528.27	OWRD	Not fully recovered
UMAT	1162	2/8/91	Int. Pmpg	E Tape	557	23.99			533.01	OWRD	Not fully recovered
UMAT	1162	8/23/91	Int. Pmpg	E Tape	557	36.13			520.87	OWRD	Not fully recovered
UMAT	1172	1/24/91	Rec Pumped	E Tape	580	7.26			572.74	OWRD	
UMAT	1198	1/22/91	Idle	E Tape	616	3.05			612.95	OWRD	Unused
UMAT	1198	8/23/91	Idle	E Tape	616	2.87			613.13	OWRD	Unused
UMAT	1198	2/14/92	Idle	E Tape	616	3.3			612.70	OWRD	Unused
UMAT	1201	1/24/91	Idle	E Tape	638	26.94			611.06	OWRD	
UMAT	1201	2/14/92	Idle	E Tape	638	26.85			611.15	OWRD	
UMAT	1269	2/14/92	Idle	E Tape	601	12.7			588.30	OWRD	Oily; bad cut.; drop
UMAT	1274	8/23/91	Idle	E Tape	608	8.57			599.43	OWRD	
UMAT	1274	2/12/92	Idle	E Tape	608	8.16			599.84	OWRD	
UMAT	1325	8/23/91	Idle	E Tape	645	8.39			636.61	OWRD	Adjacent canal full.
UMAT	1325	2/14/92	Idle	E Tape	645	7.45			637.55	OWRD	
UMAT	1523	1/15/91	Idle		645.66	66.12			579.54	Lamb Weston	
UMAT	1523	2/12/91	Idle		645.66	68.54			577.12	Lamb Weston	
UMAT	1523	3/5/91	Idle		645.66	73.7			571.96	Lamb Weston	
UMAT	1523	4/16/91	Idle		645.66	74.08			571.58	Lamb Weston	
UMAT	1523	5/3/91	Idle		645.66	74.08			571.58	Lamb Weston	
UMAT	1523	6/18/91	Idle		645.66	74.33			571.33	Lamb Weston	
UMAT	1523	7/24/91	Idle		645.66	73.33			572.33	Lamb Weston	
UMAT	1523	9/20/91	Idle		645.66	72.91			572.75	Lamb Weston	
UMAT	1523	10/8/91	Idle		645.66	72.92			572.74	Lamb Weston	
UMAT	1523	1/21/92	Idle		645.66	72.67			572.99	Lamb Weston	
UMAT	1523	2/12/92	Idle		645.66	72.66			573.00	Lamb Weston	
UMAT	1523	3/27/92	Idle		645.66	74			571.66	Lamb Weston	
UMAT	1524	1/15/91	Idle		647.69	72.58			575.11	Lamb Weston	
UMAT	1524	2/12/91	Idle		647.69	73.25			574.45	Lamb Weston	
UMAT	1524	3/5/91	Idle		647.69	72.62			575.07	Lamb Weston	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	1524	4/16/91	Idle		647.69	72.5			575.20	Lamb Weston	
UMAT	1524	5/3/91	Idle		647.69	73.08			574.61	Lamb Weston	
UMAT	1524	6/18/91	Idle		647.69	73.12			574.57	Lamb Weston	
UMAT	1524	7/24/91	Idle		647.69	71.91			575.78	Lamb Weston	
UMAT	1524	9/20/91	Idle		647.69	72.58			575.11	Lamb Weston	
UMAT	1524	10/8/91	Idle		647.69	72.63			575.06	Lamb Weston	
UMAT	1524	1/21/92	Idle		647.69	71.33			576.36	Lamb Weston	
UMAT	1524	2/12/92	Idle		647.69	71.33			576.36	Lamb Weston	
UMAT	1524	3/27/92	Idle		647.69	71.79			575.90	Lamb Weston	
UMAT	1525	1/15/91	Idle		620.6	70.07			550.54	Lamb Weston	
UMAT	1525	2/12/91	Idle		620.6	68.02			552.58	Lamb Weston	
UMAT	1525	3/5/91	Idle		620.6	68.88			551.72	Lamb Weston	
UMAT	1525	4/16/91	Idle		620.6	69.4			551.20	Lamb Weston	
UMAT	1525	5/3/91	Idle		620.6	68.98			551.62	Lamb Weston	
UMAT	1525	6/18/91	Idle		620.6	68.94			551.66	Lamb Weston	
UMAT	1525	7/24/91	Idle		620.6	68.36			552.24	Lamb Weston	
UMAT	1525	9/20/91	Idle		620.6	68.9			551.70	Lamb Weston	
UMAT	1525	10/8/91	Idle		620.6	68.73			551.87	Lamb Weston	
UMAT	1525	1/21/92	Idle		620.6	67.48			553.12	Lamb Weston	
UMAT	1525	2/12/92	Idle		620.6	65.48			555.12	Lamb Weston	
UMAT	1525	3/27/92	Idle		620.6	68.57			552.03	Lamb Weston	
UMAT	1526	2/28/91			520	211			309.00	OWRD	
UMAT	1526	3/31/91			520	206			314.00	OWRD	
UMAT	1526	6/1/91			520	229			291.00	OWRD	
UMAT	1526	7/1/91			520	237			283.00	OWRD	
UMAT	1526	8/1/91			520	241			279.00	OWRD	
UMAT	1526	9/1/91			520	238			282.00	OWRD	
UMAT	1526	10/1/91			520	238			282.00	OWRD	
UMAT	1526	11/1/91			520	244			276.00	OWRD	
UMAT	1526	1/1/92			520	212			308.00	OWRD	
UMAT	1526	2/1/92			520	216			304.00	OWRD	
UMAT	1526	3/1/92			520	215			305.00	OWRD	
UMAT	1526	4/1/92			520	224			296.00	OWRD	
UMAT	1526	5/1/92			520	231			289.00	OWRD	
UMAT	1527	12/31/90			540	240			300.00	OWRD	
UMAT	1527	1/30/91			540	239			301.00	OWRD	
UMAT	1527	2/28/91			540	232			308.00	OWRD	
UMAT	1527	3/31/91			540	228			312.00	OWRD	
UMAT	1527	6/1/91			540	249			291.00	OWRD	
UMAT	1527	7/1/91			540	258			282.00	OWRD	
UMAT	1527	8/1/91			540	262			278.00	OWRD	
UMAT	1527	9/1/91			540	260			280.00	OWRD	
UMAT	1527	10/1/91			540	260			280.00	OWRD	
UMAT	1527	11/1/91			540	240			300.00	OWRD	
UMAT	1527	1/1/92			540	237			303.00	OWRD	
UMAT	1527	2/1/92			540	237			303.00	OWRD	
UMAT	1527	3/1/92			540	236			304.00	OWRD	
UMAT	1527	4/1/92			540	245			295.00	OWRD	
UMAT	1527	5/1/92			540	252			288.00	OWRD	
UMAT	1531	12/31/90			618	200			418.00	OWRD	
UMAT	1531	1/30/91			618	199			419.00	OWRD	
UMAT	1531	2/28/91			618	197			421.00	OWRD	
UMAT	1531	3/31/91			618	195			423.00	OWRD	
UMAT	1531	6/1/91			618	193			425.00	OWRD	
UMAT	1531	7/1/91			618	194			424.00	OWRD	
UMAT	1531	8/1/91			618	198			420.00	OWRD	
UMAT	1531	9/1/91			618	200			418.00	OWRD	
UMAT	1531	10/1/91			618	194			424.00	OWRD	
UMAT	1531	1/1/92			618	199			419.00	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	1531	2/1/92			618	198			420.00	OWRD	
UMAT	1531	3/1/92			618	195			423.00	OWRD	
UMAT	1531	4/1/92			618	195			423.00	OWRD	
UMAT	1531	5/1/92			618	194			424.00	OWRD	
UMAT	1536	1/15/91	Idle		561.22	17.53			543.70	Lamb Weston	
UMAT	1536	2/12/91	Idle		561.22	16.86			544.36	Lamb Weston	
UMAT	1536	3/5/91	Idle		561.22	17.11			544.11	Lamb Weston	
UMAT	1536	4/16/91	Idle		561.22	17.03			544.20	Lamb Weston	
UMAT	1536	5/3/91	Idle		561.22	17.07			544.15	Lamb Weston	
UMAT	1536	6/18/91	Idle		561.22	17.03			544.20	Lamb Weston	
UMAT	1536	7/24/91	Idle		561.22	19.53			541.70	Lamb Weston	
UMAT	1536	9/20/91	Idle		561.22	19.4			541.82	Lamb Weston	
UMAT	1536	10/8/91	Idle		561.22	20.65			540.57	Lamb Weston	
UMAT	1536	1/21/92			561.22	31.04			530.18	Lamb Weston	
UMAT	1536	2/12/92	Pumping		561.22	31.04			530.18	Lamb Weston	
UMAT	1536	2/27/92	Pumping		561.22	33.53			527.69	Lamb Weston	
UMAT	1542	2/8/91	Idle	E Tape	569	68.79			500.21	OWRD	
UMAT	1542	2/12/92	Idle	E Tape	569	67.06			501.94	OWRD	Some oil
UMAT	1543	12/31/90			585	120			465.00	OWRD	
UMAT	1543	1/30/91			585	110			475.00	OWRD	
UMAT	1543	2/28/91			585	107			478.00	OWRD	
UMAT	1543	3/31/91			585	105			480.00	OWRD	
UMAT	1543	6/1/91			585	104			481.00	OWRD	
UMAT	1543	7/1/91			585	105			480.00	OWRD	
UMAT	1543	8/1/91			585	111			474.00	OWRD	
UMAT	1543	9/1/91			585	142			443.00	OWRD	
UMAT	1543	10/1/91			585	142			443.00	OWRD	
UMAT	1543	1/1/92			585	105			480.00	OWRD	
UMAT	1543	2/1/92			585	105			480.00	OWRD	
UMAT	1543	3/1/92			585	102			483.00	OWRD	
UMAT	1543	4/1/92			585	103			482.00	OWRD	
UMAT	1543	5/1/92			585	102			483.00	OWRD	
UMAT	1544	2/1/91			587	98			489.00	OWRD	
UMAT	1544	6/1/91			587	96			491.00	OWRD	
UMAT	1544	7/1/91			587	97			490.00	OWRD	
UMAT	1544	8/1/91			587	97			490.00	OWRD	
UMAT	1544	9/1/91			587	103			484.00	OWRD	
UMAT	1544	10/1/91			587	103			484.00	OWRD	
UMAT	1544	1/1/92			587	95			492.00	OWRD	
UMAT	1544	2/1/92			587	96			491.00	OWRD	
UMAT	1544	3/1/92			587	95			492.00	OWRD	
UMAT	1544	4/1/92			587	105			482.00	OWRD	
UMAT	1544	5/1/92			587	105			482.00	OWRD	
UMAT	1552	2/8/91	Idle	E Tape	569	45.02			523.98	OWRD	
UMAT	1552	2/8/91			569	45.02			523.98	OWRD	
UMAT	1552	2/11/92	Idle	E Tape	569	44.15			524.85	OWRD	
UMAT	1560	12/11/90	Idle	E Tape	584.12	71.85			512.27	OWRD	
UMAT	1560	2/8/91	Idle	E Tape	584.12	87.5			496.62	OWRD	
UMAT	1565	12/11/90	Idle	E Tape	582	85.42			496.58	OWRD	
UMAT	1565	2/8/91	Idle	E Tape	582	83.19			498.81	OWRD	Very oily; bad cut.
UMAT	1565	8/22/91	Idle	E Tape	582	82.67			499.33	OWRD	Off since last night
UMAT	1566	2/8/91			584	86.77			497.23	OWRD	
UMAT	1566	8/22/91	Idle	E Tape	584	86.16			497.84	OWRD	
UMAT	1566	2/11/92	Idle	E Tape	584	85.02			498.98	OWRD	
UMAT	1568	12/11/90	Idle	E Tape	585	86.75			498.25	OWRD	
UMAT	1568	2/8/91	Idle	E Tape	585	87.19			497.81	OWRD	
UMAT	1568	8/22/91	Idle	E Tape	585	87.02			497.98	OWRD	Nearby well on
UMAT	1568	2/11/92	Idle	E Tape	585	85.71			499.29	OWRD	
UMAT	1568	3/30/92	Idle	E Tape	585	85.5			499.50	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	1572	3/15/91			603	102.21			500.79	OWRD	
UMAT	1572	3/21/92	Idle	E Tape	603	102.06			500.94	OWRD	
UMAT	1572	3/30/92	Idle	E Tape	603	102.23			500.77	OWRD	Unused
UMAT	1579	2/8/91	Idle	E Tape	571	46.79			524.21	OWRD	
UMAT	1579	8/22/91	Idle	E Tape	571	48.25			522.75	OWRD	
UMAT	1579	2/11/92	Idle	E Tape	571	45.86			525.14	OWRD	
UMAT	1581	3/24/92			560	28.83			531.17	OWRD	
UMAT	1675	12/13/90	Idle	E Tape	519	76.6			442.40	OWRD	
UMAT	1710	2/9/91	Idle	E Tape	462	19.69			442.31	OWRD	
UMAT	1710	8/20/91	Idle	E Tape	462	20.08			441.92	OWRD	
UMAT	1710	2/11/92	Idle	E Tape	462	19.76			442.24	OWRD	
UMAT	1752	8/24/91	Idle	E Tape	461	17.5			443.50	OWRD	
UMAT	1772	2/11/92	Idle	E Tape	451	9.74			441.26	OWRD	
UMAT	1772	2/13/92	Idle	E Tape	451	8.82			442.18	OWRD	
UMAT	1854	1/15/91	Idle		567.66	13.02			554.64	Lamb Weston	
UMAT	1854	2/12/91	Idle		567.66	15.19			552.47	Lamb Weston	
UMAT	1854	3/5/91	Idle		567.66	10.75			556.91	Lamb Weston	
UMAT	1854	4/16/91	Idle		567.66	11.02			556.64	Lamb Weston	
UMAT	1854	5/3/91	Idle		567.66	10.69			556.97	Lamb Weston	
UMAT	1854	6/18/91	Idle		567.66	11.08			556.58	Lamb Weston	
UMAT	1854	7/24/91	Idle		567.66	11.29			556.37	Lamb Weston	
UMAT	1854	9/20/91	Idle		567.66	11.44			556.22	Lamb Weston	
UMAT	1854	10/8/91	Idle		567.66	11.48			556.18	Lamb Weston	
UMAT	1854	1/21/92	Idle		567.66	15.56			552.10	Lamb Weston	
UMAT	1854	2/12/92	Idle		567.66	15.56			552.10	Lamb Weston	
UMAT	1854	3/27/92	Idle		567.66	16.35			551.31	Lamb Weston	
UMAT	1855	1/15/91	Idle		580.71	16.77			563.95	Lamb Weston	
UMAT	1855	2/12/91	Idle		580.71	16.56			564.15	Lamb Weston	
UMAT	1855	3/5/91	Idle		580.71	16.85			563.86	Lamb Weston	
UMAT	1855	4/16/91	Idle		580.71	16.43			564.28	Lamb Weston	
UMAT	1855	5/3/91	Idle		580.71	17.1			563.61	Lamb Weston	
UMAT	1855	6/18/91	Idle		580.71	17.1			563.61	Lamb Weston	
UMAT	1855	7/24/91	Idle		580.71	16.77			563.95	Lamb Weston	
UMAT	1855	9/20/91	Idle		580.71	16.39			564.32	Lamb Weston	
UMAT	1855	10/8/91	Idle		580.71	16.76			563.95	Lamb Weston	
UMAT	1855	1/21/92	Idle		580.71	14.34			566.37	Lamb Weston	
UMAT	1855	2/12/92	Idle		580.71	14.35			566.36	Lamb Weston	
UMAT	1855	3/27/92	Idle		580.71	15.68			565.03	Lamb Weston	
UMAT	1974	2/15/91	Idle	E Tape	473	49.55			423.45	OWRD	
UMAT	1974	8/21/91	Idle	E Tape	473	55.88			417.12	OWRD	
UMAT	1974	2/12/92	Idle	E Tape	473	50.69			422.31	OWRD	
UMAT	2028	2/9/91	Idle	E Tape	454	20.67			433.33	OWRD	
UMAT	2028	8/21/91	Idle	E Tape	454	20.88			433.12	OWRD	
UMAT	2028	2/13/92	Idle	E Tape	454	21.41			432.59	OWRD	
UMAT	2067	12/13/90	Idle	E Tape	457	14.35			442.65	OWRD	
UMAT	2067	2/7/91	Idle	E Tape	457	15.04			441.96	OWRD	
UMAT	2067	8/20/91	Idle	E Tape	457	16.41			440.59	OWRD	
UMAT	2067	2/13/92	Idle	E Tape	457	15.85			441.15	OWRD	
UMAT	2068	2/9/91	Idle	E Tape	462	24.02			437.98	OWRD	
UMAT	2068	8/24/91	Idle	E Tape	462	24.51			437.49	OWRD	
UMAT	2068	2/13/92	Idle	E Tape	462	23.85			438.15	OWRD	
UMAT	2130	2/9/91	Idle	E Tape	642	24.7			617.30	OWRD	
UMAT	2130	2/13/92	Idle	E Tape	642	24.33			617.67	OWRD	
UMAT	2143	2/11/91	Idle	E Tape	557	14.3			542.70	OWRD	
UMAT	2143	2/13/92	Idle	E Tape	557	15.49			541.51	OWRD	
UMAT	2151	2/15/91	Idle	E Tape	542	45.14			496.86	OWRD	
UMAT	2151	8/21/91	Idle	E Tape	542	63.73			478.27	OWRD	Wheel lines on next door
UMAT	2151	2/13/92	Idle	E Tape	542	44.86			497.14	OWRD	
UMAT	2188	2/15/91	Idle	E Tape	480	46.09			433.91	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	2188	8/21/91	Idle	E Tape	480	33.41			446.59	OWRD	
UMAT	2188	2/13/92	Idle	E Tape	480	45.2			434.80	OWRD	
UMAT	2307	2/9/91	Idle	E Tape	527	31.55			495.45	OWRD	
UMAT	2307	8/21/91	Int. Pmpg	E Tape	527	28.21			498.79	OWRD	Recovering
UMAT	2307	8/21/91	Int. Pmpg	E Tape	527	27.78			499.22	OWRD	Very slow recovery
UMAT	2307	2/13/92	Int. Pmpg	E Tape	527	32.08			494.92	OWRD	Slow recovery
UMAT	2338	2/8/91	Idle	E Tape	530	39.87			490.13	OWRD	
UMAT	2338	8/22/91	Idle	E Tape	530	38.03			491.97	OWRD	
UMAT	2338	2/12/92	Idle	E Tape	530	38.63			491.37	OWRD	
UMAT	2382	2/13/91	Idle	E Tape	549	52.49			496.51	OWRD	Very oily; bad cut.
UMAT	2382	8/22/91	Idle	E Tape	549	62.47			486.53	OWRD	Very oily; bad cut.
UMAT	2405	3/15/91			560	60.72			499.28	OWRD	Off 1 week
UMAT	2406	2/8/91	Idle	E Tape	563	68.48			494.52	OWRD	
UMAT	2406	8/23/91	Idle	E Tape	563	65.66			497.34	OWRD	
UMAT	2406	2/12/92	Idle	E Tape	563	66.75			496.25	OWRD	
UMAT	2414	2/8/91	Idle	E Tape	528	22.14			505.86	OWRD	
UMAT	2517	2/11/91	Idle	E Tape	641	61.69			579.31	OWRD	
UMAT	2517	8/21/91	Int. Pmpg	E Tape	641	96.42			544.58	OWRD	Recovering
UMAT	2517	2/13/92	Idle	E Tape	641	61.1			579.90	OWRD	
UMAT	2524	2/9/91	Rec Pumped	E Tape	637	17.77			619.23	OWRD	Slow recovery
UMAT	2524	8/20/91	Idle	E Tape	637	12.12			624.88	OWRD	
UMAT	2524	2/13/92	Idle	E Tape	637	17.52			619.48	OWRD	
UMAT	2591	2/9/91	Idle	E Tape	581	84.27			496.73	OWRD	
UMAT	2591	8/21/91	Idle	E Tape	581	81.88			499.12	OWRD	
UMAT	2591	2/12/92	Idle	E Tape	581	84.39			496.61	OWRD	
UMAT	2601	2/14/91	Idle	E Tape	545	37.76			507.24	OWRD	
UMAT	2601	8/22/91	Idle	E Tape	545	31.59			513.41	OWRD	Pump off 1 week
UMAT	2601	2/12/92	Idle	E Tape	545	37.98			507.02	OWRD	
UMAT	2628	2/8/91	Rec Pumped	E Tape	549	37.74			511.26	OWRD	
UMAT	2628	8/21/91	Idle	E Tape	549	46.58			502.42	OWRD	Off since yesterday
UMAT	2628	2/13/92	Idle	E Tape	549	36.77			512.23	OWRD	
UMAT	2696	2/12/91	Idle	E Tape	525	18.32			506.68	OWRD	
UMAT	2696	8/20/91	Idle	E Tape	525	13.65			511.35	OWRD	Full irrig canal 50 ft west.
UMAT	2696	2/11/92	Idle	E Tape	525	16.75			508.25	OWRD	
UMAT	2753	2/12/91	Idle	E Tape	465	14.78			450.22	OWRD	
UMAT	2753	8/20/91	Idle	E Tape	465	11.81			453.19	OWRD	
UMAT	2753	2/11/92	Idle	E Tape	465	13.93			451.07	OWRD	
UMAT	2774	2/12/91	Idle	E Tape	617	44.61			572.39	OWRD	
UMAT	2774	8/20/91	Idle	E Tape	617	52.97			564.03	OWRD	
UMAT	2774	2/12/92	Rec Pumped	E Tape	617	43.51			573.49	OWRD	
UMAT	2806	12/13/90	Idle	E Tape	627	62.57			564.43	OWRD	
UMAT	2806	2/7/91	Idle	E Tape	627	62.07			564.93	OWRD	
UMAT	2806	8/20/91	Rec Pumped	E Tape	627	66.75			560.25	OWRD	Cycling; slow recov.
UMAT	2806	2/11/92	Idle	E Tape	627	61.64			565.36	OWRD	
UMAT	2811	1/25/91	Idle	E Tape	653	60.32			592.68	OWRD	
UMAT	2811	2/7/91	Idle	E Tape	653	60.37			592.63	OWRD	
UMAT	2811	2/11/92	Int. Pmpg	E Tape	653	59.73			593.27	OWRD	
UMAT	2813	1/23/91	Rec Pumped	E Tape	622	29.25			592.75	OWRD	
UMAT	2813	2/7/91	Int. Pmpg	E Tape	622	57.61			564.39	OWRD	
UMAT	2830	2/11/91	Idle	E Tape	660	14.57			645.43	OWRD	
UMAT	2844	1/23/91	Idle	E Tape	671	20.88			650.12	OWRD	
UMAT	2844	2/11/91	Idle	E Tape	671	20.25			650.75	OWRD	
UMAT	2844	8/20/91	Idle	E Tape	671	84.94			586.06	OWRD	
UMAT	2844	2/12/92	Idle	E Tape	671	19.96			651.04	OWRD	
UMAT	2857	2/12/91	Int. Pmpg	E Tape	660	15.01			644.99	OWRD	Very slow recov.
UMAT	2857	8/20/91	Int. Pmpg	E Tape	660	12.39			647.61	OWRD	
UMAT	2857	2/12/92	Idle	E Tape	660	14.02			645.98	OWRD	
UMAT	2863	2/14/91	Idle	E Tape	660	46.17			613.83	OWRD	
UMAT	2866	1/24/91	Idle	E Tape	686	49.08			636.92	OWRD	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	2866	2/7/91	Idle	E Tape	686	48.14			637.86	OWRD	
UMAT	2866	8/20/91	Idle	E Tape	686	55.25			630.75	OWRD	
UMAT	2866	2/12/92	Idle	E Tape	686	47.03			638.97	OWRD	
UMAT	2867	2/12/91	Idle	E Tape	692	85.51			606.49	OWRD	Very oily; bad cut.
UMAT	2867	8/24/91	Idle	E Tape	692	107.95			584.05	OWRD	Very oily; bad cut.
UMAT	2867	2/11/92	Idle	E Tape	692	82.01			609.99	OWRD	Very oily; bad cut.
UMAT	2875	2/12/91	Idle	E Tape	645	35.99			609.01	OWRD	
UMAT	2875	8/23/91	Int. Pmpg	E Tape	645	43.21			601.79	OWRD	Very slow recov.
UMAT	2901	2/12/91	Idle	E Tape	663	15.05			647.95	OWRD	
UMAT	2901	2/12/92	Idle	E Tape	663	13.83			649.17	OWRD	
UMAT	2924	1/23/91	Idle	E Tape	650	26.98			623.02	OWRD	
UMAT	2924	2/12/92	Idle	E Tape	650	26.05			623.95	OWRD	
UMAT	2925	2/12/92	Idle	E Tape	637	3.23			633.77	OWRD	
UMAT	2941	2/12/91	Idle	E Tape	653	30.29			622.71	OWRD	Unused
UMAT	2941	8/20/91	Idle	E Tape	653	28.38			624.62	OWRD	Adjacent welll on
UMAT	2941	2/12/92	Idle	E Tape	653	28.79			624.21	OWRD	
UMAT	2963	2/11/91	Idle	E Tape	598	17.68			580.32	OWRD	
UMAT	2963	2/12/92	Idle	E Tape	598	16.63			581.37	OWRD	
UMAT	2965	2/11/91	Idle	E Tape	618	23.6			594.40	OWRD	
UMAT	2965	8/20/91	Rec Pumped	E Tape	618	22.7			595.30	OWRD	
UMAT	2965	2/12/92	Idle	E Tape	618	23.07			594.93	OWRD	
UMAT	2983	2/12/91	Idle	E Tape	601	5.65			595.35	OWRD	
UMAT	2983	8/20/91	Int. Pmpg	E Tape	601	6.09			594.91	OWRD	Cycling; slow recov.
UMAT	2983	2/12/92	Idle	E Tape	601	5.25			595.75	OWRD	
UMAT	3271	2/11/91	Idle	E Tape	311	42.55			268.45	OWRD	
UMAT	3271	8/23/91	Idle	E Tape	311	39.49			271.51	OWRD	
UMAT	3271	2/10/92	Idle	E Tape	311	43.07			267.93	OWRD	
UMAT	3294	2/15/91	Idle	E Tape	330	64.2			265.80	OWRD	
UMAT	3294	8/24/91	Idle	E Tape	330	61.65			268.35	OWRD	
UMAT	3294	2/10/92	Idle	E Tape	330	64.8			265.20	OWRD	
UMAT	3297	2/15/91	Idle	E Tape	362	95.24			266.76	OWRD	
UMAT	3297	8/24/91	Idle	E Tape	362	92.69			269.31	OWRD	
UMAT	3297	2/10/92	Idle	E Tape	362	95.84			266.16	OWRD	
UMAT	3373	2/8/91	Idle	E Tape	295	24.94			270.06	OWRD	
UMAT	3373	8/23/91	Idle	E Tape	295	21.85			273.15	OWRD	
UMAT	3373	2/12/92	Idle	E Tape	295	24.81			270.19	OWRD	
UMAT	3374	2/8/91	Idle	E Tape	321	52.26			268.74	OWRD	
UMAT	3374	2/12/92	Idle	E Tape	321	52.53			268.47	OWRD	
UMAT	3380	2/8/91	Idle	E Tape	550	52.56			497.44	OWRD	
UMAT	3380	8/21/91	Idle	E Tape	550	49.2			500.80	OWRD	Adj. field flooded
UMAT	3380	2/13/92	Idle	E Tape	550	52.85			497.15	OWRD	
UMAT	3405	2/8/91	Int. Pmpg	E Tape	469	22.98			446.02	OWRD	
UMAT	3405	8/21/91	Idle	E Tape	469	25.68			443.32	OWRD	Nearby well on
UMAT	3405	2/12/92	Int. Pmpg	E Tape	469	22.91			446.09	OWRD	
UMAT	3415	2/9/91	Idle	E Tape	459	23.46			435.54	OWRD	
UMAT	3415	8/21/91	Idle	E Tape	459	34.58			424.42	OWRD	
UMAT	3415	2/11/92	Idle	E Tape	459	24.47			434.53	OWRD	
UMAT	3424	2/8/91	Int. Pmpg	E Tape	475	34.66			440.34	OWRD	Recovering
UMAT	3424	8/21/91	Int. Pmpg	E Tape	475	36.8			438.20	OWRD	Very slow recov.
UMAT	3424	2/11/92	Int. Pmpg	E Tape	475	35.56			439.44	OWRD	
UMAT	3530	8/24/91	Idle	E Tape	522	87.78			434.22	OWRD	
UMAT	3530	2/11/92	Idle	E Tape	522	83.62			438.38	OWRD	
UMAT	3537	1/25/91	Int. Pmpg	E Tape	532	97.58			434.42	OWRD	
UMAT	3537	8/21/91	Rec Pumped	E Tape	532	102.27			429.73	OWRD	Very slow recov.
UMAT	3537	2/11/92	Rec Pumped	E Tape	532	96.75			435.25	OWRD	Very slow recov.
UMAT	3607	2/7/91	Idle	E Tape	536	89.23			446.77	OWRD	
UMAT	3607	8/21/91	Idle	E Tape	536	91.05			444.95	OWRD	
UMAT	3607	2/11/92	Idle	E Tape	536	90.19			445.81	OWRD	
UMAT	3626	2/7/91	Idle	E Tape	479	35.87			443.13	OWRD	

Lower Umatilla Basin
Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	3626	8/21/91	Rec Pumped	E Tape	479	38.41			440.59	OWRD	
UMAT	3626	2/11/92	Idle	E Tape	479	35.78			443.22	OWRD	
UMAT	3638	2/7/91	Idle	E Tape	529	88.06			440.94	OWRD	
UMAT	3638	2/11/91	Idle	E Tape	529	88.95			440.05	OWRD	
UMAT	3638	8/21/91	Idle	E Tape	529	90.05			438.95	OWRD	
UMAT	3661	1/23/91	Idle	E Tape	412	63.56			348.44	OWRD	
UMAT	3661	2/7/91	Idle	E Tape	412	62.79			349.21	OWRD	
UMAT	3661	2/10/92	Idle	E Tape	412	63.41			348.59	OWRD	
UMAT	3663	1/23/91	Idle	E Tape	416	87.76			328.24	OWRD	
UMAT	3663	2/7/91	Idle	E Tape	416	66.84			349.16	OWRD	
UMAT	3663	8/20/91	Idle	E Tape	416	65.1			350.90	OWRD	Nearby well on
UMAT	3663	2/10/92	Rec Pumped	E Tape	416	67.18			348.82	OWRD	
UMAT	3666	1/25/91	Rec Pumped	E Tape	408	11.17			396.83	OWRD	
UMAT	3667	2/7/91	Idle	E Tape	471	31.43			439.57	OWRD	
UMAT	3667	2/11/91			471				471.00	OWRD	
UMAT	3667	8/20/91	Rec Pumped	E Tape	471	33.52			437.48	OWRD	
UMAT	3676	1/25/91	Idle	E Tape	443	10.35			432.65	OWRD	
UMAT	3676	2/7/91	Idle	E Tape	443	10.51			432.49	OWRD	
UMAT	3676	8/20/91	Pumping		443				443.00	OWRD	
UMAT	3676	2/10/92	Idle	E Tape	443				443.00	OWRD	Very oily
UMAT	3679	1/23/91	Idle	E Tape	408	55.26			352.74	OWRD	
UMAT	3679	2/7/91	Idle	E Tape	408	56.28			351.72	OWRD	
UMAT	3679	8/20/91	Idle	E Tape	408	52.1			355.90	OWRD	
UMAT	3704	2/7/91	Idle	E Tape	471	12.68			458.32	OWRD	
UMAT	3704	8/20/91	Int. Pmpg	E Tape	471	5.55			465.45	OWRD	Very slow recov.
UMAT	3704	2/11/92	Idle	E Tape	471	11.72			459.28	OWRD	
UMAT	3727	1/24/91	Rec Pumped	E Tape	455	21.05			433.95	OWRD	
UMAT	3727	2/7/91	Idle	E Tape	455	20.22			434.78	OWRD	
UMAT	3727	8/20/91	Rec Pumped	E Tape	455	21.24			433.76	OWRD	
UMAT	3727	2/10/92	Idle	E Tape	455	20.93			434.07	OWRD	
UMAT	3755	1/23/91	Idle	E Tape	460	17.53			442.47	OWRD	
UMAT	3755	2/7/91	Idle	E Tape	460	17.64			442.36	OWRD	
UMAT	3755	2/10/92	Idle	E Tape	460	18.36			441.64	OWRD	
UMAT	3809	2/7/91	Idle	E Tape	462	7.84			454.16	OWRD	
UMAT	3809	8/20/91	Int. Pmpg	E Tape	462	4.5			457.50	OWRD	
UMAT	3809	2/11/92	Idle	E Tape	462	7.71			454.29	OWRD	
UMAT	3826	1/24/91	Idle	E Tape	472	9.22			462.78	OWRD	
UMAT	3826	8/20/91	Int. Pmpg	E Tape	472	4.77			467.23	OWRD	
UMAT	3826	2/11/92	Idle	E Tape	472	9.44			462.56	OWRD	
UMAT	5255	1/25/91	Idle	E Tape	495	160.57			334.43	OWRD	
UMAT	5255	2/7/91	Idle	E Tape	495	159.23			335.77	OWRD	
UMAT	5255	2/10/92	Idle	E Tape	495	159.98			335.02	OWRD	
UMAT	5286	2/6/91	Idle		583.11	10.5			572.61	Staley	
UMAT	5286	6/12/91	Idle		583.11	9.25			573.86	DEQ	
UMAT	5286	10/8/91	Idle		583.11	11			572.11	DEQ	
UMAT	5286	12/15/91	Idle		583.11	9			574.11	DEQ	
UMAT	5286	2/17/92	Idle		583.11	9.2			573.91	Staley	
UMAT	5286	3/4/92	Idle		583.11	8.58			574.53	DEQ	
UMAT	5287	2/6/91	Idle		590.66	16			574.66	Staley	
UMAT	5287	6/12/91	Idle		590.66	15.06			575.60	DEQ	
UMAT	5287	10/8/91	Idle		590.66	17			573.66	DEQ	
UMAT	5287	12/15/91	Idle		590.66	14.9			575.76	DEQ	
UMAT	5287	2/17/92	Idle		590.66	15.3			575.36	Staley	
UMAT	5287	3/4/92	Idle		590.66	14.66			576.00	DEQ	
UMAT	5288	2/6/91	Idle		586.1	17.5			568.60	Staley	
UMAT	5288	6/12/91	Idle		586.1	16			570.10	DEQ	
UMAT	5288	10/8/91	Idle		586.1	18			568.10	DEQ	
UMAT	5288	12/15/91	Idle		586.1	15			571.10	DEQ	
UMAT	5288	2/17/92	Idle		586.1	15.9			570.20	Staley	

Lower Umatilla Basin

Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	5288	3/4/92	Idle		586.1	15.66			570.44	DEQ	
UMAT	5289	2/6/91	Idle		585.2	15.5			569.70	Staley	
UMAT	5289	6/12/91	Idle		585.2	14.5			570.70	DEQ	
UMAT	5289	10/8/91	Idle		585.2	16			569.20	DEQ	
UMAT	5289	12/15/91	Idle		585.2	14			571.20	DEQ	
UMAT	5289	2/17/92	Idle		585.2	14.9			570.30	Staley	
UMAT	5289	3/4/92	Idle		585.2	14			571.20	DEQ	
UMAT	5290	2/6/91	Idle		583.57	12			571.57	Staley	
UMAT	5290	6/12/91	Idle		583.57	8.75			574.82	DEQ	
UMAT	5290	10/8/91	Idle		583.57	12			571.57	DEQ	
UMAT	5290	12/15/91	Idle		583.57	9			574.57	DEQ	
UMAT	5290	2/17/92	Idle		583.57	10.2			573.37	Staley	
UMAT	5290	3/4/92	Idle		583.57	9.5			574.07	DEQ	
UMAT	5291	2/6/91	Idle		585.72	12.5			573.22	Staley	
UMAT	5291	6/12/91	Idle		585.72	10.5			575.22	DEQ	
UMAT	5291	10/8/91	Idle		585.72	11.5			574.22	DEQ	
UMAT	5291	12/15/91	Idle		585.72	10.2			575.52	DEQ	
UMAT	5291	2/17/92	Idle		585.72	10.5			575.22	Staley	
UMAT	5291	3/4/92	Idle		585.72	10.08			575.64	DEQ	
UMAT	5292	2/6/91	Idle		590.87	20.5			570.37	Staley	
UMAT	5292	6/12/91	Idle		590.87	18.75			572.12	DEQ	
UMAT	5292	10/8/91	Idle		590.87	20.25			570.62	DEQ	
UMAT	5292	12/15/91	Idle		590.87	15.6			575.27	DEQ	
UMAT	5292	2/17/92	Idle		590.87	15.65			575.22	Staley	
UMAT	5292	3/4/92	Idle		590.87	18.17			572.70	DEQ	
UMAT	5300	1/25/91	Idle	E Tape	462	11.6			450.40	OWRD	
UMAT	5300	2/7/91	Idle	E Tape	462	11.97			450.03	OWRD	
UMAT	5300	8/20/91	Int. Pmpg	E Tape	462	10.38			451.62	OWRD	Slow recovery
UMAT	5300	2/11/92	Idle	E Tape	462	11.89			450.11	OWRD	
UMAT	5328	2/13/91			691.42	84.56			606.86	OWRD	
UMAT	5328	4/17/91			691.42	85.15			606.27	DEQ	
UMAT	5328	8/20/91			691.42	87.61			603.81	OWRD	
UMAT	5328	2/11/92			691.42	80.41			611.01	OWRD	
UMAT	5342	2/9/91	Rec Pumped	E Tape	511	138.3			372.70	OWRD	Slow recovery
UMAT	5342	2/21/91	Idle	E Tape	511	178.5			332.50	OWRD	
UMAT	5342	2/13/92	Idle	E Tape	511	115.7			395.30	OWRD	Slow recovery.
UMAT	5363	1/15/91	Idle		581.32	12.54			568.78	Lamb Weston	
UMAT	5363	2/12/91	Idle		581.32	11.29			570.03	Lamb Weston	
UMAT	5363	3/5/91	Idle		581.32	11.56			569.76	Lamb Weston	
UMAT	5363	4/16/91	Idle		581.32	11.58			569.74	Lamb Weston	
UMAT	5363	5/3/91	Idle		581.32	11.85			569.47	Lamb Weston	
UMAT	5363	6/18/91	Idle		581.32	11.54			569.78	Lamb Weston	
UMAT	5363	7/24/91	Idle		581.32	11.87			569.45	Lamb Weston	
UMAT	5363	9/20/91	Idle		581.32	10.54			570.78	Lamb Weston	
UMAT	5363	10/8/91	Idle		581.32	10.67			570.65	Lamb Weston	
UMAT	5363	1/21/92	Idle		581.32	10.08			571.24	Lamb Weston	
UMAT	5363	2/12/92	Idle		581.32	10.08			571.24	Lamb Weston	
UMAT	5363	3/27/92	Idle		581.32	10.17			571.15	Lamb Weston	
UMAT	5364	1/15/91	Idle		567.29	18.37			548.92	Lamb Weston	
UMAT	5364	2/12/91	Idle		567.29	20.17			547.13	Lamb Weston	
UMAT	5364	3/5/91	Idle		567.29	15.08			552.21	Lamb Weston	
UMAT	5364	4/16/91	Idle		567.29	15.67			551.63	Lamb Weston	
UMAT	5364	5/3/91	Idle		567.29	15.29			552.00	Lamb Weston	
UMAT	5364	6/18/91	Idle		567.29	15.54			551.75	Lamb Weston	
UMAT	5364	7/24/91	Idle		567.29	16.17			551.13	Lamb Weston	
UMAT	5364	9/20/91	Idle		567.29	17.54			549.75	Lamb Weston	
UMAT	5364	10/8/91	Idle		567.29	17.67			549.62	Lamb Weston	
UMAT	5364	1/21/92	Idle		567.29	20.29			547.00	Lamb Weston	
UMAT	5364	2/12/92	Idle		567.29	20.29			547.00	Lamb Weston	

Lower Umatilla Basin
Synoptic Water Level Data (includes all water levels measured between 12/1/90 and 5/1/92

WRD	ID	Date	Status	Method	Land Surface Elev (LS Elev)	Water Level Below LS	Top of Casing Elev (TOC Elev)	Water Level Below TOC	Water Level Elev	Source	Comments
UMAT	5364	3/27/92	Idle		567.29	20.92			546.37	Lamb Weston	
UMAT	5365	1/15/91	Idle		622.75	60.05			562.71	Lamb Weston	
UMAT	5365	2/12/91	Idle		622.75	57.96			564.79	Lamb Weston	
UMAT	5365	3/5/91	Idle		622.75	58.13			564.62	Lamb Weston	
UMAT	5365	4/16/91	Idle		622.75	58.21			564.54	Lamb Weston	
UMAT	5365	5/3/91	Idle		622.75	58.5			564.25	Lamb Weston	
UMAT	5365	6/18/91	Idle		622.75	58.3			564.46	Lamb Weston	
UMAT	5365	7/24/91	Idle		622.75	59.3			563.46	Lamb Weston	
UMAT	5365	9/20/91	Idle		622.75	59.88			562.87	Lamb Weston	
UMAT	5365	10/8/91	Idle		622.75	59.38			563.37	Lamb Weston	
UMAT	5365	1/21/92	Idle		622.75	60.46			562.29	Lamb Weston	
UMAT	5365	2/12/92	Idle		622.75	60.46			562.29	Lamb Weston	
UMAT	5365	3/27/92	Idle		622.75	61.46			561.29	Lamb Weston	
UMAT	5373	1/24/91	Int. Pmpg	E Tape	605	6.36			598.64	OWRD	
UMAT	5373	8/23/91	Int. Pmpg	E Tape	605	4.7			600.30	OWRD	Very slow recovery
UMAT	5373	2/14/92	Idle	E Tape	605	6.37			598.63	OWRD	
UMAT	5476	1/24/91	Idle	E Tape	579	5.98			573.02	OWRD	
UMAT	5476	2/13/91	Idle	E Tape	579	6.97			572.03	OWRD	
UMAT	5525	4/17/91			653	28.86			624.14	DEQ	
UMAT	5526	4/17/91			658.4	47.6			610.80	DEQ	
UMAT	5527	4/17/91			669.4	38.61			630.79	DEQ	
UMAT	5528	4/17/91			677.1	68.55			608.55	DEQ	
UMAT	5546	2/13/92	Idle	E Tape	450	6.8			443.20	OWRD	
UMAT	5569	10/1/91	Idle		643.3	14.75			628.55	Lamb Weston	
UMAT	5569	2/1/92	Idle		643.3	13.17			630.13	Lamb Weston	
UMAT	5569	3/1/92	Idle		643.3	13			630.30	Lamb Weston	
UMAT	5569	4/1/92	Idle		643.3	12.88			630.42	Lamb Weston	
UMAT	5569	5/1/92	Idle		643.3	12.88			630.42	Lamb Weston	
UMAT	5570	10/1/91	Idle		618.6	32.58			586.02	Lamb Weston	
UMAT	5570	2/1/92	Idle		618.6	32.71			585.89	Lamb Weston	
UMAT	5570	3/1/92	Idle		618.6	32.5			586.10	Lamb Weston	
UMAT	5570	4/1/92	Idle		618.6	32.96			585.64	Lamb Weston	
UMAT	5570	5/1/92	Idle		618.6	32.92			585.68	Lamb Weston	
UMAT	5571	10/1/91	Idle		636.5	58.25			578.25	Lamb Weston	
UMAT	5571	2/1/92	Idle		636.5	59.94			576.56	Lamb Weston	
UMAT	5571	3/1/92	Idle		636.5	59.96			576.54	Lamb Weston	
UMAT	5571	4/1/92	Idle		636.5	60.21			576.29	Lamb Weston	
UMAT	5571	5/1/92	Idle		636.5	59.83			576.67	Lamb Weston	
UMAT	5572	3/1/92	Idle		792	14.58			777.42	Lamb Weston	
UMAT	5572	4/1/92	Idle		792	12.71			779.29	Lamb Weston	
UMAT	5572	5/1/92	Idle		792	14.08			777.92	Lamb Weston	
UMAT	5594	10/1/91	Idle		764.2	154.38			609.82	Lamb Weston	
UMAT	5594	2/1/92	Idle		764.2	154			610.20	Lamb Weston	
UMAT	5594	3/1/92	Idle		764.2	154.5			609.70	Lamb Weston	
UMAT	5594	4/1/92	Idle		764.2	154.79			609.41	Lamb Weston	
UMAT	5594	5/1/92	Idle		764.2	154			610.20	Lamb Weston	

Appendix 2C
Summary of Aquifer Test for MORR 964

An aquifer test was conducted in the predominantly coarse-grained flood deposits in the spring of 1992 to determine bulk aquifer parameters. The test consisted of one pumping well, two nearby observation wells, and several distant observation wells. Table 2C.1 lists wells which were included in the test and summarizes data pertinent to the test. Well locations are shown on Figure 2C.1 and well logs are shown in Figures 2C.2, 2C.3, and 2C.4.

Total pumping time for the test was 11,884 minutes (8.25 days). Recovery time was 1580 minutes (1.10 days). The extracted water was pumped through a one-mile long pipeline and then delivered to 4 center-pivots which were disposed along the northern tier of sections 4 and 5 of 3N/27E. Discharge was measured by an in-line flowmeter located one mile south of the pumping well.

Although efforts were made to maintain a constant pumping rate, discharge ranged from 1500 to 1650 gpm (gallons per minute) during the test. The average discharge over the first 6000 minutes was about 1580 gpm and total discharge over the entire test was 1615 gpm.

Ambient water-level trends were monitored in several wells equipped with float-and-counterweight recording devices (Figure 2C.5A). Observations from these wells show that water levels in the area were rising prior to the test due to the influence of artificial recharge from the County Line Water Improvement District recharge canal. Recorder wells beyond the influence of the test also show that ambient water levels began to fall in the early part of the test after the recharge canal was turned off. Water-level trends in one of these wells was used to correct the pumping and post-pumping drawdown data in observation wells which were influenced by the test. Corrected data are shown on drawdown plots in Figures 2C.6 and 2C.7. Disparities in the pre-pumping trends for the recorder wells suggest that these corrections are subject to some uncertainty. The magnitude of the uncertainty is larger for the late time and recovery data because the magnitude of the correction increases with time. This may account for much of the decrease in the drawdown rate which is observed in the corrected data after 6000 minutes of elapsed pumping (Figure 2C.7).

Data from the nearby observation wells (150 and 300 feet from the pumping well) were used to calculate aquifer parameters using a variety of methods. Results are summarized in Table 2C.2. Because of the large uncertainties in the late-time pumping-data corrections, pumping-phase calculations were restricted to data collected prior to about 6000 minutes of elapsed time. Because of the large uncertainties in the recovery-data corrections, parameters based on the early pumping-phase data are considered to be the most reliable. Results indicate a transmissivity of approximately 80,000 feet squared per day, an hydraulic conductivity of about 2000 feet per day (based on an average saturated thickness of about 40 feet in the area), and a specific yield of about 0.18. These results are typical of unconsolidated gravels (Freeze and Cherry, 1979). Theoretical drawdowns based on these parameters are shown in Figure 2C.6.

Drawdowns attributable to the test were not observed in the distant observation wells.

Raw data for the tests will be provided on floppy disk or via the Internet upon request to DEQ or WRD.

Table 2C.1 Aquifer test wells.

Well	Location	Measurement Method	Distance from pumped well (ft)	Maximum uncorrected drawdown (ft)	Maximum corrected drawdown (ft)
MORR 964	4N/27E-30ddd1	Electric Tape	0		
MORR 962	4N/27E-30ddd2	Electric Tape	150	2.11	1.80
MORR 963	4N/27E-30ddd3	Digital Recorder	300	1.50	1.19
MORR 969	4N/27E-31aab	Electric Tape	1300		
MORR 965	4N/27E-30cdb	Electric Tape	1750		
MORR 971	4N/27E-32baa	Electric Tape	2660		
MORR 984	4N/27E-33cba2	Analog Recorder	7100		
MORR 955	4N/27E-27cbc	Analog Recorder	10750		

Table 2C.2 Summary of aquifer test results.

Well	Distance from pumped well (ft)	Method of Analysis	Transmissivity T (ft^2/day)	Hydraulic Conductivity K (ft/day)	Specific Yield Sy
MORR 962	150	Theis*	80,580	2,014	0.16
		Cooper-Jacob*	73,733	1,843	0.17
		Recovery	59,500	1,488	
MORR 963	300	Theis*	83,359	2,084	0.21
		Cooper-Jacob*	85,077	2,127	0.16
		Recovery	62,806	1,570	
* Pumping phase					
Average Pumping Parameters			81,000	2,000	0.18
Average Recovery Parameters			61,000	1,500	

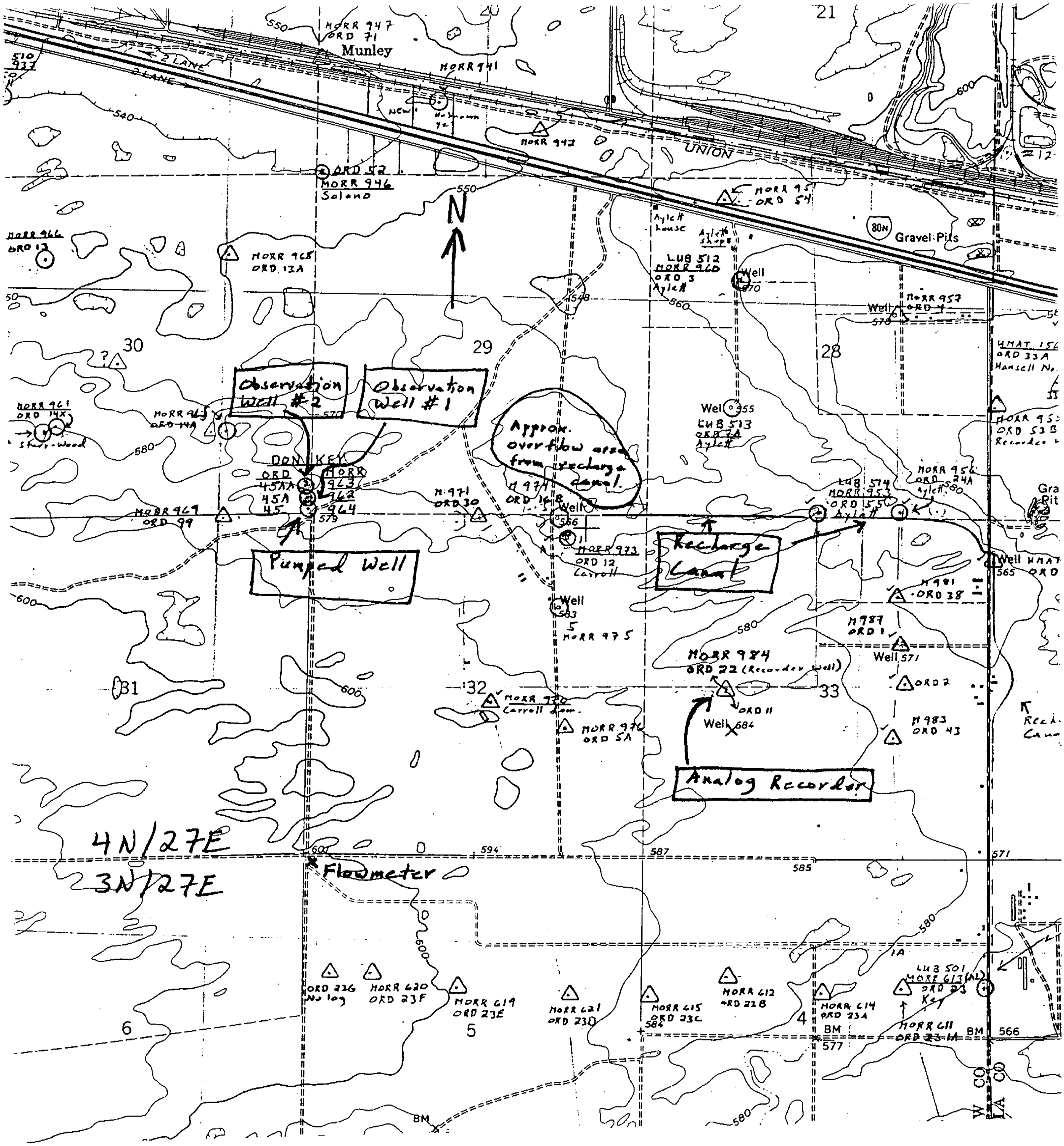
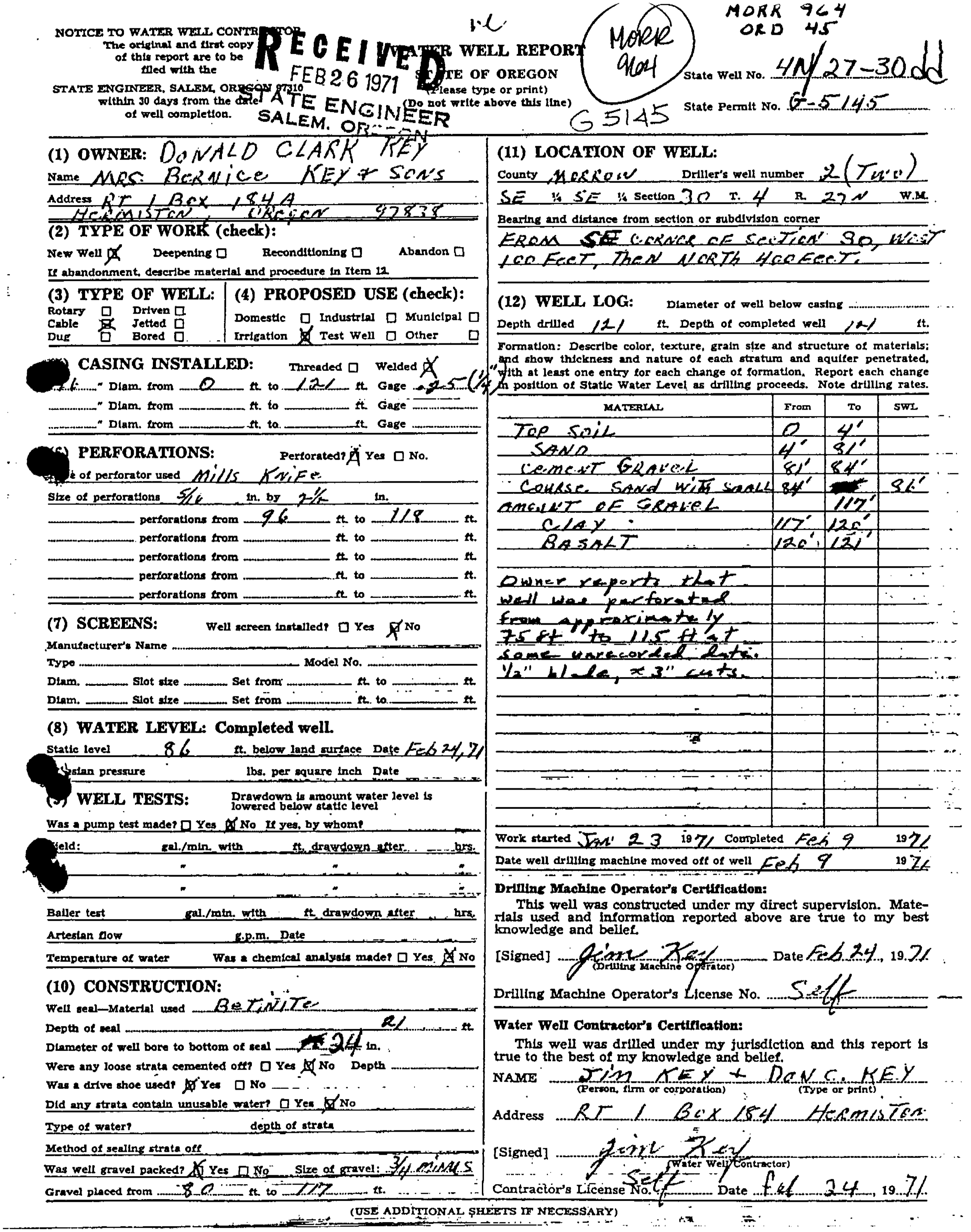


Figure 2C.1 Location map.



NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
FEB 26 1971
STATE ENGINEER
SALEM. OR

rl

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

MORR 964

G5145

MORR 964
ORD 45

State Well No. 4N/27-30dd
State Permit No. G-5145

(1) OWNER: DONALD CLARK KEY
Name MRS BERNICE KEY + SONS
Address RT 1 BOX 184A
HERMISTON, OREGON 97838

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

CASING INSTALLED: Threaded ☐ Welded ☒
[illegible]" Diam. from 0 ft. to 121 ft. Gage .25 (1/4")
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

PERFORATIONS: Perforated? ☒ Yes ☐ No.
of perforator used Mills Knife
Size of perforations 5/16 in. by 2 1/2 in.
perforations from 96 ft. to 118 ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
Static level 86 ft. below land surface Date Feb 24, 71
sian pressure lbs. per square inch Date

WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
ield: gal./min. with ft. drawdown after hrs.
" " "
" " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

(10) CONSTRUCTION:
Well seal—Material used BETINITE
Depth of seal 21 ft.
Diameter of well bore to bottom of seal ~~14~~ 24 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☒ Yes ☐ No
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☒ Yes ☐ No Size of gravel: 3/4 minus
Gravel placed from 80 ft. to 117 ft.

(11) LOCATION OF WELL:
County MORROW Driller's well number 2 (Two)
SE 1/4 SE 1/4 Section 30 T. 4 R. 27 N W.M.
Bearing and distance from section or subdivision corner
FROM SE CORNER OF SECTION 30, WEST
100 FEET, THEN NORTH 400 FEET.

(12) WELL LOG: Diameter of well below casing
Depth drilled 121 ft. Depth of completed well 121 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
TOP SOIL	0	4'	
SAND	4'	81'	
CEMENT GRAVEL	81'	84'	
COURSE SAND WITH SMALL	84'	[illegible]	86'
AMOUNT OF GRAVEL		117'	
CLAY	117'	120'	
BASALT	120'	121'	

Owner reports that
well was perforated
from approximately
75 ft to 115 ft at
some unrecorded date.
1/2" blade, x 3" cuts.

Work started Jan 23 1971 Completed Feb 9 1971
Date well drilling machine moved off of well Feb 9 1971

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.

[Signed] Jim Key (Drilling Machine Operator) Date Feb 24, 1971

Drilling Machine Operator's License No. Self

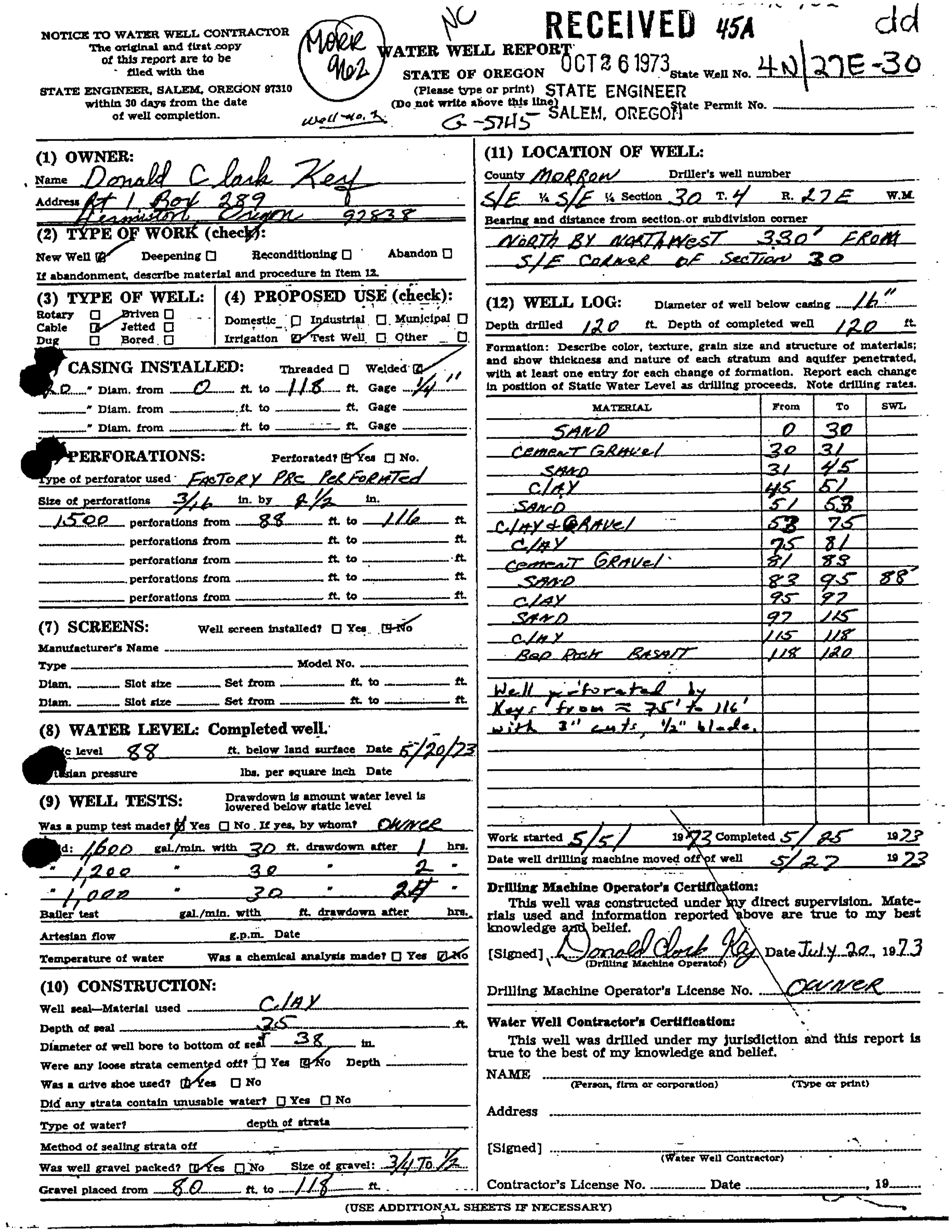
Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME JIM KEY + DON C. KEY (Person, firm or corporation) (Type or print)
Address RT 1 BOX 184 HERMISTON

[Signed] Jim Key (Water Well Contractor)
Contractor's License No. Self Date Feb 24, 1971

(USE ADDITIONAL SHEETS IF NECESSARY)

Figure 2C.2 MORR 964 well log.



NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

MORR 962

well no. 1

NC

WATER WELL REPORT

STATE OF OREGON
(Please type or print)
(Do not write above this line)

RECEIVED 45A
OCT 26 1973
STATE ENGINEER
SALEM, OREGON

G-5745

dd

State Well No. 4N/27E-30
State Permit No.

(1) OWNER:

Name Donald Clark Key
Address Rt 1 Box 289
Hermiston, Oregon 92838

(2) TYPE OF WORK (check):

New Well ☑ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:

Rotary ☐ Driven ☐
Cable ☑ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☑ Test Well ☐ Other ☐

[illegible] CASING INSTALLED: Threaded ☐ Welded ☑

[illegible]0" Diam. from 0 ft. to 118 ft. Gage 1/4"
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible] PERFORATIONS: Perforated? ☑ Yes ☐ No.

[illegible]ype of perforator used FACTORY PRC PERFORATED
Size of perforations 3/16 in. by 2 1/2 in.
1500 perforations from 88 ft. to 116 ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes ☑ No

Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.

[illegible]c level 88 ft. below land surface Date 5/20/73
[illegible]tesian pressure lbs. per square inch Date

(9) WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? ☑ Yes ☐ No If yes, by whom? OWNER
[illegible]d: 1600 gal./min. with 30 ft. drawdown after 1 hrs.
" 1,200 " 30 " 2 "
" 1,000 " 30 " 24 "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☑ No

(10) CONSTRUCTION:

Well seal—Material used CLAY
Depth of seal 25 ft.
Diameter of well bore to bottom of seal 38 in.
Were any loose strata cemented off? ☐ Yes ☑ No Depth
Was a drive shoe used? ☑ Yes ☐ No
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☑ Yes ☐ No Size of gravel: 3/4 To 1/2
Gravel placed from 80 ft. to 118 ft.

(11) LOCATION OF WELL:

County MORROW Driller's well number
S/E ¼ S/E ¼ Section 30 T. 4 R. 27E W.M.
Bearing and distance from section or subdivision corner
NORTH BY NORTHWEST 330' FROM
S/E CORNER OF SECTION 30

(12) WELL LOG: Diameter of well below casing 16"

Depth drilled 120 ft. Depth of completed well 120 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
SAND	0	30	
CEMENT GRAVEL	30	31	
SAND	31	45	
CLAY	45	51	
SAND	51	53	
CLAY & GRAVEL	53	75	
CLAY	75	81	
CEMENT GRAVEL	81	83	
SAND	83	95	88'
CLAY	95	97	
SAND	97	115	
CLAY	115	118	
BED ROCK BASALT	118	120	

Well perforated by
Keys from ≈ 75' to 116'
with 3" cuts, 1/2" blade.

Work started 5/5/ 1973 Completed 5/25 1973
Date well drilling machine moved off of well 5/27 1973

Drilling Machine Operator's Certification:

This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.

[Signed] Donald Clark Key Date July 20, 1973
(Drilling Machine Operator)

Drilling Machine Operator's License No. OWNER

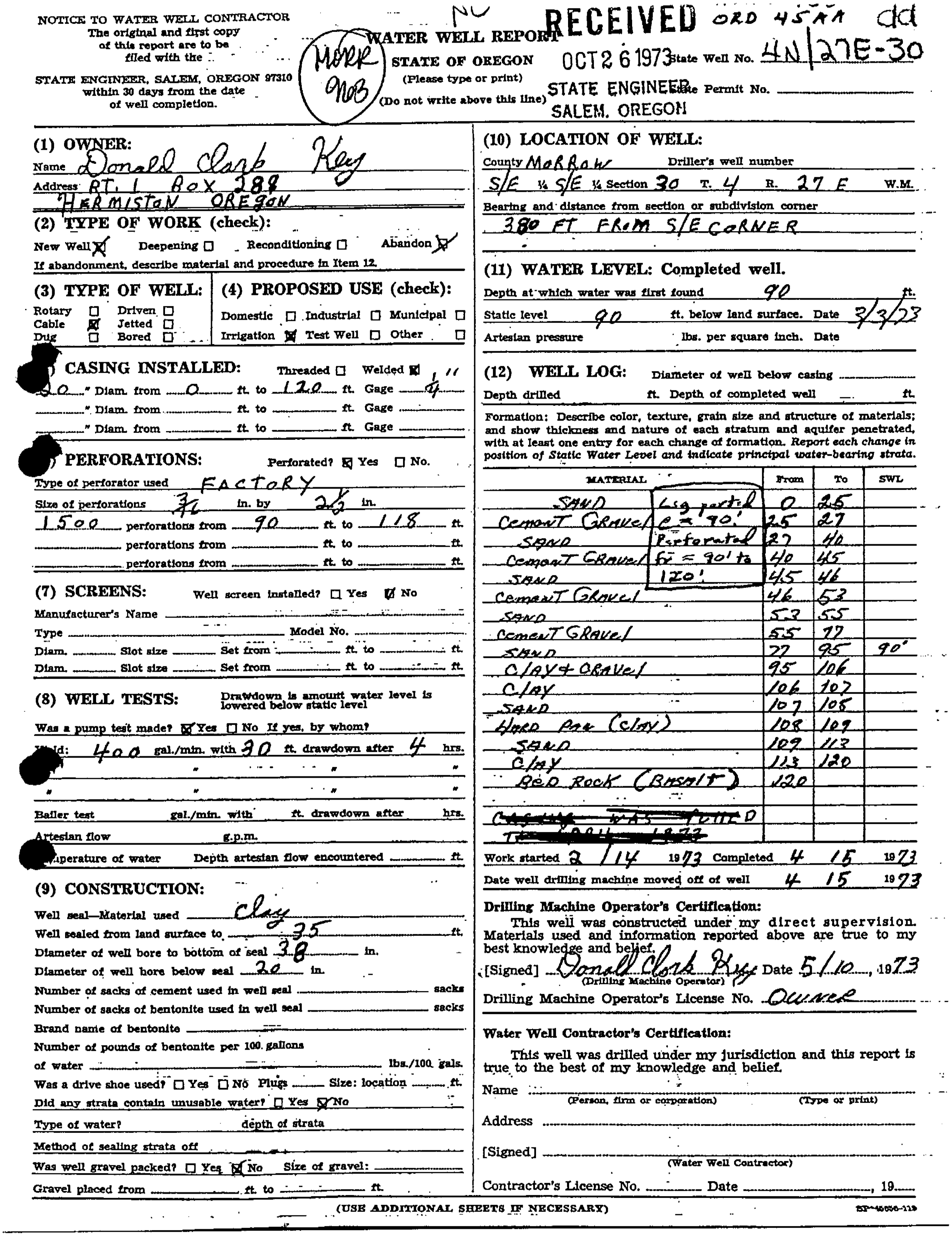
Water Well Contractor's Certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME
(Person, firm or corporation) (Type or print)
Address
[Signed]
(Water Well Contractor)
Contractor's License No. Date , 19

(USE ADDITIONAL SHEETS IF NECESSARY)

Figure 2C.3 MORR 962 well log.



NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

MORR 963

NU

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

RECEIVED
OCT 26 1973
STATE ENGINEER
SALEM, OREGON

ORD 45AA dd

State Well No. 4N/27E-30
State Permit No.

(1) OWNER:
Name Donald Clark Key
Address RT. 1 BOX 288
HERMISTON OREGON

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☒
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

[illegible]) CASING INSTALLED: Threaded ☐ Welded ☒
20" Diam. from 0 ft. to 120 ft. Gage 1/4"
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible]) PERFORATIONS: Perforated? ☒ Yes ☐ No.
Type of perforator used FACTORY
Size of perforations 3/16 in. by 2½ in.
1500 perforations from 90 ft. to 118 ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom?
[illegible]ld: 400 gal./min. with 30 ft. drawdown after 4 hrs.
" " "
" " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
[illegible]perature of water Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used Clay
Well sealed from land surface to 35 ft.
Diameter of well bore to bottom of seal 38 in.
Diameter of well bore below seal 20 in.
Number of sacks of cement used in well seal sacks
Number of sacks of bentonite used in well seal sacks
Brand name of bentonite
Number of pounds of bentonite per 100 gallons of water lbs./100 gals.
Was a drive shoe used? ☐ Yes ☐ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:
County MORROW Driller's well number
S/E ¼ S/E ¼ Section 30 T. 4 R. 27 E W.M.
Bearing and distance from section or subdivision corner
380 FT FROM S/E CORNER

(11) WATER LEVEL: Completed well.
Depth at which water was first found 90 ft.
Static level 90 ft. below land surface. Date 3/3/73
Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing
Depth drilled ft. Depth of completed well ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. *Report each change in position of Static Water Level and indicate principal water-bearing strata.*

MATERIAL	From	To	SWL
SAND	0	25	
CEMENT GRAVEL	25	27	
SAND	27	40	
CEMENT GRAVEL	40	45	
SAND	45	46	
CEMENT GRAVEL	46	53	
SAND	53	55	
CEMENT GRAVEL	55	77	
SAND	77	95	90'
CLAY + GRAVEL	95	106	
CLAY	106	107	
SAND	107	108	
HARD PAN (CLAY)	108	109	
SAND	109	113	
CLAY	113	120	
BED ROCK (BASALT)	120		
~~CASING WAS PULLED~~			
~~T[illegible] 1973~~			

Log partial
@ = 90'
Perforated
fr = 90' to
120'

Work started 2/14 1973 Completed 4/15 1973
Date well drilling machine moved off of well 4/15 1973

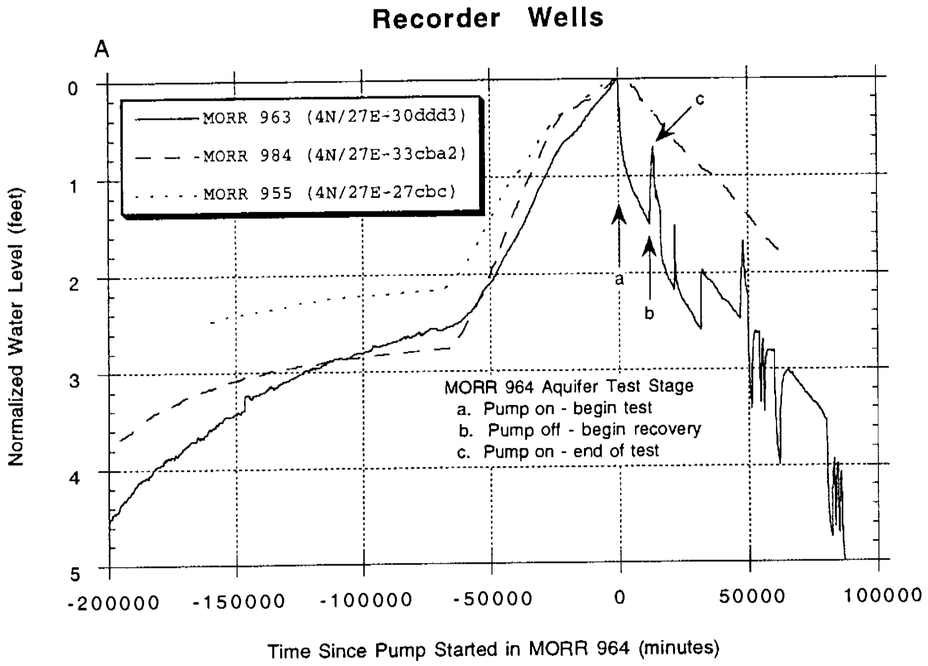
Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Donald Clark Key (Drilling Machine Operator) Date 5/10, 1973
Drilling Machine Operator's License No. Owner

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Name (Person, firm or corporation) (Type or print)
Address
[Signed] (Water Well Contractor)
Contractor's License No. Date , 19

(USE ADDITIONAL SHEETS IF NECESSARY)

SP*45656-119

Figure 2C.4 MORR 963 well log.



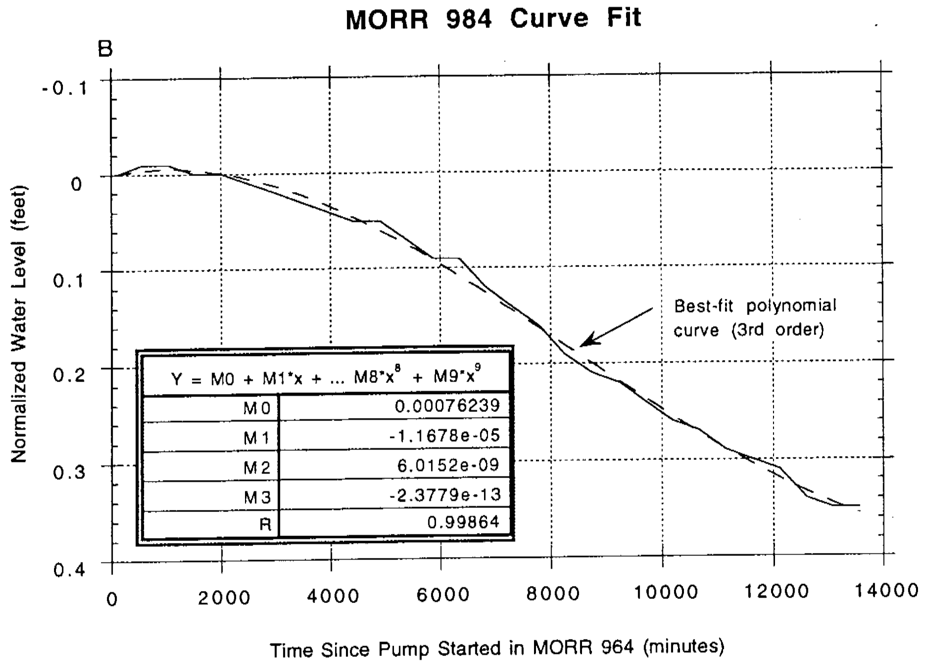


Figure 2C.5 Ambient water-level corrections. A, Water-level trends in recorder wells before, during, and after aquifer test; B, Best-fit polynomial curve for ambient water-level trends in MORR 984 during drawdown and recovery phases of aquifer test.

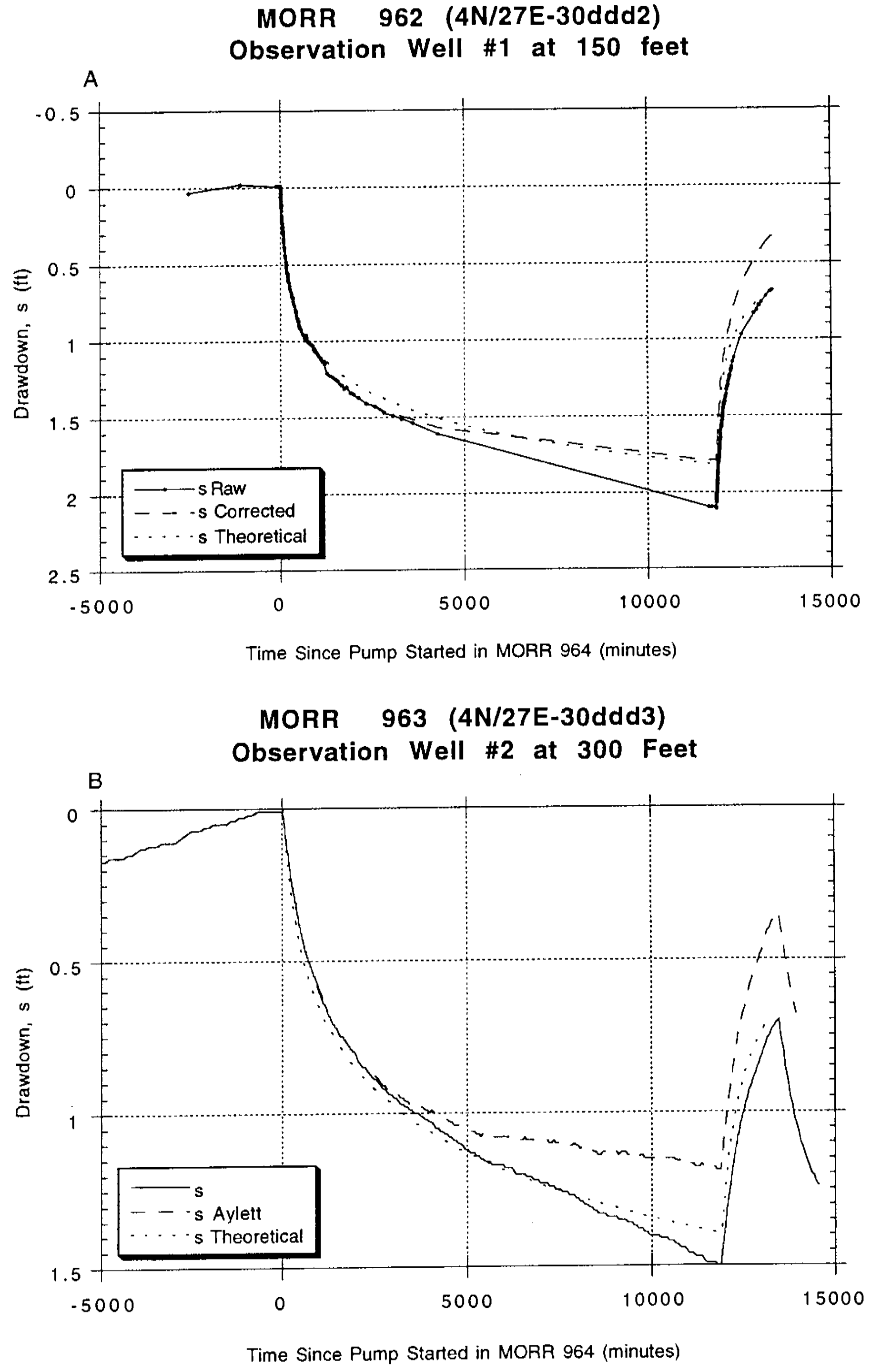
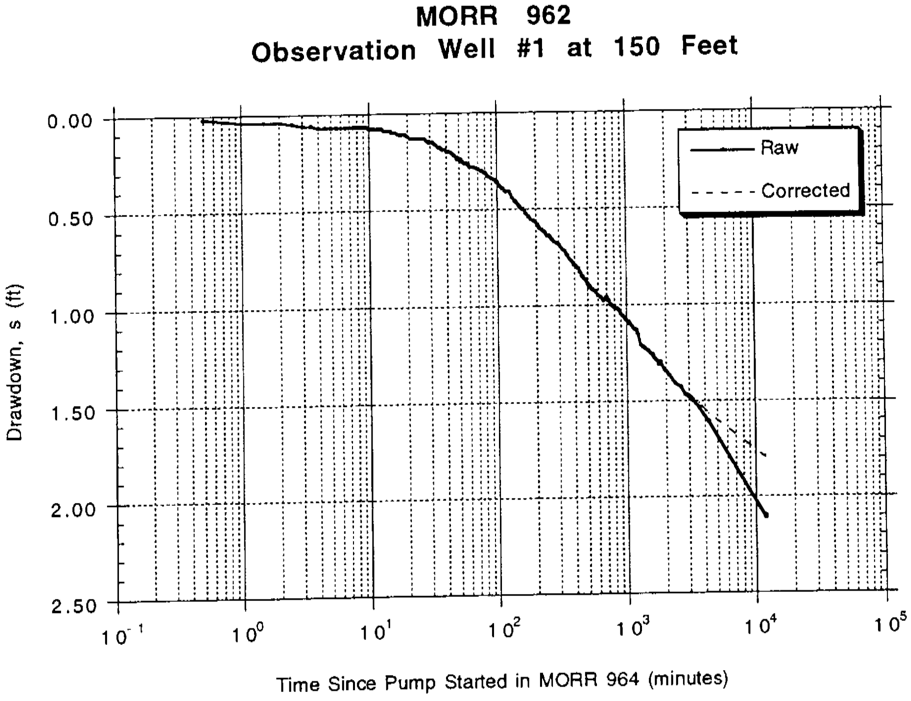


Figure 2C.6 Linear drawdown and recovery in nearby observation wells. A, MORR 962; B, MORR 963.



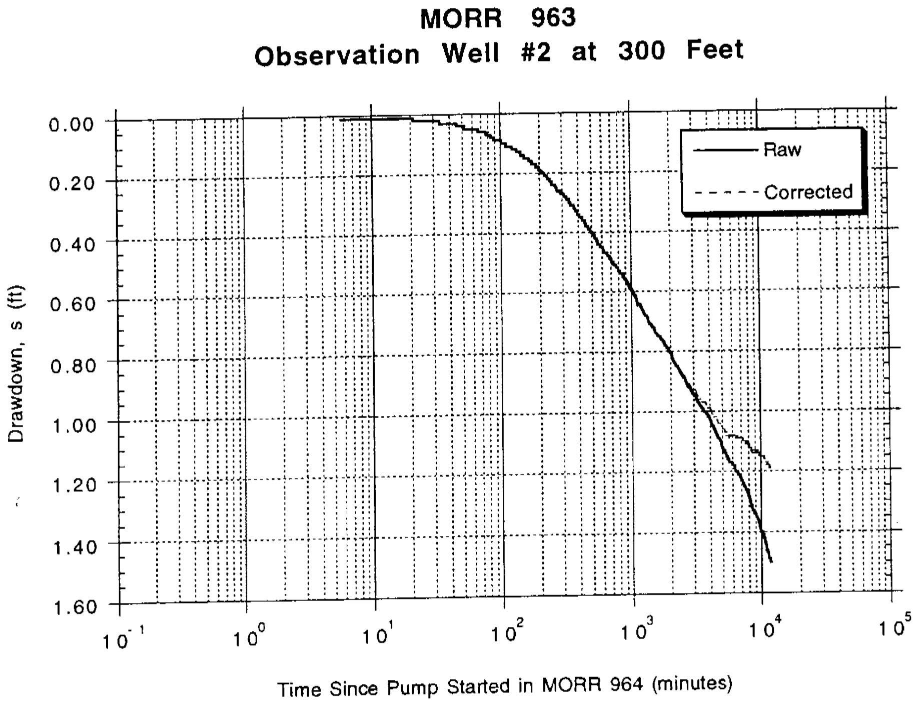


Figure 2C.7 Semi-log drawdown in nearby observation wells. A, MORR 962; B, MORR 963.

Appendix 3A

Nitrogen in Soil Background Discussion

and

General Soil Characteristics for the Lower Umatilla Basin

The Nitrogen Cycle

Introduction

The fate of nitrogen, either land applied or discharged to the subsurface, varies. That fate depends upon a relationship between land use and nitrogen input, output, and transformations. Discussions about the nitrogen cycle in soils and/or groundwater include Tisdale and Nelson (1975), Broadbent and Reisenauer (1986), Blackmer (1987), Follett (1989), Hallberg and Keeney (1993), and Overton (1993).

The Fate of Nitrogen in Soils

Figure 1 illustrates the fate of nitrogen in soils. Nitrogen can enter the soil from a variety of sources including:

- rainfall,
- biologic fixation,
- plant residue,
- fertilizers,
- application of animal and/or human waste, and
- application of industrial process waste containing nitrogen.

Nitrogen enters soil in various forms: organic, ammonium, nitrate, or nitrite (Blackmer 1987, Hallberg and Keeney, 1993). Once in the soil, the nitrogen becomes involved with complex interactive processes (mineralization, nitrification, immobilization, and denitrification). Oxidizing and reducing conditions (molecules gain or lose oxygen) and the availability of oxygen and carbon (Overton, 1993) affect these processes. Nitrogen escapes the soil via volatilization/gaseous loss to the atmosphere, plant harvest, runoff, or leaching/deep percolation (Hallberg and Keeney, 1993).

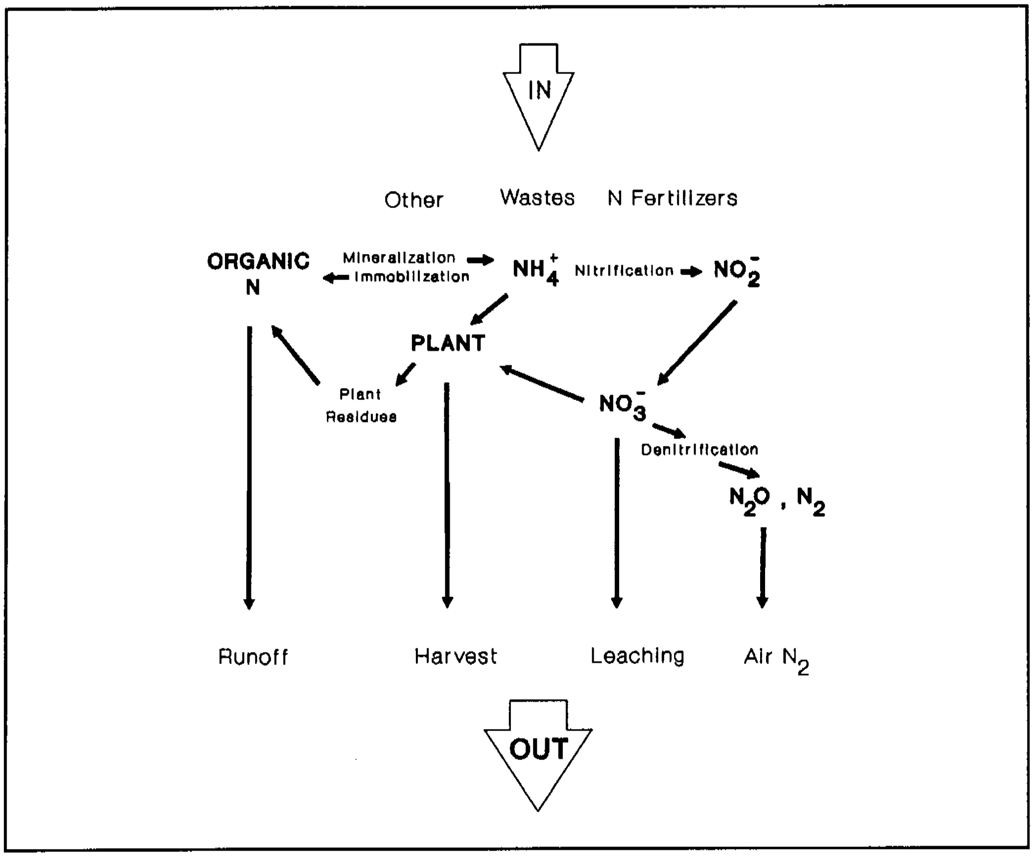


Figure 1 General nitrogen cycle.

Mineralization - Immobilization

The mineralization and immobilization processes determine if nitrogen will convert to another form (Hallberg and Keeney, 1993). Organic-nitrogen is the largest pool of nitrogen in the soil. Inorganic nitrogen (NH_4^+, NO_3^-, NO_2^-, N_20, NO and N_2) entering the soil system may enter the organic-nitrogen pool (immobilization), while forms of organic-nitrogen may exit the pool (mineralization) via conversion to inorganic or mineral nitrogen. These opposing processes occur simultaneously (Jansson and Persson, 1982).

Mineralization

Mineralization processes transform soil organic matter nitrogen into ammonium ions (NH_4) which are released to the soil (Overton, 1993). The transformation occurs through aminization and ammonification reactions (Tisdale and Nelson, 1975). Ammonium is relatively immobile in the soil because it strongly absorbs to clay minerals and organic matter. It can be carried away from a site via sediment or in solution (Overton, 1993). Ammonium readily converts into nitrate through nitrification reactions when soil temperatures generally exceed 48°F (Overton, 1993, Tisdale and Nelson, 1975).

Immobilization

Immobilization includes a variety of processes through which ammonium ions and nitrates convert to organic nitrogen and become immobilized in the soil. The conversion occurs when plants or microorganisms in the soil take up the ammonium and nitrate ions and transform the nitrogen into organic matter (Overton, 1993). This transformation makes the nitrogen unavailable to plants (Blackmer, 1987).

The C:N Ratio

The ratio of organic carbon and nitrogen (the C:N ratio) affects the direction of the mineralization-immobilization transformations (Hallberg and Keeney, 1993). Conversely, the net direction of the immobilization-mineralization transformations affect whether the organic matter content of a soil increases or decreases (Blackmer, 1987). Immobilization generally occurs during the decay of organic materials with a C:N ratio greater than 30. Mineralization generally occurs with a C:N ratio less than 20, and neither immobilization or mineralization may occur for C:N ratios between 20 and 30 (Tisdale and Nelson, 1975, Blackmer, 1987). Lower Umatilla Basin soils have a C:N ratio less than 20, which means the local soil conditions promote mineralization (Clough, 1994).

Nitrification

Nitrification is the oxidation of ammonium to nitrite (NO_2) and then to nitrate (NO_3). Autotrophic bacteria in the soil perform the nitrification which can occur rapidly if adequate soil moisture, temperature, and oxidizing conditions exist (Tisdale and Nelson, 1975, Hallberg and Keeney, 1993, Overton, 1993).

Nitrate is the form of nitrogen primarily absorbed by plants (Tisdale and Nelson, 1975). It is also the form of nitrogen most commonly related to water quality problems, because it is soluble and mobile in water. Nitrate escaping plants, microorganisms, and immobilization can readily leach through soils and deep percolate to groundwater (Goldberg, 1989, Overton, 1993). However, nitrate can readily be denitrified too.

Dentrification

Dentrification is the biology reduction of nitrate to nitrite and then to gaseous nitrogen (N_2) and nitrous oxide (N_2O) (Overton, 1993). It is an important pathway for nitrogen loss. Denitrification requires an anaerobic (lack of free oxygen) environment, and organic matter or reduced sulfur compounds (Hallberg and Keeney, 1993). Denitrification occurs when denitrifying bacteria use nitrate, nitrite, or nitrous oxide as an oxygen source under anaerobic conditions (Tisdale and Nelson, 1975, Hallberg and Keeney, 1993). The organic matter or reduced sulfur compounds are needed for energy and as a source of electrons (Hallberg and Keeney, 1993).

Chemical denitrification may occur involving the oxidation of ferrous iron also (Strebel and others, 1989). However, this reaction may require biological catalysis (acceleration or deceleration of a reaction) sulfide mineral oxidation (Pastma and others, 1991).

Soil Characteristics Relevant to Contaminant Transport

Introduction

Soil characteristics determine how nitrates move through the soil. These characteristics that influence contaminant transport include:

- soil texture,
- organic matter content cation exchange capacity,
- soil water content, soil structure,
- porosity, and
- hydraulic conductivity.

Soil Texture

Soil texture refers to the proportion of different size particles (usually sand, silt and clay) in a particular soil. The texture determines how a soil will absorb, store and transmit water as well as interact with solutes/chemicals in water (Donahue and others, 1977, Hillel, 1982). For example, sandy soils easily wet, but they also dry rapidly and easily lost plant nutrients.

Soils with high clay contents (more than 30 percent) are difficult to wet and drain, because the space between clay particles provides small spaces for water to flow (Donahue and others, 1977). Clay is also the most active soil component in physiochemical processes, because clay has the greatest specific surface area, most are negatively charged, and most form an electrostatic double layer with exchangeable cations. Conversely, silt and sand have relatively small specific surface areas and thus exhibit little physiochemical activity (Hillel, 1982).

Soil Organic Matter

Soil organic matter includes plant and animal residues at various stages of decomposition. A small percentage can modify the soils physical properties, and it can strongly affect the soil's chemical and biological properties (Donahue and others, 1977). For example, soil organic matter can influence the pH, the cation exchange capacity, and the maximum moisture retentive capacity of the soil

(Gerba and Bitton, 1984). These in turn can influence the mobility of some dissolved constituents as described below.

Cation Exchange Capacity.

All minerals have surfaces with small unbalanced electrical charges which attract water and ions in the water (Davis and DeWeist, 1966. Ion exchange occurs when the ions in solution replace ions already attracted/electrostatically attached to the solid surface. Sites available for this exchange occur primarily on clays and organic materials (Fetter, 1988, Davis and DeWeist, 1966). The exchange process is reversible, because ion exchange depends upon the difference between the relative size, electrostatic attraction and concentration of the ions present (Grim, 1953, Carroll, 1959, Hem, 1959).

Both cation (positive ion) and anion (negative ion) exchange can occur, because the surface charge may be positive or negative (Fetter, 1988, Hem, 1985). However, most rock and soil mineral surfaces have a negative rather than a positive electrical charge. One influence on the surface charge is the pH of the water solution (Hem, 1985). A high pH can make the surface charge strongly negative (Bitton, 1980a, 1980b). Another pH can neutralize the negatively charged surface sites (Hem, 1985).

The cation exchange capacity is a measure of the total number of negatively charged sites of which cations can adsorb or desorb for a given amount of solid (Hem, 1985). It is usually reported as milliequivalents per 100 grams of soil or other solid. This measurement provides an indication about the potential of a soil or another solid to attenuate contaminants with exchangeable ions (Fetter, 1988).

Soil Water Content

Soil Water Content is the amount of water contained in a unit mass or a unit volume of soil. It can be measured as mass wetness, volume wetness, or degree of saturation (Hillel, 1982). The water content can affect contaminant transport by influencing the mobility of water in the soil and the adsorption of constituents in solution to soil solid surfaces. The influence on water mobility is discussed in the following hydraulic conductivity section. The influence on adsorption occurs as follows. The adsorption of some constituents onto a solid medium increases as the water content decreases (Lance, 1984, Lance and Gerba 1984). This occurs because the constituents remain closer to the solid surface when a porous medium (like soil) becomes less saturated, which increases the opportunity for adsorption (Gerba and Bitton, 1984, Lance and Gerba, 1984). Conversely, increased water content decreases the opportunity of constituents to contact the solid surface (Bitton, 1980a). It can even cause desorption of attached constituents (Wellings and others, 1974).

Soil Structure

Soil Structure is the arrangement and organization of the particles in the soil (Hillel, 1982). The structure determines the total soil porosity (total open spaces) as well as the individual shape and size distribution of the soil pores. This in-turn affects the infiltration retention and transmission of water and air in the soil (Hillel, 1982, Donahue and others, 1977).

The soil particle arrangement and organization can be grouped into three broad categories: single grained, massive, and aggregated (Hillel, 1982). Single grained structure (also called structureless) refers to soil with completely unattached particles such as coarse grained soils and unconsolidated desert dust deposits. Massive structure refers to soil tightly packed into large cohesive blocks such as large blocks of dried clay. The aggregated (also called pod) soil structure is intermediate between the single grained and massive soil structure extremes (Hillel, 1982).

Porosity

Porosity measures pre volume (the volume not occupied by a solid) in the soil (Donahue and others, 1977; Hillel, 1982). The value generally ranges from 30 to 60 percent (Hillel, 1982).

Soil pores tend to be irregular in size, shape and direction (Donahue and others, 1977). Sands and other coarse-textured soils have large and continuous pores, but they often have less total porosity than fine-textured soils (Donahue and others, 1977, Hillel, 1982). Conversely, clayey soils have greater total porosity, but the small pore size restricts water movement and increases water retention (Donahue and others, 1977, Hillel, 1982). This influence on water movement directly affects the transport of contaminants dissolved in the water.

Hydraulic Conductivity

Hydraulic Conductivity (also known as the coefficient of permeability) is a number that expresses the ease with which a given fluid (like water) can move through a given porous substance such as soil (Freeze & Cherry, 1979, Bear, 1979). This in-turn affects how easily the fluid transports contaminants. The hydraulic conductivity value depends upon the solid media and fluid properties as well as the degree of saturation of the solid media (Freeze and Cherry, 1979, Bear, 1979, Hillel, 1982).

Solid media properties relevant to hydraulic conductivity include grain size and shape, total porosity, pore size distribution, pore tortuosity (direction variability), and relative surface area. Together, these properties are called the permeability or intrinsic permeability of the solid media (Bear, 1979). Sands and gravels often have high hydraulic conductivity values, because they have high permeability which allow water and other fluids to flow more easily. Conversely, clays and nearly solid rocks often have lower hydraulic conductivity values, because water and other fluids flow less easily through these less permeable solids (Freeze & Cherry, 1979).

Fluid properties become important whenever more than one fluid is considered. Fluid properties relevant to hydraulic conductivity are fluid density and viscosity (Bear, 1979). Fluids with higher densities (such as salt water relative to fresh water) and lower viscosity (such as hot versus cold molasses) flow more readily through solid media which yield higher hydraulic conductivity values (Freeze and Cherry, 1979).

The degree of saturation influences the hydraulic conductivity also. The hydraulic conductivity value increases and decreases with increasing and decreasing degrees of saturation respectively, (Hillel, 1982).

Lower Umatilla Basin Soil Characteristics

Table 3A.1 lists the general soil characteristics for the Lower Umatilla Basin. Soils in the Lower Umatilla Basin promote mineralization, which convert nitrogen to ammonium. This ammonium attaches to soil and then converts to nitrate in soil temperatures above 48 degrees Farenheit. The sandy soils also create a high potential for leaching, given enough moisture.

Nitrogen penetrates the root zone of some irrigated crop fields, but this can be prevented by timing water and nitrogen application to crop needs.

Table 3A.1 General soil characteristics for the Lower Umatilla Basin.

SOIL TEXTURE	PERMEABILITY	DEPTH	TYPICAL SERIE	TOTAL AVAILABLE WATER (INCHES)	AVAILABLE WATER (IN/FT)
Sand Fine sand	Rapid to excessive	Moderate	Winchester Quincy	2.5-4.5	0.7-0.8 1.0-1.3
Loamy fine sand Fine sandy loam	Rapid	Moderate	Adkins Quincy Quinton Sagehill Shano Koehler	2.0-10	1.7-2.0 1.0-1.3 0.7-1.0 2.2-2.4 2.2-2.4 1.0-1.2
Coarse silt loam	Moderate	Moderate	Shano Powder Pedigo	6.0-10	2.2-2.4 2.2-3.0 1.8-2.4

From Soil Surveys of Morrow County (1983) and Umatilla County (1988) Areas, OR. Soil Conservation Service.

Appendix 3B

Irrigated Agriculture

Nitrogen Possibly Applied
and
Possibly Leached

Table 3B.1 Range of nitrogen (total pounds) possibly land applied annually to agricultural crops within the Lower Umatilla Basin.

Period	Available Crop Acreage	Possible nitrogen application rates (pounds/acre)									
		50	100	150	200	250	300	350	400	450	500
1986-1992	179,880	8,994,000	17,988,000	26,982,000	35,976,000	44,970,000	53,964,000	62,958,000	71,952,000	80,946,000	89,940,000
1976-1985	171,181	8,559,050	17,118,100	25,677,150	34,236,200	42,795,250	51,354,300	59,913,350	68,472,400	77,031,450	85,590,500
1966-1975	141,243	7,062,150	14,124,300	21,186,450	28,248,600	35,310,750	42,372,900	49,435,050	56,497,200	63,559,350	70,621,500
1956-1965	85,488	4,274,400	8,548,800	12,823,200	17,097,600	21,372,000	25,646,400	29,920,800	34,195,200	38,469,600	42,744,000

See Table 3.3 in Chapter 3 for an explanation of how the available crop acreages were obtained.

Table 3B.2 Total pounds of nitrogen possibly lost annually to deep percolation if five percent of the total nitrogen applied in Table 3A.1 escapes to deep percolation.

Period	Available Crop Acreage	Possible nitrogen application rates (pounds/acre)									
		50	100	150	200	250	300	350	400	450	500
1986-1992	179,880	449,700	899,400	1,349,100	1,798,800	2,248,500	2,698,200	3,147,900	3,597,600	4,047,300	4,497,000
1976-1985	171,181	427,953	855,905	1,283,858	1,711,810	2,139,763	2,567,715	2,995,668	3,423,620	3,851,573	4,279,525
1966-1975	141,243	353,108	706,215	1,059,323	1,412,430	1,765,538	2,118,645	2,471,753	2,824,860	3,177,968	3,531,075
1956-1965	85,488	213,720	427,440	641,160	854,880	1,068,600	1,282,320	1,496,040	1,709,760	1,923,480	2,137,200

Values in this table are 5 percent of the possible total nitrogen loading values in Table 3A.1.

Table 3B.3 Total pounds of nitrogen possibly lost annually to deep percolation if 20 percent of the total nitrogen applied in Table 3A.1 escapes to deep percolation.

Period	Available Crop Acreage	Possible nitrogen application rates (pounds/acre)									
		50	100	150	200	250	300	350	400	450	500
1986-1992	179,880	1,798,800	13,597,600	25,396,400	37,195,200	8,994,000	10,792,800	12,591,600	14,390,400	16,189,200	17,988,000
1976-1985	171,181	1,711,810	13,423,620	25,135,430	36,847,240	8,559,050	10,270,860	11,982,670	13,694,480	15,406,290	17,118,100
1966-1975	141,243	1,412,430	12,824,860	24,237,290	25,649,720	7,062,150	8,474,580	9,887,010	11,299,440	12,711,870	14,124,300
1956-1965	85,488	854,880	1,709,760	12,564,640	13,419,520	4,274,400	5,129,280	5,984,160	6,839,040	7,693,920	8,548,800

Values in this table are 20 percent of the possible total nitrogen loading values in Table 3A.1.

Appendix 3C

Food Processing Industry

Land Application

Table 3C.1 Estimated nitrogen loading by Lower Umatilla Basin food processing industries for selected periods.

Period	Facility	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1977	Lamb Weston, Inc.	575	Nitrogen	pounds/acre	2,000	<1,000	-
	Port of Morrow	242	Nitrogen	pounds/acre-day	25	-	-
	A.E. Staley Mfg.	7.4	Nitrogen	pounds/acre	-	-	373
1981 - 1984	Lamb Weston, Inc (1982)	575	Nitrogen	pounds/acre	-	-	940
	Port of Morrow (1981)	842	Nitrogen	pounds/acre-day	7	-	-
	J.R. Simplot Co (1983-1984)	670	TKN	pounds/acre-year	1,354	-	794
	A.E. Staley Mfg (1983)	9.5	Nitrogen	pounds/acre	-	-	198
1985 - 1989	Lamb Weston, Inc. (1985)	784	Nitrogen	pounds/acre	1,202	162	785
	Port of Morrow (1987)	1,382	TKN	pounds/acre	-	-	772
	J.R. Simplot Co. (1986-1987)	615	TKN	pounds/acre-year	2,647	266	1,266
	A.E. Staley Mfg. (1989)	7.6	Nitrogen	pounds/acre	-	-	129
	Universal Frozen Food (1988)	16	TKN	pounds/acre	-	-	2,784
1991 - 1992	Hermiston Foods (1991)	250	Nitrogen	pounds/acre	-	-	169
	Lamb Weston, Inc. (1991-1992)	2,207	Nitrogen	pounds/acre-year	269	19	137
	Port of Morrow (1992)	2,833	TKN	pounds/acre	679	3	296
	J.R. Simplot Co. (1992)	1,941	TKN	pounds/acre	394	49	195
	A.E. Staley Mfg. (1992)	43	TKN	pounds/acre	-	-	272
	Universal Frozen Foods (1992)	218	TKN	pounds/acre	-	-	85

Note: Nitrogen loading tables for individual facilities follows.

Sources of Information and Data came from:

- DEQ files: 9584, 18702, 48780, 70590, and 81590
- Port of Morrow Reports (1990, 1992a, 1992b, 1992c, 1993)
- Barlow (1992)
- Ruby (1992, 1993)
- Barlow and Scott (1991a, 1991b)
- Columbia Sun, Inc., quarterly reports

Table 3C.2 Loading estimates for Hermiston Foods.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1990	Land Application Area (Standfield-Hermiston Cooridor)	125	Water	feet	-	-	4.00[a]
			Nitrogen	pounds/acre	-	-	337[a]
			Salt	pounds/acre	-	-	6611[a]
1991	Land Application Area (Standfield-Hermiston Corridor)	250	Water	feet	-	-	2.00[b]
			Nitrogen	pounds/acre	-	-	169[b]
			Salt	pounds/acre	-	-	3,306[b]

[a] Values obtained from Barlow and Scott (1991)

[b] Estimate assumes the same total volume of water and total mass of nitrogen and salt were land applied in 1991 as in 1990. The difference between 1991 and 1990 reflect distributing the water, nitrogen, and salt over 250 acres total rather than 125 acres.

Table 3C.3 Loading estimates for Lamb Weston, Incorporated.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1973 - 1977	North Site	320	Water	feet	-	-	-
			Nitrogen	pounds/acre-yr	2,500	1,400	-
1977	North Site	575	Water	feet	-	-	-
			Nitrogen	pounds/acre	2,000	< 1,000	-
1982	North Site	575	Water	feet	-	-	2.13
			Nitrogen	pounds/acre	-	-	940
1985	North Site	784	Water	feet	5.45	0.73	3.54
			Nitrogen	pounds/acre	1,202	162	785
1991 - 1992	North Site	737	Water	feet	1.42	0.58	0.92
			Nitrogen	pounds/acre-yr	190	30	96
	Madison Ranch	1,470	Water	feet	1.60	0.17	0.93
			Nitrogen	pounds/acre-yr	269	19	157

Values were obtained and calcualted from information and data in DEQ file 48780.

Table 3C.4 Loading estimates for the Port of Morrow.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1974 - 1980	North Site	242	Water (effluent)	feet	-	-	-
			Nitrogen	pounds/acre-day	25[a]	-	-
1981	North Site	842	Water (effluent)	feet	-	-	-
			Nitrogen	pounds/acre-day	7[a]	-	-
1986	North Site	1,281	Water	feet	-	-	2.49
			TKN	pounds/acre	-	-	773
1987	North Site	1,382	Water (effluent)	feet	-	-	2.25
			TKN	pounds/acre	-	-	772
1988	North Site	1,285	Water (effluent)	feet	-	-	1.85
			TKN	pounds/acre	-	-	742
1989	North Site	1,636	Water	feet	-	-	1.27
			TKN	pounds/acre	677	14	452
1990	North Site	1,665	Water	feet	-	-	1.80
			TKN	pounds/acre	-	-	521
1991	North Site	1,655	Water	feet	-	-	1.6
			TKN	pounds/acre	646	25	420
1992	North Site	1,655	Water	feet	-	-	-
			TKN	pounds/acre	679	112	471
	Carlson Farm	1,178	Water	feet	-	-	-
			TKN	pounds/acre	115	3	50

[a] Reported as pounds per acre-day rather than pounds per acre-year becuase the number of days of applicaiton was not found.

Values were obtained from information and data in DEQ file 70590 and Port of Morrow Report (1990, 1992a, 1992b, 1992c, 1993)

Table 3C.5 Loading estimates for the J.R. Simplot Company potato processing facility.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
Early 1980s	North Irrigation Area	?	Water	feet	-	-	-
			Nitrogen	pounds/acre-yr	>2,000	-	-
1983 - 1984	North (and Southeast) Irrigation Area	670	Water	feet	-	-	-
			TKN	pounds/acre-yr	1354	-	794
1984 - 1985	North (and Southeast ?) Irrigation Area	684	Water	feet	-	-	-
			TKN	pounds/acre-yr	1,900	-	757
1985 - 1986	North (and Southeast) Irrigaiton Area	618	Water	feet	-	-	-
			TKN	pounds/acre-yr	1,663	-	889
1986 - 1987	North Irrigation Area	199	Water	feet	-	-	-
			TKN	pounds/acre-yr	2,647	544	1,372
	South Central Irrigation Area	49	Water	feet	-	-	-
			TKN	pounds/acre-yr	414	266	338
	Southeast Irrigation Area	367	Water	feet	-	-	-
			TKN	pounds/acre-yr	1,627	1,099	1,333
1989	North Irrigation Area	199	Water	feet	-	-	-
			TKN	pounds/acre	1,366	346	913
	South Central Irrigation Area	24	Water	feet	-	-	-
			TKN	pounds/acre	120	120	120
	Southeast Irrigation Area	543	Water	feet	-	-	-
			TKN	pounds/acre	1,458	144	636
1990	North Irrigation Area	199	Water	feet	5.06	2.34	3.89
			TKN	pounds/acre	1,217	495	893
	South Central Irrigation Area	46	Water	feet	1.45	1.24	1.33
			TKN	pounds/acre	530	454	489
	Southeast Irrigation Area	543	Water	feet	4.63	0.57	3.32
			TKN	pounds/acre	1,306	256	804

1991	North Irrigation Area	201	Water	feet	7.24	2.61	5.21
			TKN	pounds/acre	1,239	245	921
	South Central Irrigation Area	46	Water	feet	-	-	-
			TKN	pounds/acre	365	309	335
	Southest Irrigation Area	557	Water	feet	-	-	-
			TKN	pounds/acre	1,443	107	863
	Southwest Irrigation Area	526	Water	feet	-	-	-
			TKN	pounds/acre	314	54	115
1992	North Irrigation Area	201	Water	feet	2.00	0.52	1.12
			TKN	pounds/acre	394	139	231
	Southeast Irrigation Area	557	Water	feet	-	-	-
			TKN	pounds/acre	387	124	263
	Southwest Irrigation Area	1,183	Water	feet	-	-	-
			TKN	pounds/acre	321	49	157

Values were obtained or calculated from information and data found in DEQ file 81590 as well as Barlow (1991), Ruby (1992), and Ruby (1993).

Table 3C.6 Loading estimates for the A.E. Staley Manufacturing Company.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1977	Plant Area	7.4	Water	feet	-	-	3.36
			Nitrogen	pounds/acre-day	-	-	373
1983	Plant Area	9.5	Water	feet	-	-	121
			Nitrogen	pounds/acre-day	-	-	198
1989	Plant Area	7.5	Water	feet	-	-	1.47
			Nitrogen	pounds/acre	-	-	129
1990	Plant Area	43	Water	feet	-	-	0.64
			Nitrogen	pounds/acre	708	188	296
			Salt	pounds/acre	29,634	6,890	15,912
1991	Plant Area	43	Water	feet	-	-	0.67
			TKN	pounds/acre	-	-	361
1992	Plant Area	43	Water	feet	-	-	0.61
			TKN	pounds/acre	-	-	272

Values were calculated from information obtained from DEQ file 9584 and Barlow and Scott (1991).

Table 3C.7 Loading estimates for the Universal Frozen Foods Company (formerly Columbia Sun, Inc.).

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1988	Plant Site	16	Water	feet	-	-	3.87
			TKN	pounds/acre	-	-	2,784
1991	Plant Site	22	Water	feet	2.76	2.55	2.64
			TKN	pounds/acre	3,039	740	1,849
1992	Plant Site	18	Water	feet	-	-	0.33
			TKN	pounds/acre	-	-	105
	New Site	200	Water	feet	-	-	2.11
			TKN	pounds/acre	-	-	83

Values were calculated by using information and data obtained from DEQ file 18702 including annual and quarterly reports from Columbia Sun, Inc. to DEQ.

Appendix 3D

Livestock

Nitrogen Produced and Land Applied

Table 3D.1 Estimated annual total nitrogen available for land application from selected animal operations in the Lower Umatilla Basin during the 1980s.

	Unit	Range	C & B Livestock, Inc.	J.R. Simplot Co.	Hillview Dairy	Hansell Brothers, Inc.	Total
Animal Type	-	-	Beef Cattle	Beef Cattle	Dairy Cattle	Hogs	-
Animal Population	Head	Minimum	12,000	-	-	12,000	-
		Average	18,500	20,000	200	13,500	-
		Maximum	25,000	-	-	15,000	-
		Capacity	25,000	32,000	400	20,000	-
Estimated Total Nitrogen Produced Annually	Pounds/Year	Minimum	1,018,350	-	-	124,830 to 308,790	-
		Average	1,569,956	1,697,250	24,638	140,434 to 347,389	3,432,278 to 3,639,233
		Maximum	2,121,563	-	-	156,038 to 385,988	-
		Capacity	2,121,563	2,715,600	49,275	208,050 to 514,650	5,094,488 to 5,401,088
Estimated Total Nitrogen Land Applied Annually	Pounds/Year	Minimum	229,129 to 529,542	-	-	28,087 to 69,478	-
		Average	353,240 to 816,377	398,379 to 863,153	5,543 to 5,913	31,598 to 78,163	788,760 to 1,763,606
		Maximum	477,352 to 1,103,213	-	-	35,108 to 86,847	-
		Capacity	477,352 to 1,103,213	637,406 to 1,381,046	11,087 to 11,826	46,811 to 115,796	1,172,656 to 2,611,881

Maximum Area Available for Land Application	Acres	Maximum	Undetermined	13,000	353	1,000	-
Recommended Annual Nitrogen Application Rate	Pounds/Year	-	-	300 to 450	-	-	-

Information Sources for Calculations: Oregon Department of Agriculture and U.S. Soil Conservation Service, 1989.
ODA Confined Animal Feeding Operation General Permit File: Facility Numbers 12903; 36630; 103222
DEQ File 81591
J-U-B Engineers, Inc. 1987, 1989

Appendix 3E

Municipal Sewage Treatment Facilities

Land Application
and
Infiltration

Table 3E.1 Loading estimates for the City of Boardman sewage treatment facility.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1986	Alfalfa	40	Water	feet	-	-	1.66
			Nitrogen	pounds/acre	-	-	49
1987	Alfalfa	40	Water	feet	-	-	2.68
			Nitrogen	pounds/acre	-	-	79
1988	Alfalfa	40	Water	feet	-	-	2.05
			Nitrogen	pounds/acre	-	-	61
1989	Alfalfa	40	Water	feet	-	-	1.26
			Nitrogen	pounds/acre	-	-	37
1990	Alfalfa	40	Water	feet	-	-	0.62
			Nitrogen	pounds/acre	-	-	18
1991	Alfalfa	40	Water	feet	-	-	0.0
			Nitrogen	pounds/acre	-	-	0.0
1992	Alfalfa	40	Water	feet	-	-	0.0
			Nitrogen	pounds/acre	-	-	0.0
1993	Poplar Trees	10	Water	feet	-	-	2.22
			Nitrogen	pounds/acre-yr	-	-	69

Values were derived from data provided by Beyeler (1993).

Table 3E.2 Loading estimates for the City of Echo sewage treatment facility.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1983[a]	Sewage Treatment Lagoons	6.55	Water	feet	-	-	7.70
			Nitrogen	pounds/acre	-	-	194
1985	Sludge Application Area 3N/29E-section 9 Tax Lot 2900	54.5?	Water	feet	-	-	[b]
			Nitrogen	pounds/acre	-	-	[b]

[a] The City of Echo sewage treatment facility lagoons lost approximately 85 percent of the influent to seepage to the subsurface from 1976 to July 1985 (DEQ file 26200). Seepage data, if any, after the 1985 repairs was not found.

[b] Lagoon sludge was land applied in 1985 for lagoon repair purposes. The amount of sludge land applied was not found.

Values were derived using lagoon data from DEQ file 26200 and by using lagoon effluent nitrogen concentrations from the City of Boardman. Lagoon effluent nitrogen concentrations for the City of Echo facility was not found.

Table 3E.3 Loading estimates for the City of Hermiston sewage treatment facility land application areas.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1992	Poplar Tree	11	Nitrogen	pounds/acre	-	-	139
	Wadekamper Ranch	125	Nitrogen	pounds/acre	-	-	6
	Wadekamper Ranch Extension	25	Nitrogen	pounds/acre	-	-	48

Values were calculated from data provided by the DEQ Pendleton Office staff.

Table 3E.4 Loading to the subsurface estimates for the City of Irrigon sewage treatment facility infiltration beds.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1989	Infiltration Beds	2	Water	feet	-	-	4.16
			Nitrogen	pounds/acre	-	-	199
1990	Infiltration Beds	2	Water	feet	-	-	39.25
			Nitrogen	pounds/acre	-	-	2,231
1991	Infiltration Beds	2	Water	feet	-	-	48.75
			Nitrogen	pounds/acre	-	-	3,811
1992	Infiltration Beds	2	Water	feet	-	-	55.22
			Nitrogen	pounds/acre	-	-	4,550
Values were calculated by using data from DEQ file 42490 and SCM Consultants, Inc. (1990)							

Table 3E.5 Loading estimates for the City of Stanfield sewage treatment facility sludge land application area.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1993	Sludge Land Application Area	48	Nitrogen	pounds/acre	-	-	16
Values were calculated from data provided by the DEQ Pendleton Office staff.							

Table 3E.6 Loading estimates for the City of Umatilla sewage treatment facility sludge land application areas.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
Historic	Historic Sludge Land Application Area	80	Nitrogen	pounds/acre	-	-	20
1992	Current Sludge Land Application Area West of the Cemetary	7.7	Nitrogen	pounds/acre	-	-	212

Values were calculated using information provided by the City of Umatilla and data provided by the DEQ Pendleton Office Staff.

Table 3E.7 Loading estimates for the City of Portland land application of sewage sludge.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1992	Madison Ranch	1809	Nitrogen	pounds/acre	-	-	75

Values were obtained from information provided by DEQ Northwest Regional Staff in Portland.

Table 3E.8 Loading estimates for the Unified Sewerage Agency, Washington County.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1993	Madison Ranch	630[a]	Nitrogen	pounds/acre	-	-	[b]

[a] Source: Richwine (1994)

[b] Land application began in September 1993. Nitrogen loading data was not obtained.

Appendix 3F

Large On-Site Sewage Systems

Infiltration

Table 3F.1 Loading estimates for the Hinkle Railroad Inn (Hinkle Hotel).

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1978 - Present	Drainfield	2.41	Water	feet	5.07	-	-
			Nitrate-N	pounds/acre	551	-	-

Values were calculated by using the maximum allowable discharge noted in Water Pollution Control Facilities Permit Number 100195 (DEQ file 100132) and using an average nitrate-nitrogen concentration of 40 mg/l for septic tank effluent percolating to groundwater. The 40 mg/l average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne and others, 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Table 3F.2 Loading estimates for the Oregon Department of Transportation Boardman Rest Area.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1977 - 1992	Land Application Area	5	Water	feet	-	-	0.0
			Nitrogen	pounds/acre	-	-	0.0
1993	Land Application Area Cemetery	5	Water	feet	-	-	0.46
			Nitrogen	pounds/acre	-	-	60

Values were calculated from data provided by the DEQ Pendleton Office Staff.

Table 3F.3 Loading estimates for the Oregon Department of Transportation Stanfield Rest Area.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1991	West Bound Rest Area Drainfield	0.165	Water	feet	-	-	7.73
			Nitrate-N	pounds total	-	-	139
1991	East Bound Rest Area Drainfield	0.165	Water	feet	-	-	7.73
			Nitrate-N	pounds total	-	-	139
1993	West Bound Rest Area Drainfield	0.165	Water	feet	-	-	13.55
			Nitrate-N	pounds total	-	-	244
1993	East Bound Rest Area Drainfield	20.165	Water	feet	-	-	13.55
			Nitrate-N	pounds total	-	-	244

Values were calculated from data obtained from Buchsler and Hansen (1990), DEQ file 105049, and Joleen Odens (1994) and using an average nitrate-nitrogen of 40 mg/l for septic tank effluent percolating to groundwater. The 40 mg/l average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne and others, 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Table 3F.4 Loading estimates for the Shady Rest Mobile Home Park.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1991	Bottomless Sand Filter	0.19	Water	feet	-	-	20.86
			Nitrate-N	pounds total	-	-	441

Values were calculated by using data from DEQ file 103745 and by using an average nitrate-nitrogen concentration of 40 mg/l for septic tank effluent percolating to groundwater. The 40 mg/l average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne and others, 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Table 3F.5 Loading estimates for the US Army Umatilla Activity Administration Area sewage facility.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1985	Drainfield	0.23	Water	feet	-	-	5.89
			Nitrate-N	pounds total	-	-	2,627
1986	Drainfield	0.23	Water	feet	-	-	7.01
			Nitrate-N	pounds total	-	-	3,126
1987	Drainfield	0.23	Water	feet	-	-	6.23
			Nitrate-N	pounds total	-	-	2,780
1988	Drainfield	0.23	Water	feet	-	-	5.94
			Nitrate-N	pounds total	-	-	2,652
1989	Drainfield	0.23	Water	feet	-	-	5.68
			Nitrate-N	pounds total	-	-	2,536
1990	Drainfield	0.23	Water	feet	-	-	5.56
			Nitrate-N	pounds total	-	-	2,483

Values were calculated by using data from DEQ file 91000 and by using an average nitrate-nitrogen concentration of 40 mg/l for septic tank effluent percolating to groundwater. The 40 mg/l average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne and others, 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Table 3F.6 Loading estimates for the Vista Park Mobile Home Park.

Year	Loading Area	Acres	Constituent	Units	Estimated Loading		
					Max	Min	Average
1986	Drainfield	4.13	Water	feet	-	-	6.91
			Nitrate-N	pounds/acre	-	-	752

Values were calculated by using data from DEQ file 100128, field observation of the drainfield area size, and by using an average nitrate-nitrogen concentration of 40 mg/l for septic tank effluent percolating to groundwater. The 40 mg/l average nitrate-nitrogen concentration was derived from EPA (1980) and DEQ (Ronayne and others, 1982) literature as well as recent work conducted by DEQ employee Henning Larson.

Appendix 3G

Individual On-Site Sewage Systems

Infiltration

Table 3G.1 Loading estimates for individual on-site sewage systems by square mile sections.

LOWER UMATILLA BASIN GROUNDWATER MANAGEMENT AREA
Source Identification: Septic System Distribution
Morrow and Umatilla Counties

T = Township (north)
R = Range (east)
S = Section

H/MH = Home/Mobile Home
PP = Public Places (Churches, Schools, Parks, Public Buildings)
B/S/I = Business/Shop/Industry
T LOAD = Total Annual Nitrate-nitrogen Loading

T	R	S	H/MH	PP	B/S/I	TOTAL	T LOAD
3	23	1	0	0	0	0	0.00
3	23	2	0	0	0	0	0.00
3	23	3	1	0	0	1	25.86
3	23	4	0	0	0	0	0.00
3	23	5	0	0	0	0	0.00
3	23	6	0	0	0	0	0.00
3	23	7	0	0	0	0	0.00
3	23	8	0	0	0	0	0.00
3	23	9	0	0	3	3	77.59
3	23	10	0	0	0	0	0.00
3	23	11	0	0	0	0	0.00
3	23	12	0	0	0	0	0.00
3	23	13	0	0	0	0	0.00
3	23	14	0	0	0	0	0.00
3	23	15	0	0	0	0	0.00
3	23	16	0	0	0	0	0.00
3	23	17	0	0	0	0	0.00
3	23	18	0	0	0	0	0.00
3	23	19	0	0	0	0	0.00
3	23	20	0	0	0	0	0.00
3	23	21	0	0	0	0	0.00
3	23	22	0	0	0	0	0.00
3	23	23	0	0	0	0	0.00

3	23	24	2	0	0	2	51.73
3	23	25	1	0	2	3	77.59
3	23	26	0	0	0	0	0.00
3	23	27	0	0	0	0	0.00
3	23	28	0	0	0	0	0.00
3	23	29	0	0	0	0	0.00
3	23	30	0	0	0	0	0.00
3	23	31	0	0	0	0	0.00
3	23	32	0	0	0	0	0.00
3	23	33	0	0	0	0	0.00
3	23	34	0	0	0	0	0.00
3	23	35	0	0	0	0	0.00
3	23	36	0	0	0	0	0.00
4	23	1	0	0	0	0	0.00
4	23	2	0	0	0	0	0.00
4	23	3	0	0	0	0	0.00
4	23	4	0	0	0	0	0.00
4	23	5	0	0	0	0	0.00
4	23	6	0	0	0	0	0.00
4	23	7	0	0	0	0	0.00
4	23	8	0	0	0	0	0.00
4	23	9	0	0	0	0	0.00
4	23	10	0	0	0	0	0.00
4	23	11	0	0	0	0	0.00
4	23	12	0	0	0	0	0.00
4	23	13	0	0	0	0	0.00
4	23	14	0	0	0	0	0.00
4	23	15	0	0	0	0	0.00
4	23	16	0	0	0	0	0.00
4	23	17	0	0	0	0	0.00
4	23	18	0	0	0	0	0.00
4	23	19	0	0	0	0	0.00
4	23	20	0	0	0	0	0.00

4	23	21	0	0	0	0	0.00
4	23	22	0	0	0	0	0.00
4	23	23	1	0	0	1	25.86
4	23	24	0	0	0	0	0.00
4	23	25	1	0	0	1	25.86
4	23	26	1	0	0	1	25.86
4	23	27	0	0	0	0	0.00
4	23	28	0	0	0	0	0.00
4	23	29	0	0	0	0	0.00
4	23	30	0	0	0	0	0.00
4	23	31	0	0	0	0	0.00
4	23	32	0	0	0	0	0.00
4	23	33	0	0	0	0	0.00
4	23	34	0	0	0	0	0.00
4	23	35	3	0	0	3	77.59
4	23	36	1	0	0	1	25.86
3	24	1	0	0	0	0	0.00
3	24	2	0	0	0	0	0.00
3	24	3	0	0	0	0	0.00
3	24	4	0	0	0	0	0.00
3	24	5	0	0	0	0	0.00
3	24	6	0	0	0	0	0.00
3	24	7	0	0	0	0	0.00
3	24	8	0	0	0	0	0.00
3	24	9	0	0	0	0	0.00
3	24	10	0	0	0	0	0.00
3	24	11	0	0	0	0	0.00
3	24	12	0	0	0	0	0.00
3	24	13	0	0	0	0	0.00
3	24	14	0	0	0	0	0.00
3	24	15	0	0	0	0	0.00
3	24	16	0	0	0	0	0.00
3	24	17	0	0	0	0	0.00

3	24	18	0	0	0	0	0.00
3	24	19	0	0	0	0	0.00
3	24	20	0	0	0	0	0.00
3	24	21	0	0	0	0	0.00
3	24	22	0	0	0	0	0.00
3	24	23	0	0	1	1	25.86
3	24	24	0	0	0	0	0.00
3	24	25	0	0	0	0	0.00
3	24	26	0	0	0	0	0.00
3	24	27	0	0	0	0	0.00
3	24	28	0	0	0	0	0.00
3	24	29	0	0	0	0	0.00
3	24	30	0	0	0	0	0.00
3	24	31	0	0	0	0	0.00
3	24	32	0	0	0	0	0.00
3	24	33	0	0	0	0	0.00
3	24	34	0	0	1	1	25.86
3	24	35	0	0	0	0	0.00
3	24	36	0	0	0	0	0.00
4	24	1	0	0	0	0	0.00
4	24	2	0	0	0	0	0.00
4	24	3	0	0	0	0	0.00
4	24	4	0	0	0	0	0.00
4	24	5	0	0	0	0	0.00
4	24	6	0	0	0	0	0.00
4	24	7	0	0	0	0	0.00
4	24	8	0	0	0	0	0.00
4	24	9	0	0	0	0	0.00
4	24	10	0	0	0	0	0.00
4	24	11	0	0	0	0	0.00
4	24	12	0	0	0	0	0.00
4	24	13	19	0	0	19	491.42
4	24	14	5	0	0	5	129.32

4	24	15	0	0	2	2	51.73
4	24	16	0	0	0	0	0.00
4	24	17	0	0	0	0	0.00
4	24	18	0	0	0	0	0.00
4	24	19	0	0	0	0	0.00
4	24	20	0	0	0	0	0.00
4	24	21	3	0	0	3	77.59
4	24	22	0	0	0	0	0.00
4	24	23	9	0	0	9	232.78
4	24	24	15	0	0	15	387.97
4	24	25	0	0	0	0	0.00
4	24	26	0	0	0	0	0.00
4	24	27	0	0	0	0	0.00
4	24	28	0	0	0	0	0.00
4	24	29	0	0	0	0	0.00
4	24	30	0	0	0	0	0.00
4	24	31	0	0	0	0	0.00
4	24	32	0	0	0	0	0.00
4	24	33	0	0	0	0	0.00
4	24	34	0	0	0	0	0.00
4	24	35	0	0	0	0	0.00
4	24	36	0	0	0	0	0.00
3	25	1	0	0	0	0	0.00
3	25	2	0	0	0	0	0.00
3	25	3	0	0	0	0	0.00
3	25	4	0	0	0	0	0.00
3	25	5	0	0	0	0	0.00
3	25	6	0	0	0	0	0.00
3	25	7	0	0	0	0	0.00
3	25	8	0	0	0	0	0.00
3	25	9	0	0	0	0	0.00
3	25	10	0	0	0	0	0.00
3	25	11	0	0	0	0	0.00

3	25	12	0	0	0	0	0.00
3	25	13	0	0	0	0	0.00
3	25	14	0	0	0	0	0.00
3	25	15	0	0	0	0	0.00
3	25	16	0	0	0	0	0.00
3	25	17	0	0	0	0	0.00
3	25	18	0	0	0	0	0.00
3	25	19	0	0	0	0	0.00
3	25	20	0	0	0	0	0.00
3	25	21	0	0	0	0	0.00
3	25	22	0	0	0	0	0.00
3	25	23	0	0	0	0	0.00
3	25	24	0	0	0	0	0.00
3	25	25	0	0	0	0	0.00
3	25	26	0	0	0	0	0.00
3	25	27	0	0	0	0	0.00
3	25	28	0	0	0	0	0.00
3	25	29	0	0	0	0	0.00
3	25	30	0	0	0	0	0.00
3	25	31	0	0	0	0	0.00
3	25	32	0	0	0	0	0.00
3	25	33	0	0	0	0	0.00
3	25	34	0	0	0	0	0.00
3	25	35	0	0	0	0	0.00
3	25	36	0	0	0	0	0.00
4	25	1	2	0	0	2	51.73
4	25	2	6	0	1	7	181.05
4	25	3	0	1	1	2	51.73
4	25	4	0	2	2	4	103.46
4	25	5	0	0	0	0	0.00
4	25	6	0	0	0	0	0.00
4	25	7	0	0	0	0	0.00
4	25	8	0	0	0	0	0.00

4	25	9	1	0	0	1	25.86
4	25	10	7	0	0	7	181.05
4	25	11	9	0	2	11	284.51
4	25	12	2	0	0	2	51.73
4	25	13	9	0	0	9	232.78
4	25	14	40	0	0	40	1034.58
4	25	15	23	0	0	23	594.88
4	25	16	27	1	1	29	750.07
4	25	17	13	0	2	15	387.97
4	25	18	16	0	0	16	413.83
4	25	19	2	0	0	2	51.73
4	25	20	69	0	0	69	1784.64
4	25	21	4	0	0	4	103.46
4	25	22	2	0	0	2	51.73
4	25	23	1	0	0	1	25.86
4	25	24	0	0	0	0	0.00
4	25	25	0	0	0	0	0.00
4	25	26	0	0	0	0	0.00
4	25	27	0	0	0	0	0.00
4	25	28	0	0	0	0	0.00
4	25	29	0	0	0	0	0.00
4	25	30	0	0	0	0	0.00
4	25	31	0	0	0	0	0.00
4	25	32	0	0	0	0	0.00
4	25	33	0	0	0	0	0.00
4	25	34	0	0	0	0	0.00
4	25	35	0	0	0	0	0.00
4	25	36	0	0	0	0	0.00
5	25	1	0	0	0	0	0.00
5	25	2	0	0	0	0	0.00
5	25	3	0	0	0	0	0.00
5	25	4	0	0	0	0	0.00
5	25	5	0	0	0	0	0.00

5	25	6	0	0	0	0	0.00
5	25	7	0	0	0	0	0.00
5	25	8	0	0	0	0	0.00
5	25	9	0	0	0	0	0.00
5	25	10	0	0	0	0	0.00
5	25	11	0	0	0	0	0.00
5	25	12	0	0	0	0	0.00
5	25	13	0	0	0	0	0.00
5	25	14	0	0	0	0	0.00
5	25	15	0	0	0	0	0.00
5	25	16	0	0	0	0	0.00
5	25	17	0	0	0	0	0.00
5	25	18	0	0	0	0	0.00
5	25	19	0	0	0	0	0.00
5	25	20	0	0	0	0	0.00
5	25	21	0	0	0	0	0.00
5	25	22	0	0	0	0	0.00
5	25	23	0	0	0	0	0.00
5	25	24	0	0	0	0	0.00
5	25	25	0	0	0	0	0.00
5	25	26	0	0	0	0	0.00
5	25	27	0	0	0	0	0.00
5	25	28	0	0	0	0	0.00
5	25	29	0	0	0	0	0.00
5	25	30	0	0	0	0	0.00
5	25	31	0	0	0	0	0.00
5	25	32	0	0	0	0	0.00
5	25	33	0	0	0	0	0.00
5	25	34	0	0	0	0	0.00
5	25	35	0	0	0	0	0.00
5	25	36	0	0	0	0	0.00
3	26	1	0	0	0	0	0.00
3	26	2	0	0	0	0	0.00

3	26	3	0	0	0	0	0.00
3	26	4	2	0	0	2	51.73
3	26	5	0	0	0	0	0.00
3	26	6	1	0	0	1	25.86
3	26	7	0	0	0	0	0.00
3	26	8	1	0	0	1	25.86
3	26	9	2	0	0	2	51.73
3	26	10	4	0	0	4	103.46
3	26	11	0	0	0	0	0.00
3	26	12	1	0	0	1	25.86
3	26	13	0	0	0	0	0.00
3	26	14	1	0	0	1	25.86
3	26	15	1	0	0	1	25.86
3	26	16	0	0	0	0	0.00
3	26	17	1	0	0	1	25.86
3	26	18	0	0	0	0	0.00
3	26	19	0	0	0	0	0.00
3	26	20	0	0	0	0	0.00
3	26	21	0	0	0	0	0.00
3	26	22	0	0	0	0	0.00
3	26	23	0	0	0	0	0.00
3	26	24	0	0	0	0	0.00
3	26	25	0	0	0	0	0.00
3	26	26	0	0	0	0	0.00
3	26	27	1	0	0	1	25.86
3	26	28	0	0	0	0	0.00
3	26	29	0	0	0	0	0.00
3	26	30	1	0	0	1	25.86
3	26	31	0	0	0	0	0.00
3	26	32	0	0	0	0	0.00
3	26	33	0	0	0	0	0.00
3	26	34	0	0	0	0	0.00
3	26	35	0	0	0	0	0.00

3	26	36	0	0	0	0	0.00
4	26	1	2	0	0	2	51.73
4	26	2	3	0	0	3	77.59
4	26	3	6	0	2	8	206.92
4	26	4	1	0	0	1	25.86
4	26	5	0	0	1	1	25.86
4	26	6	0	0	1	1	25.86
4	26	7	1	0	0	1	25.86
4	26	8	0	0	0	0	0.00
4	26	9	0	0	0	0	0.00
4	26	10	0	0	1	1	25.86
4	26	11	1	0	0	1	25.86
4	26	12	0	0	0	0	0.00
4	26	13	0	0	0	0	0.00
4	26	14	0	0	1	1	25.86
4	26	15	0	0	5	5	129.32
4	26	16	0	0	2	2	51.73
4	26	17	0	0	1	1	25.86
4	26	18	0	0	0	0	0.00
4	26	19	0	0	0	0	0.00
4	26	20	0	0	0	0	0.00
4	26	21	2	0	0	2	51.73
4	26	22	2	0	0	2	51.73
4	26	23	1	0	0	1	25.86
4	26	24	0	0	0	0	0.00
4	26	25	0	0	0	0	0.00
4	26	26	0	0	0	0	0.00
4	26	27	2	0	0	2	51.73
4	26	28	1	0	0	1	25.86
4	26	29	0	0	0	0	0.00
4	26	30	0	0	0	0	0.00
4	26	31	0	0	0	0	0.00
4	26	32	0	0	0	0	0.00

4	26	33	1	0	0	1	25.86
4	26	34	0	0	0	0	0.00
4	26	35	0	0	0	0	0.00
4	26	36	1	0	0	1	25.86
5	26	1	0	0	0	0	0.00
5	26	2	0	0	0	0	0.00
5	26	3	0	0	0	0	0.00
5	26	4	0	0	0	0	0.00
5	26	5	0	0	0	0	0.00
5	26	6	0	0	0	0	0.00
5	26	7	0	0	0	0	0.00
5	26	8	0	0	0	0	0.00
5	26	9	0	0	0	0	0.00
5	26	10	0	0	0	0	0.00
5	26	11	0	0	0	0	0.00
5	26	12	0	0	0	0	0.00
5	26	13	0	0	0	0	0.00
5	26	14	0	0	0	0	0.00
5	26	15	6	0	2	8	206.92
5	26	16	0	0	2	2	51.73
5	26	17	0	0	0	0	0.00
5	26	18	0	0	0	0	0.00
5	26	19	0	0	0	0	0.00
5	26	20	0	0	0	0	0.00
5	26	21	0	0	0	0	0.00
5	26	22	19	0	0	19	491.42
5	26	23	100	1	0	101	2612.30
5	26	24	36	0	0	36	931.12
5	26	25	113	0	1	114	2948.54
5	26	26	23	0	0	23	594.88
5	26	27	5	0	0	5	129.32
5	26	28	0	0	0	0	0.00
5	26	29	0	0	0	0	0.00

5	26	30	0	0	0	0	0.00
5	26	31	0	0	0	0	0.00
5	26	32	0	0	0	0	0.00
5	26	33	2	0	0	2	51.73
5	26	34	3	0	0	3	77.59
5	26	35	31	0	0	31	801.80
5	26	36	81	0	0	81	2095.02
3	27	1	3	0	0	3	77.59
3	27	2	5	0	0	5	129.32
3	27	3	4	0	1	5	129.32
3	27	4	5	0	0	5	129.32
3	27	5	2	0	0	2	51.73
3	27	6	1	0	0	1	25.86
3	27	7	0	0	0	0	0.00
3	27	8	2	0	0	2	51.73
3	27	9	1	0	0	1	25.86
3	27	10	0	0	0	0	0.00
3	27	11	0	0	0	0	0.00
3	27	12	0	0	0	0	0.00
3	27	13	0	0	0	0	0.00
3	27	14	0	0	0	0	0.00
3	27	15	0	0	0	0	0.00
3	27	16	0	0	0	0	0.00
3	27	17	0	0	0	0	0.00
3	27	18	0	0	0	0	0.00
3	27	19	1	0	0	1	25.86
3	27	20	0	0	0	0	0.00
3	27	21	0	0	0	0	0.00
3	27	22	0	0	0	0	0.00
3	27	23	0	0	0	0	0.00
3	27	24	0	0	0	0	0.00
3	27	25	1	0	0	1	25.86
3	27	26	1	0	0	1	25.86

3	27	27	0	0	0	0	0.00
3	27	28	0	0	0	0	0.00
3	27	29	0	0	0	0	0.00
3	27	30	0	0	0	0	0.00
3	27	31	0	0	0	0	0.00
3	27	32	0	0	0	0	0.00
3	27	33	0	0	0	0	0.00
3	27	34	0	0	0	0	0.00
3	27	35	0	0	0	0	0.00
3	27	36	2	0	0	2	51.73
4	27	1	0	0	0	0	0.00
4	27	2	2	0	0	2	51.73
4	27	3	4	0	0	4	103.46
4	27	4	0	0	0	0	0.00
4	27	5	0	0	0	0	0.00
4	27	6	0	0	0	0	0.00
4	27	7	0	0	0	0	0.00
4	27	8	0	0	0	0	0.00
4	27	9	0	0	0	0	0.00
4	27	10	0	0	0	0	0.00
4	27	11	0	0	0	0	0.00
4	27	12	1	0	0	1	25.86
4	27	13	4	0	0	4	103.46
4	27	14	0	0	0	0	0.00
4	27	15	0	0	0	0	0.00
4	27	16	0	0	0	0	0.00
4	27	17	0	0	0	0	0.00
4	27	18	0	0	0	0	0.00
4	27	19	0	0	0	0	0.00
4	27	20	12	0	0	12	310.37
4	27	21	0	0	0	0	0.00
4	27	22	15	2	0	17	439.69
4	27	23	0	0	0	0	0.00

4	27	24	0	0	0	0	0.00
4	27	25	6	0	6	12	310.37
4	27	26	0	0	0	0	0.00
4	27	27	20	0	0	20	517.29
4	27	28	4	0	0	4	103.46
4	27	29	0	0	0	0	0.00
4	27	30	2	0	0	2	51.73
4	27	31	1	0	0	1	25.86
4	27	32	3	0	0	3	77.59
4	27	33	5	0	0	5	129.32
4	27	34	5	0	1	6	155.19
4	27	35	0	0	0	0	0.00
4	27	36	2	0	1	3	77.59
5	27	1	0	0	0	0	0.00
5	27	2	0	0	0	0	0.00
5	27	3	0	0	0	0	0.00
5	27	4	0	0	0	0	0.00
5	27	5	0	0	0	0	0.00
5	27	6	0	0	0	0	0.00
5	27	7	0	0	0	0	0.00
5	27	8	0	0	0	0	0.00
5	27	9	0	0	0	0	0.00
5	27	10	0	0	0	0	0.00
5	27	11	0	0	0	0	0.00
5	27	12	0	0	0	0	0.00
5	27	13	54	0	0	54	1396.68
5	27	14	34	0	1	35	905.25
5	27	15	0	0	0	0	0.00
5	27	16	1	0	0	1	25.86
5	27	17	0	0	0	0	0.00
5	27	18	0	0	0	0	0.00
5	27	19	5	0	1	6	155.19
5	27	20	10	0	0	10	258.64

5	27	21	31	0	0	31	801.80
5	27	22	13	0	2	15	387.97
5	27	23	16	0	0	16	413.83
5	27	24	2	0	0	2	51.73
5	27	25	1	0	0	1	25.86
5	27	26	0	0	0	0	0.00
5	27	27	0	0	0	0	0.00
5	27	28	1	0	0	1	25.86
5	27	29	1	0	0	1	25.86
5	27	30	18	0	0	18	465.56
5	27	31	2	0	0	2	51.73
5	27	32	0	0	0	0	0.00
5	27	33	0	0	0	0	0.00
5	27	34	0	0	0	0	0.00
5	27	35	0	0	0	0	0.00
5	27	36	0	0	0	0	0.00
3	28	1	0	0	0	0	0.00
3	28	2	0	0	0	0	0.00
3	28	3	0	0	0	0	0.00
3	28	4	0	0	0	0	0.00
3	28	5	5	0	2	7	181.05
3	28	6	0	0	0	0	0.00
3	28	7	0	0	0	0	0.00
3	28	8	3	0	0	3	77.59
3	28	9	0	0	0	0	0.00
3	28	10	0	0	0	0	0.00
3	28	11	6	0	0	6	155.19
3	28	12	3	0	0	3	77.59
3	28	13	0	0	0	0	0.00
3	28	14	3	0	0	3	77.59
3	28	15	0	0	0	0	0.00
3	28	16	0	0	0	0	0.00
3	28	17	1	0	0	1	25.86

3	28	18	0	0	0	0	0.00
3	28	19	2	0	0	2	51.73
3	28	20	0	0	0	0	0.00
3	28	21	0	0	0	0	0.00
3	28	22	0	0	0	0	0.00
3	28	23	1	0	1	2	51.73
3	28	24	0	0	0	0	0.00
3	28	25	0	0	0	0	0.00
3	28	26	0	0	0	0	0.00
3	28	27	0	0	0	0	0.00
3	28	28	3	0	0	3	77.59
3	28	29	0	0	0	0	0.00
3	28	30	4	0	0	4	103.46
3	28	31	1	0	0	1	25.86
3	28	32	0	0	0	0	0.00
3	28	33	0	0	0	0	0.00
3	28	34	0	0	0	0	0.00
3	28	35	0	0	0	0	0.00
3	28	36	0	0	0	0	0.00
4	28	1	237	1	2	240	6207.46
4	28	2	46	0	8	54	1396.68
4	28	3	86	1	14	101	2612.30
4	28	4	46	1	1	48	1241.49
4	28	5	25	0	0	25	646.61
4	28	6	3	0	0	3	77.59
4	28	7	30	0	0	30	775.93
4	28	8	82	0	1	83	2146.75
4	28	9	33	1	0	34	879.39
4	28	10	0	0	0	0	0.00
4	28	11	12	0	1	13	336.24
4	28	12	95	0	0	95	2457.12
4	28	13	15	0	3	18	465.56
4	28	14	18	0	1	19	491.42

4	28	15	54	1	0	55	1422.54
4	28	16	41	0	1	42	1086.30
4	28	17	66	1	2	69	1784.64
4	28	18	27	0	2	29	750.07
4	28	19	27	0	1	28	724.20
4	28	20	48	0	0	48	1241.49
4	28	21	82	0	2	84	2172.61
4	28	22	3	0	2	5	129.32
4	28	23	6	2	5	13	336.24
4	28	24	8	0	0	8	206.92
4	28	25	1	0	0	1	25.86
4	28	26	0	0	0	0	0.00
4	28	27	0	0	21	21	543.15
4	28	28	1	1	12	14	362.10
4	28	29	2	0	0	2	51.73
4	28	30	17	0	5	22	569.02
4	28	31	22	0	1	23	594.88
4	28	32	6	0	1	7	181.05
4	28	33	27	0	3	30	775.93
4	28	34	2	0	0	2	51.73
4	28	35	2	0	0	2	51.73
4	28	36	5	0	0	5	129.32
5	28	1	0	0	0	0	0.00
5	28	2	0	0	0	0	0.00
5	28	3	0	0	0	0	0.00
5	28	4	0	0	0	0	0.00
5	28	5	0	0	0	0	0.00
5	28	6	0	0	0	0	0.00
5	28	7	0	0	0	0	0.00
5	28	8	0	0	0	0	0.00
5	28	9	0	4	0	4	103.46
5	28	10	0	7	0	7	181.05
5	28	11	0	2	7	9	232.78

5	28	12	0	0	0	0	0.00
5	28	13	0	0	0	0	0.00
5	28	14	0	0	1	1	25.86
5	28	15	40	0	15	55	1422.54
5	28	16	45	0	5	50	1293.22
5	28	17	27	0	3	30	775.93
5	28	18	24	0	7	31	801.80
5	28	19	0	0	0	0	0.00
5	28	20	1	1	0	2	51.73
5	28	21	7	0	4	11	284.51
5	28	22	32	0	5	37	956.98
5	28	23	5	0	0	5	129.32
5	28	24	3	0	0	3	77.59
5	28	25	9	0	0	9	232.78
5	28	26	24	0	3	27	698.34
5	28	27	60	0	56	116	3000.27
5	28	28	37	0	2	39	1008.71
5	28	29	0	0	2	2	51.73
5	28	30	0	0	0	0	0.00
5	28	31	0	0	0	0	0.00
5	28	32	0	0	0	0	0.00
5	28	33	45	0	1	46	1189.76
5	28	34	140	1	46	187	4836.64
5	28	35	40	0	1	41	1060.44
5	28	36	38	0	1	39	1008.71
3	29	1	0	0	0	0	0.00
3	29	2	0	0	0	0	0.00
3	29	3	0	0	0	0	0.00
3	29	4	14	0	1	15	387.97
3	29	5	14	0	0	14	362.10
3	29	6	2	0	0	2	51.73
3	29	7	5	0	0	5	129.32
3	29	8	5	0	0	5	129.32

3	29	9	2	0	0	2	51.73
3	29	10	0	0	0	0	0.00
3	29	11	1	0	1	2	51.73
3	29	12	0	0	0	0	0.00
3	29	13	2	0	0	2	51.73
3	29	14	0	0	0	0	0.00
3	29	15	4	0	0	4	103.46
3	29	16	15	1	0	16	413.83
3	29	17	4	0	0	4	103.46
3	29	18	1	0	0	1	25.86
3	29	19	4	2	2	8	206.92
3	29	20	2	0	0	2	51.73
3	29	21	2	0	0	2	51.73
3	29	22	2	0	0	2	51.73
3	29	23	0	0	0	0	0.00
3	29	24	4	0	0	4	103.46
3	29	25	0	0	0	0	0.00
3	29	26	3	0	0	3	77.59
3	29	27	1	0	0	1	25.86
3	29	28	0	0	0	0	0.00
3	29	29	0	0	0	0	0.00
3	29	30	0	0	0	0	0.00
3	29	31	0	0	0	0	0.00
3	29	32	0	0	0	0	0.00
3	29	33	0	0	0	0	0.00
3	29	34	10	0	0	10	258.64
3	29	35	0	0	0	0	0.00
3	29	36	0	0	0	0	0.00
4	29	1	0	0	0	0	0.00
4	29	2	0	0	0	0	0.00
4	29	3	0	0	0	0	0.00
4	29	4	20	0	0	20	517.29
4	29	5	126	1	0	127	3284.78

4	29	6	210	1	4	215	5560.85
4	29	7	52	0	0	52	1344.95
4	29	8	20	0	1	21	543.15
4	29	9	14	0	0	14	362.10
4	29	10	18	0	0	18	465.56
4	29	11	16	0	0	16	413.83
4	29	12	2	0	0	2	51.73
4	29	13	1	0	0	1	25.86
4	29	14	17	0	0	17	439.69
4	29	15	0	0	0	0	0.00
4	29	16	0	0	0	0	0.00
4	29	17	2	0	0	2	51.73
4	29	18	12	0	0	12	310.37
4	29	19	4	0	0	4	103.46
4	29	20	1	0	0	1	25.86
4	29	21	0	0	0	0	0.00
4	29	22	1	0	0	1	25.86
4	29	23	24	0	0	24	620.75
4	29	24	1	0	0	1	25.86
4	29	25	4	0	0	4	103.46
4	29	26	4	0	0	4	103.46
4	29	27	11	0	0	11	284.51
4	29	28	12	0	0	12	310.37
4	29	29	5	0	0	5	129.32
4	29	30	0	0	1	1	25.86
4	29	31	5	0	0	5	129.32
4	29	32	4	0	0	4	103.46
4	29	33	31	0	1	32	827.66
4	29	34	14	0	0	14	362.10
4	29	35	0	0	0	0	0.00
4	29	36	1	0	0	1	25.86
5	29	1	0	0	0	0	0.00
5	29	2	0	0	0	0	0.00

5	29	3	0	0	0	0	0.00
5	29	4	0	0	0	0	0.00
5	29	5	0	0	0	0	0.00
5	29	6	0	0	0	0	0.00
5	29	7	0	0	0	0	0.00
5	29	8	0	0	0	0	0.00
5	29	9	0	0	0	0	0.00
5	29	10	0	0	0	0	0.00
5	29	11	0	0	0	0	0.00
5	29	12	0	0	0	0	0.00
5	29	13	1	0	0	1	25.86
5	29	14	0	0	0	0	0.00
5	29	15	39	1	1	41	1060.44
5	29	16	0	0	0	0	0.00
5	29	17	1	0	0	1	25.86
5	29	18	0	1	0	1	25.86
5	29	19	12	0	0	12	310.37
5	29	20	0	0	0	0	0.00
5	29	21	3	0	0	3	77.59
5	29	22	4	0	0	4	103.46
5	29	23	0	0	0	0	0.00
5	29	24	0	0	0	0	0.00
5	29	25	1	0	0	1	25.86
5	29	26	7	0	3	10	258.64
5	29	27	16	0	1	17	439.69
5	29	28	43	0	1	44	1138.03
5	29	29	57	0	0	57	1474.27
5	29	30	11	0	0	11	284.51
5	29	31	82	0	0	82	2120.88
5	29	32	122	2	2	126	3258.91
5	29	33	40	0	0	40	1034.58
5	29	34	6	0	0	6	155.19
5	29	35	0	0	0	0	0.00

5	29	36	0	0	0	0	0.00
		TOTAL	4015	40	320	4375	113156.75

Sources: Umatilla County Planning Office (Information = April 19, 1993)
Morrow County Planning Office (Information = 1992)
Spreadsheet Date = June 15, 1993

Appendix 3H

U.S. Army Umatilla Depot Activity

Chronologic History

Remedial Investigation Sites

Sites with Soil and/or Groundwater Contamination

Table 3H.1 Chronologic history of the U.S. Army Umatilla Depot Activity.

Year	Activity
1940 and earlier	Private fruit, dairy, and poultry operations and undeveloped land at Depot site
1940	U.S. Army acquired original 16,000 acres for Depot by purchase from private land owners and land transfer from the U.S. Bureau of Land Management
1941	U.S. Army Umatilla Depot established to store conventional munitions construction of 1001 ammunition storage igloos began
1945	ammunition demolition added to Depot activity
1947	ammunition renovation added to Depot activity ammunition renovation complex constructed
1955	ammunition maintenance added to Depot activity ammunition maintenance building added
mid 1950 to early 1960	missile and missile fuel components stored: UDMH: unsymmetrical dimethyl hydrazine RFNA: red fuming nitric acid
mid 1950 to mid 1960	Explosive Washout Plant active: explosives removed from munitions, bombs and projectiles by water or steam cleaning and residual effluent discharged to 2 lagoons
1957 and 1960	4,000 additional acres of private and public land annexed for safety zones
1958	ammunition maintenance building added
1962	storing chemical munitions and 1 ton containers of chemical agents in K-block began
1973	U.S. Army Material Command redesignated the Umatilla installation as an Activity
1978	Depot included in U.S. Army Installation Restoration Program (IRP) Initial Installation Assessment (IIA) conducted to evaluate the environmental quality of past use, treatment and disposal of toxic and hazardous materials
1979	IIA findings indicated past demilitarization and disposal operations caused parts of the Depot to be contaminated with explosives.
1981	Battelle Pacific Northwest Laboratory conducted an exploratory and confirmatory environmental survey. Results indicated soil contamination existed at several locations and the explosive washout operations had contaminated groundwater in an unconfined aquifer with 2,4,6-trinitrotoluene (TNT), Hexahydro-1,3,4-triazine (RDX, and some 2,4-and 2,6 dinitrotoluene (DNT). U.S. Army Environmental Hygiene Agency (AEHA) conducted limited soil sampling at 5 selected open burning/open detonation ground sites which found low concentration of explosives in several samples and hazardous levels or arsenic and chromium in one sample.
1985	U.S. Army submitted a Resource Conservation and Recovery Act (RCRA) Permit application to the U.S. Environmental Protection Agency (EPA) at Region X to allow the Army to construct and operate an incineration facility to demilitarize obsolete chemical agents at the depot.

1986	U.S. EPA conducted a RCRA Facility Assessment (RFA) to identify releases or potential releases at various solid waste management units (SWMU) or spill sites at the Depot. The U.S. EPA concluded more investigation was needed before corrective measures could be determined for the following areas: Ammunition Demolition Activity (ADA) Explosive Washout Plant Explosive Washout Lagoons Inactive Landfills Active Landfill Storm Sewer Tile Field Sewage Treatment Plant Septics associated with Buildings 417, 419, 486, 489, 655 Former Agent H Storage Deactivation Furnace Waste Oil Tanks
1987	Explosive Washout Lagoons placed on National Priorities List
1988	Initial Remedial Investigation conducted by Roy F. Weston, Inc. to determine the extent of contamination at the following sites: Explosive Washout Lagoons Ammunition Demolition Activity Active Landfill Inactive Landfills Deactivation Furnace Septic Tanks Serving Buildings 417, 419, 486, 489, 655 Base Realignment and Closure Program directed some or all the Depot land be excessed which made conducting more Remedial Investigation/Feasibility Study (RI/FS) necessary for 50 Depot sites. U.S. Army, Umatilla Depot Activity, U.S. Environmental Protection Agency at Region X, and Oregon Department of Environmental Quality agree upon additional RI/FS work.
1988 to 1992	Dames and Moore, Inc. conducted the additional RI/FS plan development and implementation.
1989	Roy F. Weston, Inc. reported the results of the initial Remedial Investigation. The investigation found explosives, nitrate/nitrite, cyanide, and certain metals in septic tanks, surface soil, subsurface soil, alluvial aquifer groundwater, and groundwater from basalt. The investigation results indicated the contamination came from multiple sources within the Depot and fertilized farming operations outside the Depot.
1992	Dames and Moore, Inc. reported the results of the additional Remedial Investigation. Varying soil and/or groundwater contamination was found at different sites. Recommendations included no further action for 16 sites; conducting additional investigation for 12 sites; and evaluating remedial action alternatives at 30 sites.
1993	Arthur D. Little, Inc. reported the results of Feasibility Studies for Depot sites.
1994	U.S. Army, U.S. Environmental Protection Agency, and Oregon Department of Environmental Quality released for public review the preferred plan for cleaning groundwater at the Explosive Washout Lagoons within the Depot.

Sources: Roy F. Weston, Inc., 1989
Ritchie and others, 1992
Mahannah and others, 1993
Bowen and others, 1993
Woodland and others, 1993
Machacek and others, 1993
U.S. Army and others, 1994

Table 3H.2 Selected sites within the U.S. Army Umatilla Depot Activity: Ammunition Demolition Area.

Ammunition Demolition Area Summary

The Ammunition Demolition Area (ADA) is made up of 20 sites occupying 1,750 acres in the northwest corner of the Depot. Activity in the area includes burning, detonating, dumping, and burying metals and explosives associated with ordnance and pesticides from 1945 to the present. Metals associated with ordnance handled in the area include lead, chromium, antimony, cadmium, copper, mercury, and nickel. Explosives handled in the area include TNT, TNB, DNT, nitrobenzene, RDX, HMX, and tetryl. Pesticides handled in the area include DDT, DDE and dieldrin.

Environmental investigations by others indicate metals and possibly explosives in some surface and shallow soil is the primary environmental concern of the ADA to date. Arsenic, nitrate, and other inorganic constituents were detected in groundwater samples. Three explosives were found separately in three samples from two ADA sites. The investigators concluded that Ammunition Demolition Area activity did not and will not contaminate groundwater.

Sources: Dawson and others, 1982
Ritchie and others, 1992
Mahannah and others, 1993

Aboveground Open Detonation (OD) Area
(Site 17)

The site was used to detonate M55 rockets and M23 land mines. Chemical agents in the M55 rocket canisters were drained and collected at a Drill and Transfer site prior to detonation.

Antimony, beryllium, cadmium, cobalt, copper, iron, lead, nickel, silver, and zinc metals as well as TNT, HMX, and RDX explosives were found in soil surface samples by other investigators. No specific groundwater data for the site was reported.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Acid Pit
(Site 8)

The site is a limestone-lined pit that was used to dispose of approximately 300 to 400 twenty gallon barrels of red fuming nitric acid (.RFNA) from 1955 to 1962. WEDAC solutions from another site may have been disposed in the Acid Pit.

Other investigators found beryllium, chromium, copper, lead, nickel, and zinc metals as well as high nitrate concentrations in subsurface soil down to 10 feet at the Acid Pit. Groundwater sampling by other investigators found metals below a "comparison criteria", vanadium above the "comparison criteria", elevated nitrate concentration in one sampling round, and the RDX explosive at low concentrations which was not duplicated.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Active Firing Range
(Site 60)

The site consists of two active target firing ranges which have been used by the National Guard since the 1980s. One range is used for rifles and machine guns. The other range is used for pistols. Bullets that miss the targets land in open areas.

Other investigators found metals in site soil within background range. They apparently did not investigate groundwater at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Aniline Pit
(Site 7)

The site currently consists of a 40 by 40 foot fenced area where aniline, a missile fuel component, was apparently disposed.

Limited soil sampling by other investigators found no detectable contamination. They apparently did not investigate groundwater at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Borrow/Burn/Disposal Area
(Site 58)

Review of aerial Photographs by other investigators indicate some kind of activity disturbed the land surface at this site from 1949 through 1968. Ammunition demolition or disposal may have been conducted at the site.

Soil sampling results found metals within background range, and no explosives or nitrate were detected. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Dunnage Pits
(Site 18)

The site currently consists of two pits separated by a gravel road. Several other dunnage pits apparently existed east of the current pits. Metal debris, waste solvents, waste oils, paint strippers, and other wastes were burned or disposed in these pits.

Soil sampling by other investigators to 10 feet depth found aluminum, magnesium, manganese, nickel, potassium, silver, and zinc metals, DDE, DDT, and dieldrin pesticides, naphthalene, and PCB's. Groundwater sampling by the other investigators found nitrate in all samples and elevated manganese. no explosives or pesticides were detected in the groundwater.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Flare and Fuse Disposal Area/Bird Cage Area
(Site 14)

The site was used to dispose burned residue from a Depot flare and fuse burning operation. The "bird cage" area of the site was apparently used to burn pyrotechnics beginning about 1956.

Soil sampling to 10 feet by other investigators nitrate in 11 of 13 samples, and barium, chromium, potassium, silver, and zinc above background concentrations. No explosives were detected. Groundwater sampling by the investigators found metals.

Sources: Ritchie, and others, 1992
Mahannah and others, 1993

Former Pit Area Locations
(Site 57)

The site consists of three areas that were apparently active from before 1950 through the early 1970s. Other investigators assume ammunition demolition or disposal activity occurred at the site.

Eighty four soil samples from 17 test pits were collected by other investigators. The sampling found: magnesium, mercury, potassium, and zinc metals, and no nitrate or explosives at area I; magnesium, mercury, nickel, and potassium metals, nitrate above background concentrations, and tetryl explosive at area II; and copper, magnesium, mercury, potassium, silver, and zinc metals, and TNT at area III. Groundwater sampling by the other investigators found vanadium above "comparison criteria" at areas II and III, antimony above "comparison criteria" at areas I and II, and no nitrate above the "comparison criteria".

Sources: Ritchie and others, 1992
Mahannah and others, 1993

GB/VX Decontamination Solution Burial Areas
(Site 41)

Former Depot employees told other investigators that decontamination solutions from a leaking GB bomb brought on-site during the early 1960s may have been disposed in one of two areas.

Soil sampling to 10 feet by other investigators found slightly elevated lead in 1988, and elevated antimony, potassium, silver, and zinc metals. Nitrate was found at law concentrations. No explosives or product related to chemical agent GB (Sarin) was found. Groundwater sampling by the other investigators found metals.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

GB/VX Decontamination Solution Disposal Areas
(Site 59)

The site consists of two areas where decontamination solutions for chemical agents GB/VX were apparently disposed on the ground two or more times during the early 1960s.

Soil and groundwater sampling for ethyl methyl phosphonate (EMPA) and isopropyl methyl phosphonate (IMPA) by other investigators detected no contamination.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Missile Fuel Storage Areas
(Site 21)

The site currently consists of three sheds and one former shed. No fuel components are currently stored at the site.

Soil sampling by other investigators found nitrate concentrations above background in one of nine samples, no explosives and other contaminants of concern. Groundwater was not investigated at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Munitions Crate Burn Area
(Site 56)

The site was apparently used to burn empty munition crates from before 1950 through 1965. Ammunition demolition or disposal may have occurred at the site.

Soil sampling by other investigators found aluminum, beryllium, calcium, magnesium, and potassium above "comparison criteria". No nitrate or explosives were detected. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Open Burning Trays
(Site 32)

The site consists of two burning trays located on gravel pads. The trays are used to burn explosive propellant powder. Cartridges are flashed with diesel fuel at one tray. The Depot conducts the operation under a permit issued by the Oregon Department of Environmental Quality.

Soil sampling by other investigators found aluminum, antimony, barium, copper, lead, manganese, potassium, silver, and zinc metals, low concentrations of DNT explosive, and low concentrations of nitrate down to 2 feet. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Open Burning Trenches/Pads
(Site 19)

The site consists of approximately 10 burning trenches/pads and an adjoining burn field where sludges containing explosives are burned.

Forty eight soil samples were collected from 10 pits by other investigators. The soil was sampled to 10 feet depth, and it contained aluminum, arsenic, calcium, magnesium, nickel, and potassium metals, tetrachloroethylene (PCE) and trichloroethylene (TCE), volatile organics, nitrate and explosives. Groundwater samples collected by the investigators contained antimony and manganese above "comparison criteria", nitrate below "comparison criteria", caprolactum, and 1,3-dinitrobenzene (DNB).

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Open Detonation (OD) Pits
(Site 16)

The site consists of numerous active and inactive pits where defective or unwanted ordnance is exploded.

Numerous soil samples collected to 10 feet depth by other investigators contained aluminum, arsenic, barium, cadmium, calcium, cobalt, copper, cyanide, iron, magnesium, mercury, potassium, and zinc metals, nitrate, and RDX, HMX, TNT, DNT, and nitrobenzene explosives. Groundwater samples collected by the other investigators contained manganese and vanadium above "comparison criterion".

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Pesticide Pits
(Site 31)

The site currently consists of a row of pits where pesticide solutions and general debris may have been disposed or burned, and where munitions may have been detonated. An area north of the existing pits was apparently a torpedo burn area. Many other pits formerly existed south of the existing pits.

Soil samples collected to 10 feet depth by other investigators contained 12 metals greater than comparison criteria, nitrate, TNT, DNT, TNB, RDX, and tetryl explosives, TCE and xylenes: volatile organic compounds, and DDD, DDE, DDT, dieldrin, and endrin pesticides. Groundwater samples collected by other investigators contained vanadium above "comparison criterion", nitrate and apparently explosives and volatile organic compounds.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Pit Field Area
(Site 38)

The site covers approximately 50 acres, and it consists of numerous 6 to 8 feet wide and 1 to 2 feet deep pits. Ordnance materials were apparently detonated or disposed at the site.

Soil samples collected to 10 feet by other investigators contained aluminum, barium, calcium, cadmium, copper, cyanide, iron, magnesium, mercury, nickel, potassium, silver, sodium and zinc metals, TNT and tetryl explosives, and nitrate within background concentrations. Groundwater samples collected by the investigators contained elevated nitrate concentrations.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Smoke Canister Disposal Area
(Site 13)

The site is currently a long, narrow, soil ridge with abundant canister debris. A trench at the site apparently existed prior to 1970. Burned debris from Depot smoke canister burning operations were disposed here. Some burning may have occurred at the site also.

Soil samples collected to 10 feet by other investigators contained 13 metals above "comparison criteria" with lead, mercury and zinc being most notable, nitrate below "comparison criterion", low concentrations of volatile organics, and low concentrations of DNT explosive. Groundwater samples collected by the investigators contained vanadium above "comparison criterion" and other metals. The investigators concluded site activity did not impact groundwater quality.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

TNT Sludge Burial and Burn Area
(Site 15)

Waste was disposed or burned at this site. The waste may have included TNT sludge, paint sludge, shot blast waste, and deactivation furnace ash. A scrap metal pile was also located within the site vicinity before October 1990.

Soil sampling to 10 feet depth by other investigators found elevated metal concentrations with cadmium above comparison criteria, moderately elevated concentrations of nitrate, low concentrations of bis(2-ethylhexyl)phthalate, naphthalene, and phenanthrene volatile organics, and moderate concentrations of TNT, HMX, and RDX explosives. Groundwater sampling by the other investigators found manganese above "comparison criterion", and nitrate was detected in all samples.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Trench/Burn Field
(Site 55)

The site was identified by aerial photographs reviewed by other investigators. Activity at the site may have occurred from at least 1950 through 1965. The investigators assume ammunition demolition and disposal activity may have occurred at the site.

Soil sampling to 10 feet depth by other investigators found arsenic and silver metals as well as HMX and RDX explosives. Groundwater sampling by the other investigators found manganese above the "comparison criteria". The investigators concluded that site activity did not contaminate groundwater.

Sources: Ritchie and others, 1992
Mahannah and others, 1993

Table 3H.3 Selected sites within the U.S. Army Umatilla Depot Activity: Deactivation Furnace and Southwest Warehouse Area.

Deactivation Furnace and Southwest Warehouse Area

The Deactivation Furnace and Southwest Warehouse Area is located in the southwest corner of the Depot. Eleven sites within the area were sampled during the remedial investigation.

Deactivation Furnace
(Site 1)

The Deactivation Furnace is used to incinerate munitions up to 50 caliber. Heavy metals, including lead and cadmium, within furnace particle emissions were discharged directly to the atmosphere until a cyclone baghouse system was installed to collect the emissions.

Soil sampling conducted by other investigators found barium, beryllium, cadmium, copper, lead, nickel, potassium, and zinc metals, slightly elevated nitrate, and low concentrations of DNT explosive. Groundwater was apparently not investigated at the site.

Source: Ritchie and others, 1992

Disposal Pit and Graded areas
(Site 80)

This site was identified by other investigators during a review of historic aerial photographs. A trench and graded areas once existed at the site. Interviews and record reviews by other investigators yielded no information about possible disposal at the site.

Soil sampling by other investigators found low concentrations of chloroform. Nitrate and explosives were not detected. Groundwater was apparently not investigated at the site.

Source: Ritchie and others, 1992

Former Raw Materials Storage Location I
(Site 81)

This site was identified by other investigators during a review of historic photographs. That review indicate piles of raw material were stored directly on the ground during the 1940s and 1950s.

Soil samples collected by other investigators contained metals at concentrations below the "comparison criterion". Groundwater was apparently not investigated at the site.

Source: Ritchie and others, 1992

Hazardous Waste Storage Facility (Building 203)
(Site 3)

The site currently consists of a large wood frame building with a metal roof and siding and a concrete floor. Hazardous wastes are stored within a small fenced area in the building. A six-inch high concrete berm around the area serves to contain any spills. Material recently stored include baghouse dust, battery acid, used oil and PCB transformers. During the early 1970s, drums of Agent Orange may have been stored in the building with leakage onto the floor. The possibly spilled Agent may have been washed out of the building onto soil north of the building.

Soil samples collected by other investigators found no herbicides greater than "certified reporting limits" and no detectable organic compounds. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Malathion Storage Leak Area
(Site 35)

The Depot received a shipment of leaking insecticide containers during the late 1970s and apparently stored the containers on gravel north of Building 108. The fate of these pesticides is uncertain. They could have been relocated, burned at the Ammunition Demolition Area, or transferred to new containers and sold.

Soil sampling by other investigators found low concentrations of DDE, DDT and chlorodane pesticides. No malathion or PCB's were detected. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Metal Ingot Stockpiles
(Site 26)

The site occupies 30,000 to 40,000 square feet where 6 foot high piles of lead and zinc ingots lie directly on gravelly soil. Aluminum may have been stored at the site in the past.

Soil sampling by other investigators found lead and zinc at concentrations greater than comparison criterion. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Metal Ore Piles Location I
(Site 25)

The site has apparently existed since before the end of World War II. Other investigators observed one metal ore pile which was uncovered and lying directly on the soil. Another pile had apparently existed in the past.

Soil sampling by other investigators found elevated lead concentrations during one investigation and thallium concentrations above "comparison criteria" during another investigation. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Building 131 Paint Sludge Discharge Area
(Site 37)

The site consists of a depression west of Building 131. Paint sludges and solvents from spray paint operations in Building 131 apparently collected in the depression. Other investigators observed a subsurface metal and wood conduit west of the building extended exposed into the depression. Investigators in 1989 observed "abundant" paint residue on the soil at the site.

Soil samples collected by other investigators contained barium, cadmium, chromium, mercury, and zinc metals above "comparison" criteria, as well as tetrachloroethylene, bis(2 ethyhexyl) phthalate and other organics. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Paint Spray and Shot Blast Areas
(Site 34)

This site consists of two areas. A portable shot blast machine and open air spray painting were conducted at the areas, and their residues were apparently disposed on surrounding soil. One area was used as a propellant transfer and storage site also.

Soil samples collected by other investigators contained chromium and zinc metals at concentrations above "comparison criterion", nitrate at concentrations below the "comparison criterion", oil, grease, petroleum hydrocarbons, di-n-butyl phthalate and phenanthrene. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Railcar Unloading Area
(Site 46)

Interpretation of aerial photographs by other investigators indicate coal or ore was stored at the site from about 1949 or before to the late 1950s or early 1960s. Apparently brass bullets were unloaded at the site during the late 1960s and early 1970s.

Soil sampling by other investigators found copper, lead, and zinc metals at concentrations above a "comparison" criteria as well as 2-methylnapthalene, anthracene, di-n-butyl phthalate, dibenzofuran, fluoranthene, n-nitrosodiphenylamine, naphthalene, pyrene and other organics. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Road Oil Application/Disposal Sites Location I
(Site 44)

Other investigators identified this site during a review of historic aerial photographs. The investigators found hardened road oil material at the site in 1989.

Apparently, one soil sample was collected from the site by the other investigators. The sample contained high concentrations of oil and grease and low concentrations of volatile and other organics. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Table 3H.4 Selected sites within the U.S. Army Umatilla Depot Activity: Explosive Washout Lagoons Area.

Explosive Washout Lagoons Area

This area is located in the central portion of the Depot. Six sites were investigated during the remedial investigation.

Boiler/Laundry Effluent Discharge Site
(Site 47)

The site consists of an approximately 25 foot diameter and 8 to 10 feet deep rock-lined pit. A metal trough connects the pit to a nearby boiler building. Boiler blowdown and effluent from laundering clothes contaminated with explosives at the boiler building were discharged to the pit.

Soil samples collected by other investigators contained antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, sodium, vanadium and zinc metals at concentrations above "comparison" criteria, and nitrate at concentrations above "comparison" criteria. The soil samples also contained chlordane, DDD, and DDT pesticides, PCB, and 19 organic chemicals. Groundwater sampling by the other investigators found antimony and vanadium metals, TNB, and two explosives at low concentrations.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Building 493 Paint Sludge Discharge Area
(Site 36)

Paint sludge, solvents and other possible wastes from spray paint booths in Building 493 were apparently discharged into a "coulee" near the building via an underground drainage system. Other investigators observed "abundant paint stains" on the soil at two pipe discharge locations. In addition, a brass cleaning solution containing cyanide was apparently disposed into the same drainage system prior to the late 1960s.

Same soil samples collected by other investigators contained calcium, cadmium, chromium, copper, iron, nickel, silver, and zinc metals at concentrations above "comparison" criteria, nitrate at concentrations above "comparison" criteria, and low concentrations of organic chemicals. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Building 493 Brass Cleaning Operations Area
(Site 67)

A cyanide containing solution, "WEDAC", was used to clean brass shells inside of Building 493 prior to the late 1960s, and on concrete pads south of the building during the late 1960s. Waste liquid was disposed in the paint spray booth drains in Building 493 (see Site 36 discussion) prior to the late 1960s. During the late 1960s, solution may have spilled onto soil adjacent to the concrete pads. Site 67 is the concrete pad area.

Soil sampling by other investigators found low concentrations of silver and calcium. No explosives were detected. Groundwater sampling by investigators found vanadium at concentrations comparable to groundwater sampling results for other areas. The other investigators concluded the vanadium was naturally occurring or came from a source outside the Depot.

Sources: Ritchie and others, 1993

Coyote Coulee Discharge Gullies
(Site 52)

Other investigators identified three erosional gullies along Coyote Coulee near the explosive washout plant (Building 489) during a review of historic aerial photographs and a site reconnaissance. Liquid discharges from activities in the area apparently created the gullies as early as 1949. The gullies may have been active through 1965. One gully originates near the north end of the explosive washout plant, and it may have served to discharge the washout plant effluents until the washout lagoons were constructed during the early 1950s. A second gully originates from a former building site north of the explosive washout plant, and the third gully originates south of the explosive washout plant near a site identified as an ammunition disassembly structure.

Soil samples collected by other investigators contained copper and zinc metals above "comparison" criteria as well as HMX and RDX explosives. No nitrate was detected. Groundwater impacts related to the gullies only was apparently not investigated.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Explosive Washout Plant (Building 489)
(Site 5)

The explosive washout plant operated from the 1950s to 1965. At this site, 500 to 700 pound composition B bombs and 90 mm projectiles were demilitarized. The process included: using pressurized hot water spray to melt and washout the explosives; collecting the liquid explosive at the bottom of the washout and settling tanks; decanting the water for reuse; and dewatering, pelletizing, and drying the explosive slurry. Liquid from the process, and liquid from flushing and draining the system weekly discharged to explosive washout lagoons. Occasional steam cleaning of the plant and floors discharged to the washout lagoons also. Solids collected in a sump were periodically removed dried and burned in the ammunition demolition area (ADA). Old equipment from the original explosive washout plant building which was replaced during the 1950s, were disposed at the ADA also after explosive residues were burned.

Soil sampling by other investigators found TNB, DNB, TNT, DNT, HMX, and RDX explosives. Nitrate was found in all samples.

Sources: Ritchie and others, 1992
Woodland and others, 1993

Explosive Washout Lagoons
(Site 4)

Two unlined, 25 by 75 feet wide and 6 feet deep explosive washout lagoons received waste water from the explosive washout plant from the mid 1950s to the mid 1960s. Approximately 85 million gallons total of explosive washout effluent discharged to the lagoons and seeped into the ground or evaporated. The waste water contained TNT, DNB, TNB, DNT, nitrobenzene, RDX, HMX, and tetryl explosives.

Soil samples collected by other investigators contained low to high concentrations of explosives especially RDX, HMX, and 2,4,6-TNT. The investigators noted the concentrations, tended to increase with soil depth, and the contamination probably extended to groundwater. Nitrate was detected in every sample.

Groundwater sampling by other investigators found HMX, tetryl, and nitrobenzene explosives and metals at concentrations below "comparison criterion", RDX, TNB, DNB, TNT, and DNT explosives at concentrations above the "comparison criterion", and high concentrations of nitrate. Explosives were detected in alluvial and basalt groundwater. Although groundwater at the lagoon site generally flows toward the northwest, the contamination in the alluvial sediments may be migrating to the southwest, northeast and predominantly to the southeast due to perched water flow and seasonal pumping of the alluvial aquifer.

Groundwater cleanup has been proposed for the site. The proposed process includes extracting groundwater at the site for 10 years, treating the water with granular activated carbon, and reinfiltrating the water through the washout lagoons at a net cost of 5.8 million dollars.

Sources: Dawson and others, 1982
Ritchie and others, 1992
Brown and others, 1993
U.S. Army and others, 1994

Table 3H.5 Selected sites within the U.S. Army Umatilla Depot Activity: Sewage Treatment Plant and vicinity.

Sewage Treatment Plant and Vicinity

The sewage treatment plant vicinity is located west of the Administrative Area and south of Igloo Block F in the south central area of the Depot.

Pipe Discharge Area
(Site 48)

The site consists of an 8 inch diameter pipe, 15 feet long that discharges into an approximately 25 foot deep ravine. A rusted 55 gallon drum was observed in the ravine by other investigators in 1989.

Soil samples collected by other investigators contained no explosives, low to moderate concentrations of nitrate, elevated concentrations of cadmium, copper, mercury, silver, and zinc metals, DDD, DDE, and DDT pesticides, and other organic compounds. Groundwater was apparently not investigated at the site.

Source: Ritchie and others, 1992

Sewage Treatment Plant
(Site 6)

The sewage treatment plant is a large on-site domestic waste system serving the administration area. The system consists of 2 Imhoff tanks, a sludge drying bed, and a drainfield.

Soil sampling by other investigators found mercury, nickel, silver, and zinc metals at concentrations above "comparison" criteria, nitrate at concentrations above "comparison" criteria, DDT pesticides, PCP 1260 and other organic compounds. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Stormwater Discharge Area
(Site 30)

This site consists of a small ditch which receives storm water from the administration area. Storm water is conveyed to the site via storm sewers.

Soil samples collected by other investigators contained silver and zinc metals at concentrations above "comparison" criteria, low concentrations of DDD, DDE, and DDT pesticides, low concentrations of oil and grease, and other organic chemicals. No nitrate was detected.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Table 3H.6 Selected sites within the U.S. Army Umatilla Depot Activity: Defense Re-utilization Marketing Office Area and other Administrative Area sites.

Defense Re-utilization Marketing Office Area and Other Administrative Area Sites

This area is located in the south central portion of the Depot north of Exit 177 on Interstate 80. Three sites in the area were investigated.

Defense Re-utilization Marketing Office Area
(Site 22)

The site is used to store material awaiting sale or offsite disposal. Material stored include scrap and salvage metals, wooden crates, waste oils, old transformers, empty shells and cartridges, vehicles, furniture, and other items. This material is stored in a warehouse or outside on a paved area or on bare ground. Leaky transformers may have been stored on bare ground in a shed at the site.

Soil samples collected by other investigators contained antimony, barium, cadmium, copper, lead, silver, and zinc metals at concentrations above the "comparison" criteria, DDD, DDE, and DDT pesticides, petroleum hydrocarbons, and other organic chemicals. No explosives or PCB's were detected. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Pesticide Storage Building
(Site 27)

A limited supply of pesticides are stored in two bermed rooms with concrete floors in the pesticide storage building. An above ground tank outside the building is used to collect liquids from a sink used to clean pesticides off of materials. The building was previously used to store paints and solvents.

Soil sampling by other investigators found zinc above "comparison" criteria, DDT pesticide, and fluoranthene, phenanthrene, and pyrene organic chemicals. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Road Oil Application/Disposal Location II
(Site 44)

A variety of oil related activity apparently occurred at the site based upon interviews and aerial photograph reviews conducted by other investigators. The eastern part of the area was used to change oil in Army vehicles and store drums of road oil and tar during the late 1940s. The waste oil was apparently drained directly onto the soil. Road oil was disposed in the area to control dust and road oil was also transferred from commercial supply trucks to Army supply vehicles from the mid 1950s to the mid 1960s.

Soil samples collected in the area by other investigators contained moderate to high concentrations of oil and grease, and low concentrations of other organic chemicals. Groundwater at the site was apparently not investigated.

Source: Ritchie and others, 1992

Table 3H.7 Selected sites within the U.S. Army Umatilla Depot Activity: Inactive Landfill Area.

Inactive Landfill Area
The inactive landfill area is located in the south central portion of the Depot between the administrative area and the sewage treatment plant area.
Inactive Landfills (Site 12) Three landfills and three other disposal areas west of the administration area were identified during previous investigations. All sites are apparently inactive. The landfills have been inactive since the late 1970s or earlier. Materials disposed at the landfills were apparently nonhazardous, but former employees told other investigators that explosives may have been disposed in the landfills. Soil sampling at 8 test pits by other investigators found chromium, copper, iron, mercury, silver, vanadium, and zinc metals at concentrations above "comparison" criteria, beryllium and nickel also, DDD, DDE, and DDT pesticides, PCB-1260, and chloroform organic chemical. Groundwater samples contained antimony and vanadium at concentrations above "comparison" criteria, slightly elevated nitrate concentrations, and RDX explosive at concentrations below the "comparison" criteria. The other investigators concluded that landfill activities were not responsible for the groundwater contamination. Source: Ritchie and others, 1992
Railroad Landfill Areas (Site 50) The site consists of two elongated landfills located north and south of railroad tracks located inside and parallel to the Depot southern boundary. Disposal in the northern landfill was apparently limited to metal scrap and possible railcar debris. The southern landfill is apparently filled with construction rubble. Soil samples collected by other investigators contained zinc metal above " comparison" criteria, and low concentrations of oil and grease. No explosives, volatile organic chemicals, pesticides, PCB's, or nitrate were detected. Groundwater samples contained calcium, magnesium metals and phosphate at concentrations similar to other Depot samples, vanadium metal at concentrations above the "comparison" criteria, nitrate at concentrations above the "comparison" criteria in one sample, low concentrations of RDX explosive, and low concentrations of oil and grease. Cyanide was detected in 1988 sampling only. Sources: Ritchie and others, 1992 Machacek and others, 1993

Table 3H.8 Selected sites within the U.S. Army Umatilla Depot Activity: Active Landfill.

Active Landfill
(Site 11)

The active landfill is located between Igloo Block D and Igloo Block E in the northeast portion of the Depot. Originally a gravel pit, the site has been an active landfill since 1968. Material disposed at the landfill include empty pesticide containers, brake liner asbestos, wood and wooden pallets, metal bands, building materials, garbage, and dried sludge from the sewage treatment facility.

Groundwater samples collected by other investigators contained antimony and elevated concentrations of selenium and vanadium metals, cyanide in 1988 sampling only, elevated concentrations of nitrate, RDX and tetryl explosives in 1988 sampling only, DNT explosive, and some organic chemicals including cyclopentanone and trichlorofluoromethane. The other investigators concluded that the nitrate and vanadium represented background conditions or came from an offsite or another source apart from the landfill.

Source: Ritchie and others, 1992
Golder Associates, Inc., 1992

Table 3H.9 Selected sites within the U.S. Army Umatilla Depot Activity: miscellaneous sites.

Miscellaneous Sites

Twelve miscellaneous sites located across the Depot were inspected by other investigators. A brief discussion of each site and the results of other investigations follow.

Building 433 Collection Sump/Cistern and Disposal Area
(Site 53)

This site is located north of the Depot Administration area and south of the explosive washout plant and lagoons. A concrete sump or cistern with a 4 inch diameter stand pipe in the center of a 3 by 3 foot pad is located approximately 40 feet south of Building 433. Apparently, boiler blowdown fluids from the building accumulated in the sump. The site area also includes a stained soil area north of Building 433.

Soil samples collected by other investigators contained potassium and nickel at concentrations above "comparison" criteria, oil and grease, as well as anthracene, phenanthrene, and pyrene. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Building 612 and Building 617 Boiler Discharge Areas
(Site 45)

Buildings 612 and 617 are both located in the northwest portion of the Depot, east of the ammunition demolition area and north of the remote munitions disassembly/GB bomb disassembly area. Building 612 is located more than 0.5 miles east of Building 617. Both buildings are boiler houses. Boiler blowdown effluent from each building discharges onto nearby soil.

Shallow soil sampling by other investigators found copper, iron, nickel, silver and zinc metals at concentrations above "comparison" criteria. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Drill and Transfer (DAT) Site
(Site 49)

The Drill and Transfer site is located in the north-central portion of the Depot, adjacent to the northwest corner of Igloo Block K. The approximately 3 acre site was used for a 1984 leaky chemical munitions disposal program. An earthen berm divided the site into two halves. The western half was used for personnel support. Munitions were drilled, emptied, and decontaminated in the eastern half. Chemical agents were placed in holding tanks. Munition casings were rinsed and monitored in decontamination tanks until chemical agent concentrations were below designated levels. Then, the casings were removed and disposed. These operations were apparently conducted on unprotected soil. One spill occurred. The spill product was treated as a chemical agent according to USATHAMA standard operating procedures.

Soil sampling conducted by other investigators detected no contamination. Groundwater at the site was apparently not investigated.

Source: Ritchie and others, 1992

Former Agent H Storage Area
(Site 10)

The former Agent H storage area is located in the north central portion of the Depot, north of Igloo Block K. Mustard agent was stored at the site in 1-ton containers. Other investigators indicate mustard agent reportedly leaked from some containers onto the gravel and soil in the area. Reportedly, the leaks and spills were cleaned up and decontaminated immediately, and the residues were buried nearby.

Soil samples collected by other investigators contained antimony metal at concentrations above "comparison" criteria and chloroform organic chemical. Groundwater at the site was apparently not investigated.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Former Gravel Pit/Disposal Location
(Site 82)

This site is located in the west central portion of the Depot at the southeast corner of Igloo Block I. The site is a gravel pit, but other investigators found transite siding containing asbestos at two places on the pit floor. The investigators search of records and former employee interviews yielded no information about disposal at the site.

Soil sampling conducted by other investigators found asbestos and chloroform organic chemical. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Former Raw Materials Storage Location II
(Site 81)

This site is located in the south central portion of the Depot at the southeast corner of Igloo Block H. Materials were stored directly on the ground at the site during the 1940s and 1950s.

Soil sampling at the site by other investigators found no contamination of concern. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Gravel Pit Disposal Area
(Site 33)

The gravel pit disposal area is located in the south central portion of the Depot, east of Igloo Block F. GB/VX decontamination solutions may have been disposed in the pit during the late 1960s. Other investigators observed crushed drums and other metal debris at the site.

No contamination was detected in the soil samples collected by other investigators. Groundwater at the site was apparently not investigated.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Metal Ore Piles - Location II
(Site 25)

This site is located in the north central portion of the Depot between Igloo Blocks J and K. Three uncovered metal ore piles in direct contact with the soil have been observed at the site by other investigators. The piles may have existed at the site since late World War II. Review of historic aerial photographs by other investigators indicate another pile may have existed west of the three piles.

Soil samples collected by other investigators contained nickel at concentrations of concern and thallium. Groundwater was apparently not investigated at the site.

Source: Ritchie and others, 1992

QA Function Range
(Site 39)

The QA function range is located in the northeast corner of the Depot. Two activities occurred at the site. The central area west of Coyote Coulee apparently served as a rifle and pistol range from the late 1940s through the mid-1970s. The southern area east of the coulee apparently served as a flare, photoflash grenade, and mine testing area from the late 1940s through the 1960s. Other investigators observed metal banding material disposed along the coulee.

Soil sampling by other investigators found antimony, copper, lead, silver, and zinc at concentrations above "comparison" criteria, and nitrate at concentrations below the "comparison" criteria. Groundwater at the site was apparently not investigated.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Remote Munitions Disassembly/GB Bomb Disassembly Area
(Site 9)

This site is located east of the ammunition demolition area in the northwest area of the Depot. Conventional munitions, including very large bombs, were disassembled at the site. Bombs containing GB/VX nerve agents may have been drained and disassembled occasionally at the site.

Soil samples collected by other investigators contained nitrate at concentrations below "comparison criterion", antimony, cadmium, chromium, silver, and zinc metals at concentrations above the "comparison, criteria, and HMX and RDX explosives. Groundwater was apparently not investigated at the site.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Septic Tanks
(Site 29)

Twenty three septic tanks are located throughout the Depot. Most septic systems at the Depot are or were apparently used for human waste or nonhazardous materials only. Two tanks are associated with the sewage treatment facility (Site 6) serving the administration area. Five tanks were sampled by other investigators in 1988, because they were suspected of containing contaminants from the buildings they served. Inorganic contaminants were found in samples from four tanks, and RDX explosive was found in one sample. GB/VX decontamination solutions may have been disposed through a septic tank and drainfield in the ammunition demolition area. Battery acid may have been disposed through a septic tank and drain field in the central portion of the Depot.

Soil sampling at various septic tanks sites by other investigators found calcium, chromium, manganese, nickel, silver, sulfate sulfide, and zinc at concentrations greater than the "comparison" criteria, and acetone, 2-butoxyethanol, phenanthrene, and 1,1,1,-trichloroethane organic chemicals. Groundwater at the site was apparently not investigated.

Sources: Ritchie and others, 1992
Machacek and others, 1993

Storage Igloos
(Site 2)

Munitions and wastes are stored in 1,001 earth covered, reinforced concrete igloos located throughout the Depot. Wastes, such as GB and VX chemical agents, are stored in 55 gallon drums in Igloo Block J. The igloos and associated drainage structures are apparently inspected regularly. Other investigators found no record of spills or releases at the igloos.

The soil and groundwater related to the igloos were apparently not investigated.

Source: Ritchie and others, 1992

Table 3H.10 Types of contamination detected at selected U.S. Army Umatilla Depot Activity Sites as identified by other investigators.

Site	Site #	Soil					Groundwater					
		Metals	Explosives	Nitrate/ Nitrite	Pesticide	Other Organics	Metals	Explosives	Nitrate/ Nitrite	Pesticide	Other Organics	No GW Sampling
Above ground open detonation area	17	X	X									X
Acid pit	8	X		X			X	X	X			
Active firing range	60	X										X
Aniline pit	7											X
Borrow/burn/disposal area	58	X										X
Dunnage pits	18	X			X	X						
Flare & fuse disposal area / bird cage area	14	X		X			X					
Former pit area locations	57	X	X				X					
GB/VX decontamination solution burial areas	41	X		X			X					
GB/VX decontamination solution disposal areas	59											
Missile fuel storage areas	21			X								X
Munitions crate burn area	56	X										X
Open burning trays	32	X	X	X								X
Open burning trenches pads	19	X	X	X		X	X		X		X	
Open detonation pits	16	X	X	X			X					
Pesticide pits	31	X	X	X	X	X	X	X	X		X	
Pit field area	38	X	X	X					X			

Smoke canister disposal area	13	X	X	X		X	X					
TNT sludge burial & burn area	15	X	X	X		X	X		X			
Trench/burn field	55	X	X				X					
Deactivation furnace	1	X	X	X								X
Disposal pit & graded areas	80					X						X
Former raw materials storage location I	81	X										X
Hazardous waste storage facility (bldg 203)	3											X
Malathion storage leak area	35				X							X
Metal ingot stockpiles	26	X										X
Metal ore piles location I	25	X										X
Bldg 131 paint sludge discharge area	37	X				X						X
Paint spray & shot blast areas	34	X		X		X						X
Railcar unloading area	46	X				X						X
Road oil application/disposal site location I	44					X						X
Boiler/laundry effluent discharge site	47	X			X	X	X	X				
Bldg 493 paint sludge discharge area	36	X		X		X						X
Bldg 493 brass cleaning operation area	67	X					X					
Coyote Coulee discharge gullies	52	X	X									X
Explosive washout plant (bldg 489)	5		X	X								X
Explosive washout lagoons	4		X					X	X			
Pipe discharge area	48	X		X	X	X						X
Sewage treatment plant	6	X		X	X	X						X
Stormwater discharge area	30	X			X	X						X

Defense re-utilization marketing office area	22	X			X	X						X
Pesticide storage building	27	X			X	X						X
Road oil application/disposal sites location II	44					X						X
Inactive landfills	12	X			X	X	X	X	X			
Railroad landfill areas	50	X				X	X	X	X		X	
Active landfill	11						X	X	X		X	
Building 433 collection sump/cistern and disposal area	53	X				X						X
Building 612 and bldg 617 boiler discharge areas	45	X										X
Drill transfer site	49											X
Former agent H storage area	10	X				X						X
Former gravel pit/disposal location	82					X						X
Former raw materials storage location II	81											X
Gravel pit disposal area	33											X
Metal ore piles - location II	25	X										X
QA function range	39	X		X								X
Remote munitions disassembly/GB bomb disassembly area	9	X	X	X								X
Septic tanks	29	X				X						X
Storage igloos	2											X

Sources: Dawson and others, 1982
Ritchie and others, 1992
Mahannah and others, 1993
Machacek and others, 1993
Woodland and others, 1993
Brown and others, 1993

Appendix 3I

Umatilla Butte Landfill

Chronologic History

Wastes Disposed

Table 3I.1 Chronologic history of the Umatilla Butte Landfill site and operation.

Date	Activity
1905	The southern 40 acres of the current 80 acre lease was withdrawn for the Umatilla River Reclamation Project. The 40 acres were restored in 1952.
1935	The State of Oregon began quarrying a 40 acre site south of the current 80 acre lease.
1954	An unnamed placer mining claim was filed at the Bureau of Land Management (BLM). The claim includes the current 80 acre lease. No mining at the claim ever developed.
July 1956	BLM granted a Recreation and Public Purposes (R & P P) patent for 160 acres to Umatilla County. The patent permitted using the area as a community dumping pit, but BLM reserved all mineral rights for rock quarrying. Open garbage dumping by the public began.
1956 to 1961	Open dumping occurred near south exit of current landfill site.
1961 to 1971	Dumping occurred below active area of current landfill and in a gravel quarry north of the current landfill active area.
October 25, 1961	A free use permit was issued.
October 3, 1962	The free use permit is terminated, but open dumping continued illegally throughout the 160 acres through 1972.
March 9, 1965	The 160 acre parcel was quitclaim deeded back to the United States Government.
January 28, 1966	Title for the 160 acres returned to the United States Government, and the land was closed to entry. However, illegal open dumping continued.
unknown	The northern 40 acres of the current 80 acre lease was used as a quarry by an unknown user.
1970	The U.S. Government issued a complaint against the 1954 placer mine claim. The complaint received no answer. The claim was subsequently declared null and void, and the case closed on October 1, 1970. Umatilla County submitted a R & P P purchase application to the BLM for the southern 40 acres of the current 80 acre lease. The County wanted the land to develop a landfill.
1971	BLM visited the site in April in response to complaints about litter and smoke. Umatilla County adopted a solid waste ordnance. (DBA) Hermiston Sanitary Service used the current 80 acre lease site for garbage disposal prior to June 1971 without authorization. Umatilla county submitted a second R & P P application to change the County request from purchase to lease since the 40 acres was not available for purchase. BLM and DEQ urged the County to submit the application in order to legalize an existing open community dump and because the site was considered the only suitable location for waste disposal in the Hermiston area. BLM tentatively approved the application in June 1971.

June 1972	(DBA) Hermiston Sanitary Service sold the waste collection and disposal service to Sanitary Disposal, Inc.
March 1973	The Hermiston Landfill became authorized on March 1, 1973 under the R & P P lease issued to Umatilla County by BLM. Umatilla County granted a garbage collection service and landfill site operation franchise to Sanitary Disposal, Inc.
1974	Landfill operator prepared and submitted a feasibility report and modified solid waste facility permit application to DEQ.
unknown	DEQ issued a temporary solid waste disposal permit.
September 6, 1977	DEQ issued Solid Waste Disposal Permit Number 143 for the landfill.
1978	Landfill operator submitted operational plans for the solid waste landfill. The plans were approved.
1980	DEQ renewed Solid Waste Disposal Permit Number 143.
1983	Umatilla County filed a R & P P application on February 17, 1983 requesting an expansion of the landfill site from the existing 40 acres to the entire 160 acres administered by BLM. The County amended the application on March 28, 1983 to exclude 40 acres in eligible for landfill use because of a pre-existing material site right of way. BLM renewed the R & P P lease on March 1, 1983 for 40 acres previously granted to Umatilla County.
1984	Umatilla County further reduced the lease request from 120 to the current 80 acres on July 20, 1984, because the 40 acre tract excluded was not adjacent to the landfill tract, and the intended use of the site as a source of material to cover waste in the landfill did not conform with the R & P P Act. BLM issued a new R & P P lease to Umatilla County for the current 80 acre area on September 24, 1984. Only 10 of the new 40 acres would be available for landfill use under the lease.
1985	An operational plan for the landfill was submitted and approved. The landfill operator apparently decided to prohibit accepting hazardous waste, asbestos, and pesticide/herbicide containers (rinsed or unrinsed) at the landfill due to an inability to obtain insurance. Sanitary Disposal, Inc. sold the garbage collection service and landfill operation franchise to the Desert Winds, Inc., DBA Sanitary Disposal Landfill.
September 26, 1986	DEQ renewed Solid Waste Disposal Permit Number 143.
August 2, 1987	A hydrogeologic evolution of the landfill site prepared by a registered engineer was submitted to DEQ as required by the 1986 solid waste permit. The landfill operation began sampling groundwater from nearby wells as a result of the report. DEQ apparently did not respond to report recommendations.

1989	Disposing potato processing waste grease from the J. R. Simplot and the Lamb-Weston, Incorporated plants ended at the landfill in June 1989 after DEQ notified the landfill operator and the potato processing companies that the landfill could no longer accept the waste grease. DEQ issued a notice of solid waste permit compliance violations to Sanitary Disposal, Incorporated on July 29, 1989. The violations included no recycling container for tin cans and inadequate cover or soil stabilization to prevent waste exposure. DEQ issued an addendum to Solid Waste Disposal Permit Number 143 on October 19, 1989.
December 28, 1990	DEQ issued an addendum to Solid Waste Disposal Permit Number 143 related to Oregon waste tire rule revisions. The addendum made accepting and storing up to 2,000 waste tires possible.
1992	Advanced Sciences, Incorporated completed a regulatory compliance audit of the landfill for the BLM by submitting a final audit report to the BLM. DEQ issued an addendum to Solid Waste Disposal Permit Number 143 on October 2, 1992.

Sources: Advanced Sciences, Inc., 1992
BLM Case File Number OR-7200
DEQ File: Solid Waste Disposal Permit Number 143

Table 3I.2 Types of waste disposed at the Umatilla Butte Landfill.

Waste	Remarks
Municipal Solid Waste	This is the primary waste disposed at the landfill.
Hazardous Waste	There is no indication that hazardous waste disposal has occurred at the landfill site. However, lack of information by a previous operator and lack of site access control keeps open the possibility of hazardous waste disposal. In 1985, the landfill operator introduced policy prohibiting acceptance of hazardous waste, asbestos, and pesticide/herbicide containers (rinsed or unrinsed) due to operator's inability to obtain insurance.
Asbestos	Thirty bags of asbestos were delivered to the landfill in 1980.
Hospital Waste	Hospital waste was delivered to the landfill through March 1990.
Oil Sludge	Oil sludge from two Union Pacific Railroad water treatment plants was used for dust suppression from October 1976 to March 1978. The deliveries stopped by 1979.
Potato Processing Waste Grease	Potato processing waste grease disposal at the landfill ended in June 1989.
Septic Tank Sewage	From 1974 to 1983, pumpage from area septic tanks was disposed in 3 lagoons/ponds located near the current landfill entrance on the west side of the access road. Approximately 29,250 gallons of septic tank pumpage was disposed in the ponds between March and November 1977. The ponds were never closed properly. They were allowed to stand idle and vegetation re-established naturally.
Waste Oil	Waste oil may have been disposed in the landfill lagoons once prior to 1979.
Large Animal Carcasses	Large animal carcasses were disposed at the landfill during the 1970s.
Small Dead Animals	The landfill continues to receive small dead animals.
Combustible Manufacturing Waste	Combustible manufacturing waste from a nearby mobile home manufacturer was routinely burned in a pit until Oregon banned open burning in 1978.
White Goods, Metals, Wood	These materials are salvaged.
Source: Advanced Sciences, Inc., 1992	

Appendix 3J

Union Pacific Railroad

Accidents Reported to DEQ

Table 3J.1 Accidents and spills within the Union Pacific Railroad Hinkle Facility from 1978 through 1992 recorded in DEQ files.

Spill Date	Spill Material	Spill Volume	Available Comments / Summary
2-27-78	diesel	2,000 gallons	Spill occurred when a spout on a rail car broke off a car during car humping. From 500 to 700 gallons spilled onto the railroad bed, and 1,500 gallons were caught in drip pans and transferred to an oil separation system. Remaining diesel in the rail car was transferred to other rail cars.
4-7-78	phosphoric acid	unknown	Entire tank car spilled
11-20-78	diesel	6,000 gallons	A rail car ran into a fuel tanker which ripped off a belly unloading spout. The car was moved to an unloading area and placed over drip pans. About 6,000 gallons of diesel sprayed "all over" when a valve on the belly drop was opened. Most of the diesel went into a waste collection system, but approximately 650 gallons spilled around the tracks and pooled and soaked 12 inches into the frozen ground. The diesel pools were pumped, and the contaminated soil was excavated and spread thinly on railroad roads at the Hinkle facility.
1-31-79	diesel	14,000 gallons	A rail car impacted a 19,346 gallon tank car during humping at the Hinkle facility. The impact ruptured a seam at one end of the tank car. The tank car was moved nearly 2 miles to a fueling area where spilling diesel could be caught. An estimated 3,000 gallons of diesel were collected in an oil separation system, and 4,000 gallons of diesel were transferred to a storage tank. More diesel was collected by removing diesel soaked snow along track C38 and by placing adsorbent pads in a ditch where diesel oil ran out from the tracks.
5-11-79	diesel	1,000 gallons	A fuel tank ruptured when a rail car derailed. The spill was cleaned up with adsorbent pads.
8-19-79	diesel	1,200 gallons	All but 200 gallons of the spilled diesel seeped into the ground. Contaminated soil was apparently excavated and thinly spread at an oil sludge land application area at the Hinkle facility.
12-16-79	diesel	200 gallons	Approximately 200 gallons of diesel spilled from an oil/water separator plant at the Hinkle facility. The diesel discharged to a slough near the Umatilla River.
1-21-80	diesel	4,000 gallons	The spill originated from a fuel tank (car?). Railroad employees recovered 1,000 gallons, and adsorbent pads collected an additional 150 gallons. Contaminated soil was removed from the spill site.
6-14-80	diesel	1,000 gallons	The spill occurred when a fuel unloading pump was left on and diesel spilled onto the ground. Approximately 850 gallons were recovered. Saturated railroad bed material was apparently distributed on railroad property roads for dust control.
2-9-81	scrap lube oil	100 gallons	The spilled oil jelled on the ground in the cold weather allowing cleanup with shovels. The oil penetrated the soil 0.5 inches only. The contaminated soil was collected in a dumpster and disposed at a Hermiston landfill.
4-24-81	waste fuel oil	10 gallons	Source of spill is unknown

6-2-81	diesel	unknown	Pooled diesel was removed by pumper truck and apparently sent to a Union Pacific Railroad oil reclaiming facility. Contaminated soil was excavated and spread on gravel roads at the Hinkle facility.
6-28-81	diesel	3,500 gallons	The diesel spill was caused by a train collision and derailment.
7-3-81	lube oil	400 gallons	Oil spill occurred when a tank rail car tipped over.
7-14-81	diesel	500 gallons	Diesel spill occurred when a tank (rail car?) was overfilled.
7-23-81	hazardous waste	less than 1 gallon	A leaking valve was the source of the spill.
8-25-81	diesel	50 gallons	The spill occurred when a fuel loading shut off valve failed.
10-18-81	diesel	3,500 gallons	A derailment caused the diesel spill. Approximately 2,500 gallons was pumped from the ground surface. The remaining diesel soaked into fresh railroad bed material. Apparently, holes were dug into the material; the diesel would accumulate in the holes, and the diesel was pumped out. The recovered diesel was apparently sold to an oil recycler.
12-2-81	diesel	50 gallons	A derailment caused the spill.
12-11-81	hazardous waste liquid sludge	unknown	The spill occurred when a wheel was lost.
1-2-82	diesel	1,600 gallons	The spill source was a leaking tank rail car.
1-5-82	diesel	small amount	The spill occurred when a refrigerator car derailed.
1-20-82	diesel	3,600 gallons	The spill came from a railroad tank car that began leaking after it was filled. The car had been moved around the Hinkle facility before the lead was discovered. Approximately 500 gallons leaked at the area where the tank car sat longest. The car was moved to drip pads and saturated soil was removed from the area where the tank car sat longest. The soil was apparently spread on gravel roads at the Hinkle facility.
4-6-82	diesel	unknown	A derailment caused the spill.
9-1-82	oil	400 gallons	
2-5-83	creosote and phenol	4,600 gallons	A rail car leaked the creosote and phenol over 530 miles.
9-7-83	diesel	50 gallons	The spill occurred when a rail tank car was over filled.
9-7-83	diesel	25 to 75 gallons	The spill occurred when a locomotive was overfilled.
10-13-83	diesel	less than 50 gallons	The spill occurred when a valve failed to shut off.
12-16-83	lube oil	50 to 75 gallons	A railroad tank car overflow caused the spill.

11-11-84	diesel	200 gallons	A ruptured engine fuel tank caused the spill.
3-11-85	diesel	200 gallons	The spill occurred when an engine derailed.
4-3-85	diesel	20 gallons	An engine derailment caused the spill.
8-23-85	Anhydrous Ammonia	unknown	The spill came from a leaking railroad tank car.
9-8-85	diesel	2,000 gallons	
10-11-86	diesel	1,000 gallons	A derailment ruptured a locomotive fuel tank which caused the spill.
3-14-88	caustic acid	100 gallons	The spill came from a leaking valve on a railroad tank car.
4-12-88	sulfuric acid	0.5 gallons	The acid splashed from a tank car, but it never hit the ground.
6-10-88	diesel	unknown	DEQ staff inspection of fueling area noted spill containment pans had overflowed, run down an embankment, and discolored the soil without ever being reported. DEQ issued a Notice of Violation on September 26, 1988.
6-23-88	diesel	30,000 to 50,000 gallons	A malfunctioning safety valve caused the spill.
6-24-90	diesel	1,000 gallons	The spill occurred during fueling of a locomotive.
9-24 or 9-25-90	diesel	1,000 gallons	DEQ issued a Notice of Noncompliance on October 7, 1990, because the railroad did not report the spill until October 4, 1990, the railroad delayed cleanup, and the railroad failed to submit a cleanup report.
12-31-90	diesel	3,000 gallons	
3-12-92	lube oil	60 gallons	
4-12-92	diesel	150 gallons	
5-6-92	diesel	100 gallons	
10-20-92	diesel	250 gallons	
11-1-92	diesel	500 gallons	
11-25-92	diesel	1,000 gallons	

Sources: DEQ Environmental Cleanup Site File 516
DEQ Environmental Cleanup Site Information System Database
DEQ Environmental Cleanup Miscellaneous Spill Response Activity Files
DEQ Water Quality File 90860

Appendix 3K

Accidents and Spills within the Lower Umatilla Basin Reported to DEQ

Table 3K.1 Accidents, spills, and leaks in the Lower Umatilla Basin from 1981 through 1992 reported to the Oregon Department of Environmental Quality.

Spill Date	Location	Responsible Party	Type/Amount Spilled	How Spill Occurred
11/25/92	Union Pacific RR	Union Pacific RR	1,000 gal diesel	unknown
11/1/92	Union Pacific RR	Union Pacific RR	500 gal diesel	unknown
10/20/92	Union Pacific RR	Union Pacific RR	250 gal diesel	unknown
9/19/92	Hermiston	unknown	? gal raw sewage	unknown
6/30/92	Hermiston High School	unknown	chlorine	unknown
6/4/92	Hermiston Foods	Hermiston Foods	~75 gal hydraulic fluid	unknown
5/7/92	Price Less Gas 711 6th Umatilla or Hwy 395 & Hwy 730 intersect	unknown	~40 gal gasoline	unknown
5/6/92	Union Pacific RR	Union Pacific RR	~100 gal diesel	unknown
4/12/92	Union Pacific RR	Union Pacific RR	150 gal diesel	unknown
3/12/92	Union Pacific RR	Union Pacific RR	60 gal lube oil	unknown
3/11/92	Big River Farms	Big River Farms	unknown open Bu	unknown
1/11/92	J. R. Simplot Co. Hermiston	J. R. Simplot Co.	20 gal diesel	unknown
1992	Buck's Corner	unknown	? gal gasoline	unknown
?	Hermiston H. S.	Hermiston H. S.	Heavy oils, gas	unknown
STET	STET	unknown STET	STET	unknown
9/27/91	Irrigon	Strebin Farms	plastic	unknown
9/19/91	J. R. Simplot Co. Hermiston	J. R. Simplot Co.	40-70 gal diesel	unknown
8/25/91	Oregon State Police McNary	Oregon State Police	450 gal gasoline	unknown
7/27/91	Hermiston (airport?)	Nyssa Air Service	50-100 gal area ammonia NI	unknown

6/14/91	Hermiston Foods Echo-Hermiston	Hermiston Foods	42-60 gal hydraulic fluid	unknown
6/3/91	Oregon Dept. of Trans. Hermiston	Oregon Dept. of Transportaton	55 gal Trichloroethane	unknown
5/20/91	City of (STP?) Umatilla	City of Umatilla	100,000-150,000 gal sewage	unknown
3/14/91	Lamb-Weston Boardman	Lamb-Weston	3 gal hydraulic oil	unknown
2/25/91	Port of Morrow	Port of Morrow	3-5 gal hydraulic oil	unknown
1/10/91	Airco Gases Hermiston	Airco Gases	Argon Refrigera.	unknown
12/13/90	Union Pacific RR Hinkle Yard	Union Pacific RR	3,000 gal diesel	unknown
9/14/89	Hwy 730 & Hwy 395	Flying J, Inc.	640 gal diesel	fitting came loose
9/6/89	UPS Station Hermiston	-	1 gal malathion	delivery container broke
6/30/89	Hermiston Rd. & Feedville Rd.	unknown	300 gal fuel	Accident Truck Back-up
1/21/89	Hwy 82, MP 40-5	unknown	15 gal diesel	Truck Wreck
1/9/89	1085 W. Highland Hermiston	unknown	25 gal gas	storage tank fell off truck
12/22/88	Hwy 395 MP-3 Hermiston	unknown	50 gal diesel	truck wreck
12/19/88	I-84 & I-82 9 mi. W. of Hermiston	unknown	low level radioactive waste	truck wreck no spill
6/23/88	Union Pacific Rr Hinkle Yard	Union Pacific RR	30 to 50,000 gal diesel	LUST Safety Value Malfunction
5/12/88	Union Pacific RR Hinkle Yard	Union Pacific RR	1/2 gal sulfuric acid	splashed from tank car - did not hit ground
3/14/88	Union Pacific RR Hinkle Yard	Union Pacific RR	100 gal caustic acid	leaking valve on tank car
2/9/88	McNary Substation	BPA	70 gal PCB at 940 ppm	transformer exploded
5/26/87	Electric Substation 3-4 mi. E. of Boardman	BPA	6 cups unknown lab chemicals	placed in garbage - bottle broke w/garbage pick-up - water added caused fire
1/9/87	Hwy 730 MP 169	David Vanlity	75 gal diesel	truck accident
10/11/86	Union Pacific RR Hinkle Yard	Union Pacific RR	1,000 gal diesel	derailment ruptured locomotive fuel tank

4/24/86	I-84 MP 180 30 mi. W. Pendleton unknown	unknown	ammonium nitrate diesel/unknown	unknown
3/5/86	Hwy 207 & E. Walls Rd. Crossing	Lamb-Weston	20 gal diesel	truck accident
1/16/86	Hwy 395 & I-84	Aster Camp Trucking	100 gal diesel	truck accident
1/1/86	Downtown Stanfield	American Transport	1,000 gal diesel	truck overturned
11/20/85	Hwy 30 & Brownhill Rd.	unknown	30-40 gal diesel	truck jack-knife
11/5/85	0.5 mi. west of Umatilla on Hwy 30	unknown	gas & diesel unknown	truck accident
9/8/85	Union Pacific Rr Hinkle Yard	Union Pacific RR	2,000 diesel	unknown
8/23/85	Union Pacific RR Hinkle Yard	Union Pacific RR	Anhydrous Ammonia unknown	tank car leak
7/18/85	MP 9.5 just north of Stanfield	unknown	5 gal monitor 4	found along side road: unknown
4/3/85	Union Pacific RR Hinkle Yard	Union Pacific RR	20 gal diesel	derailed engine
3/20/85	Hwy 763 by Irrigon	unknown	<80 gal diesel	truck tank leak
3/11/85	Union Pacific RR Hinkle Yard	Union Pacific RR	200 gal diesel	engine derailment
2/14/85	I St., City of Umatilla, RR crossing	Union Pacific RR	3,000 to 4,000 gal diesel	broken rail punctured fuel tank
1/20/85	I-84 near MP 198 westbound	unknown	jet fuel unknown	truck leaking truck accident
11/11/84	Union Pacific RR Hinkle	Union Pacific RR	200 gal diesel	ruptured engine fuel tank
9/10/84	W. of Echo	Union Pacific RR	150 gal diesel	leaked over 1/4 mile of tracks: vandalism
3/25/84	Hermiston	PP&L	<5 gal Transformer oil non-PCB	blown transformer
12/16/83	Union Pacific RR Hinkle Yard	Union Pacific RR	50-75 gal lube oil	tank overflow
10/13/83	Union Pacific RR Hinkle Yard	Union Pacific RR	<50 gal diesel	failed to shut off valve
9/7/83	Union Pacific RR Hinkle Yard	Union Pacific RR	25-75 gal diesel	overfilled locomotive
9/7/83	Union Pacific RR Hinkle Yard	Union Pacific RR	50 gal diesel	tank overfill
8/24/83	201 Orchard St. Hermiston	Pendleton Grain Growers	200 gal unleaded gas	tank overfill

4/12/83	between Pendleton & Hinkle	Union Pacific RR	50 gal diesel	spilled over 1/4 mile of track
4/6/82	Union Pacific RR Hinkle Yard	Union Pacific RR?	diesel unknown	train derailed
3/21/83	between LeGrande & Hinkle	Union Pacific RR	oil-diesel small amount	broken fuel pump
2/5/82	Union Pacific RR Hinkle Yard	Union Pacific RR	4,600 gal creosote & phenol over 530 mi.	railcar leak
12/28/82	Hermiston	Union Pacific RR	Fuel	broken line
10/13/82	Port of Umatilla Forest Recovery	B-C & Forest Recovery	100 gal diesel	accident
9/17/82	101 SW Frontage Rd. Boardman	Russell Oil Co.	400 gal gas	transferring fuel valve stuck
9/1/82	Union Pacific RR Hinkle Yard Pump House	Union Pacific RR	400 gal oil	unknown
6/9/82	1.5 mi. NW of Hermiston	unknown	herbicide or pesticide	train derailed
3/23/82	between Boardman & Hinkle	Union Pacific RR	3.75 gal engine lube oil	broken oil line
1/5/82	Union Pacific RR Hinkle Yard	Union Pacific RR	small amount #2 diesel	derailed refrigerator car
1/2/82	Union Pacific RR Hinkle Yard	Union Pacific RR	1,600 gal diesel fuel	leaking tank car
12/11/81	Union Pacific RR Hinkle Yard	Union Pacific RR	liquid sludge HW unknown	lost wheel transporting lat yards
12/2/81	Union Pacific RR Hinkle Yard	Union Pacific RR	50 gal diesel	derailed train
10/18/91	Union Pacific RR Hinkle Yard	Union Pacific RR	3,500 gal diesel	derailment
8/25/81	Union Pacific RR Hinkle Yard	Union Pacific RR	50 gal diesel	fuel loading - shut off valve failed
7/24/81	Stanfield STP	Stanfield STP	sewage unknown	broken water main
7/24/81	Union Pacific RR Hinkle Yard	Union Pacific RR	methylene chloride vapor	loose hatch on top of tank car
7/23/81	Union Pacific RR Hinkle Yard	Union Pacific RR	HW <1 gal	valve leaking
7/14/81	Union Pacific RR Hinkle Yard	Union Pacific RR	500 gal diesel	tank overfill
7/3/81	Union Pacific RR Hinkle Yard	Union Pacific RR	400 gal lube oil	tank car being moved tipped over
6/28/81	Union Pacific RR Hinkle Yard	Union Pacific RR	3,500 gal diesel	train collision & derailment

4/24/81	Union Pacific RR Hinkle Yard	Union Pacific RR	10 gal waste fuel oil	unknown
3/17/81	Powerline Rd. Outside Hermiston	unknown	1,000 gal 32 solution fertilizer	truck accident
3/8/81	Stanfield STP	Stanfield STP	90,000 gpd sewage	lift station flooded out
2/9/81	Union Pacific RR Hinkle Yard	Union Pacific RR	100 gal scrap lube oil	unknown

Source: DEQ Environmental Clean-up Miscellaneous Spill Response Activity Files

Appendix 3L

Hazardous Waste Handlers within the Lower Umatilla Basin

Table 3L.1 Facilities generating or handling hazardous waste in the Lower Umatilla Basin.

Facility	Location	EPA ID	SIC Code	Permit and Generator Status
Boeing Agri Industrial Co.	Tower Rd. 6 miles South of I-84 Boardman, OR 97818	ORD981769136	3721	Conditionally Exempt Generator
Finley Buttes Landfill	I-84 Exit 168 10 mi S Bombing Range Rd Boardman, OR 97818	ORD987199643	4953	Conditionally Exempt Generator
Lamb Weston Inc. Boardman Plant	Columbia Ave & Olsen Rd Boardman, OR 97818	ORD981769987	2037	Conditionally Exempt Generator
Portland General Electric Co.	Tower Rd Boardman, OR 97818	ORD088592233	4911	Small Quantity Generator
2 Hour Cleanery	892 HWY 395 S Hermiston, OR 97838	ORD987187564	7216	Conditionally Exempt Generator
Columbia Autobody & Paint	955 N 1st PL Hermiston, OR 97838	ORD156919631		Conditionally Exempt Generator
Hermiston High School	600 S 1st Hermiston, OR 97838	ORD982659120	8211	Conditionally Exempt Generator
JR Simplot Company Food Group	Hinkle Junction Rd Hermiston, OR 97838	ORD070722863	2037	Small Quantity Generator
Lamb Weston Inc. Hermiston Plant	Westland Rd Hermiston, OR 97838	ORD065273427	2037	Conditionally Exempt Generator
Marlette Homes, Inc.	400 West Elm Hermiston, OR 97838	ORD006536247	2451	Conditionally Exempt Generator
Northwest Pipeline/ Hermiston Meter Stn	T5N, R28E, Sec. 35 Hermiston, OR 97838	ORD987175148	4922	Conditionally Exempt Generator
ODOT Hwy Div Hermiston Maintenance	1840 S HWY 395 Hermiston, OR 97838	ORD987191897	1611 7538	Large Quantity Generator
Pioneer Implement Corp.	HWY 207/Butter Creek HWY Hermiston, OR 97838	ORD061493136	3523 3524	Conditionally Exempt Generator
Sherrell Chevrolet	296 E. Main St. Hermiston, OR 97838	ORD027654151	5511	Conditionally Exempt Generator

USA Umatilla Depot Activity	I-84 & Exit 178 Hermiston, OR 97838-9544	OR6213820917	7538 9711	Large Quantity Generator Treatment Storage
USA Umatilla Depot Activity	I-84 & Exit 178 Hermiston, OR 97838-9544	OR6213820917	7538 9711	Small Quantity Generator Treatment Storage
USWCOM Hermiston Serv Ops	999 E Elm Hermiston, OR 97838	ORD103010070	4813	Conditionally Exempt Generator
Umatilla Electric Coop Association	750 W Elm St Hermiston, OR 97838	ORD041268376	4911	Conditionally Exempt Generator
Wares Auto Body Inc.	885 N 1st Place Hermiston, OR 97838	ORD980983530		Conditionally Exempt Generator
Countrywide Truck Service Inc.	295 NE 7th Irrigon, OR 97844	ORD982659211		
Eastern Oregon Farming Co.	Paterson Ferry Rd Irrigon, OR 97844	ORD059403089	111 115 191	Conditionally Exempt Generator
Western Empires Corp.	Paterson Ferry Rd Rt 2 Box 230 Irrigon, OR 97844	ORD065264020	191	Small Quantity Generator
Mikami Bros. Farm	Despain Gulch Rd Stanfield, OR 97875	ORD082626573	111 191	Conditionally Exempt Generator
Mills Mint Farm Inc.	Loop Rd. Stanfield, OR 97875	ORD070730007	191 212	Conditionally Exempt Generator
PGT Stanfield City Meter Station	Hinkle Rd, 1 mi NW/O Sherman St. Stanfield, OR 97875	ORD987198934	4922	Conditionally Exempt Generator
PGT Stanfield Meter Station	.8 MI E of Stanfield Loop Rd Stanfield, OR 97875	ORD987185584	4922	Conditionally Exempt Generator
USWCOM Stanfield Co.	Stanfield, OR 97875	ORT420010852	4813	Conditionally Exempt Generator
Boise Cascade Corp. Umatilla Chipper	Port Industrial Pk Umatilla, OR 97882	ORD079933750	2499	Conditionally Exempt Generator
Crop Production Services Inc.	321 5th St. Umatilla, OR 97882	ORD045769551	5191	Conditionally Exempt Generator
Simplot Soil Builders	1013 Old River Rd. Umatilla, OR 97882	ORD096251392	711 721 782	Conditionally Exempt Generator
Tidewater Terminal Company	535 Port Ave. Umatilla, OR 97882	OR0000255182	4226	Small Quantity Generator

USACE McNary Project	Columbia River MI 292 Umatilla, OR 97882	OR2960010690	4911	Small Quantity Generator
USWCOM Umatilla Co.	7th & J St. Umatilla, OR 97882	ORT420010894	4813	Conditionally Exempt Generator

Source: Oregon Department of Environmental Quality Hazardous Waste Generator and Permit Database

Table 3L.2 Facilities with potentially hazardous and toxic substances which would need specialized attention in a fire or spill event.

Facility	Location	EPA ID	Parent Company	Chemical Name	Tri Chm id	Sic Code
Lamb-Weston, Inc.	Columbia Ave. & Olson Rd. Boardman, OR 97818	ORD981769987	Conagra	Ammonia	007664417	2037
Lamb-Weston, Inc.	Westland Rd. Hermiston OR 97838-0705	ORD065273427	Conagra	Sulfuric Acid	007664939	2037
Lamb-Weston, Inc.	Westland Rd. Hermiston, OR 97838-0705	ORD065273427	Conagra	Chlorine	007782505	2037
Lamb-Weston, Inc.	Westland Rd. Hermiston, OR 97838-0705	ORD065273427	Conagra	Ammonia	007664417	2037
J.R.Simplot Co.	Hinkle Junction Rd. Hermiston, OR 97838-0850	ORD070722863	J.R.Simplot Co.	Chlorine Dioxide	010049044	2037
J.R. Simplot Co.	Hinkle Junction Rd. Hermiston, OR 97838-0850	ORD070722863	J.R.Simplot Co.	Chlorine	007782505	2037
J.R.Simplot Co.	Hinkle Junction Rd. Hermiston, OR 97838-0850	ORD070722863	J.R.Simplot Co.	Ammonia	007664417	2037
A.E. Staley Mfg. Co.	Hoosier Ln. Stanfield, OR 97875	NA	NA	Hdyrochloric Acid	007647010	2046

Source: Oregon State Fire Marshall Toxic Release Inventory Database

Appendix 3M

Underground Storage Tanks within the Lower Umatilla Basin

Table 3M.1 Underground storage tanks in the Lower Umatilla Basin on file at the Oregon Department of Environmental Quality.

Facility ID Number	Facility Name	Address, City, Zip	Number of Permitted Tanks	Number of Active Tanks	Number of Decommissioned Tanks
9999	Baker, Harold C.	Rt 1, Box 49-F Kunze Rd, Boardman, 97818	1		1
7079	Boardman Conoco	101 SE Front, Boardman, 97818	5	5	
6519	Boardman Mobil Service	100 Front NW, Boardman, 97818		4	
5779	Boardman Park & Recreation Dist	100 W Marine Dr, Box 8, Boardman, 97818		2	
833	Boardman Plant	Tower Road, Boardman, 97818	9	3	6
5066	Boardman Texaco	100 Main St N, Boardman, 97818	4	4	1
8460	Boardman, City of - Sewer System	Columbia Ave at N Main St, Boardman, 97818	1	1	
8461	Boardman, City of - Sewer System	Columbia Ave at Rippee Rd, Boardman, 97818	1	1	
8459	Boardman, City of - Sewer System	SW Front ST - Wildlife AR, Boardman, 97818	1	1	
4240	Boardman, City of - Water Plant	Marine Dr, Boardman, 97818	1	1	
8207	Boeing Aerospace Co, Boardman Tes	Tower Rd, Boardman, 97818	2	2	
9888	Boardman Chip Re-Load	20 Marine Dr, P.O. Box 615, Boardman, 97818	1		1
11242	Coyote Springs Project	Port of Morrow Industrial, Boardman, 97818			
244	Dewey's Chevron	101 N Main, Boardman,97818	5	5	
3018	Homestead Road	Morrow, Boardman, 97818	2		2
7435	Lamb-Weston Inc.	Columbia Ave NE, Boardman, 97818	2		2
10028	Naval Weapons System Training Facility	Boardman, 97818	2		2
5190	Rivercrest Farms, Inc.	Bombing Range Rd., Boardman, 97818	2	2	2
4901	Riverside High School	Box 140 Boardman Ave, Boardman, 97818			2

8882	Russell Oil Cardlock	Laurel Lane I84 Exit 165, Boardman, 97818	6	6	
4188	Russell Oil Co	101 SW Front, Boardman, 97818	8	8	
2228	Sharkey, William P.	306 Olsen Rd, Boardman, 97818			1
5424	Simplot Livestock	Three-Mile Canyon Rd, Boardman, 97818	4	4	
9849	Taggares Farms, Inc.	Rt 1 Box 1120, Boardman, 97818	4	1	3
3391	U & I Group Inc	Columbia Ave, Boardman, 97818			1
8311	Union Pacific RR - Boardman Tool	MP 164.2, Boardman, 97818	1		1
8323	Union Pacific RR - Castle Tool HO	Castle Section, Boardman, 97818	1		1
9271	Amstad Farms	Star Rt, Echo, 97826	2	2	
8844	Eagle Ranch	HC70, Box 110, Echo, 97826	2	2	
6539	Echo Mobil Station	Main St, Echo, 97826	3	6	
6542	Echo Plant	Willow & Thielson St, Echo, 97826	4	4	
3033	L & L Farms	Hwy 320 1 mile E of Madison, Echo, 97826	2	2	
3036	Madison, Kent	HC 70 Box 304, Echo, 97826	1		1
4872	Macatee, Kaye	Rt 2, Box 11A, Echo, 97826	1	1	
9421	McCarty, Mike	Star Rt, Echo, 97826	1	1	
9226	Sixty-Six Ranch	Star Rt, Echo, 97826	3		3
10566	Union Pacific RR - Barnhart Station	Hwy 84 Near Echo, Echo, 97826			1
7272	West Flying Service, Inc.	HC 70, Box 322, Echo, 97826	5	5	
8389	7th & Main Pump Station	100 NE 7th, Hermiston, 97838	1	1	
6079	AM/PM #63	1050 Hwy 395S, Hermiston, 97838	3	3	5
6190	Astro Western #501/Short Stop Market	Rt 3, Canal Rd, Hermiston, 97838	3		3
3081	Aylett, J	Rt 1, Box 818, Hermiston, 97838	2		2

4841	Best Way Equipment Rental & Sales	Rt 2, Box 2376, Hermiston, 97838			2
8630	Big Bend Truck Stop	256 E Hurlburt Ave, Hermiston, 97838		3	
2645	Bill Wolfe Ranches	Rt 2, Box 2743, Klaus Lane, Hermiston, 97838	2	2	
5275	Blue Chimney Truck Stop	Hermiston-McNary Hwy, Hermiston, 97838	7		7
10093	Blue Mountain Asphalt	W Bensel Rd, Hermiston, 97838	1	1	
10427	Brock, Courtland	230 SW 11th, Hermiston, 97838			4
5348	C & B Livestock Inc.	Butter Creek Hwy, Hermiston, 97838	3	3	
3218	Campbell Motors, Inc.	P.O. Box 87, Hermiston, 97838	4	4	
2461	Carroll, Dwayne M.	Rt 1, Box 1816, Hermiston, 97838	1	1	
10319	Cer Pril Industries	1855 NW 7th, Hermiston, 97838	1		1
10034	Circle 'C' Cubing Inc	Feedville & Hinkle Rd, Hermiston, 97838	2		2
8805	Circle C Farm	Hermiston, Hermiston, 97838	3		3
4359	Coachman Housing of Oregon	400 W Elm, Hermiston, 97838			1
6504	Copeland Lumber Yards Inc	Rt 2 Box 2557, Hermiston, 97838	1		1
9908	Deseral Ind, Inc	845 E Ridgeway, Hermiston, 97838	2	2	
10262	Dority Used Cars	255 S Hwy 395, Hermiston, 97838			1
2409	Dres-well Cleaners	379 E Main, Hermiston, 97838	1		1
11342	Estate of Ethel O Hagg	Hwy 395, Hermiston, 97838			2
10253	Ferguson Trucking	Rt 4 Box 4116, Hermiston, 97838	2		2
969	Former Chevron USA Inc - 96443	105 N 1st, Hermiston, 97838	4		4
6380	Goo Inc	905 Diagonal Blvd, Hermiston, 97838	2		2
8640	Gotta Stop Mini Mart	1580 Highland, Hermiston, 97838	2	2	
10164	Growers Fertilizer Inc	445 W Elm Ave, Hermiston, 97838			2

6844	Harley Swain Subaru	1915 N 1st, Hermiston, 97838	1		1
6486	Heller & Son Dist Inc	615 N 1st, Hermiston, 97838	4	4	5
9942	Hermiston Airport	Airport Way, Hermiston, 97838	3	3	2
6042	Hermiston C O - 010283	105 SE 3rd, Hermiston, 97838	1	1	
2215	Hermiston Gas & Deli-Time Oil Co	Hwy 32, Hermiston, 97838	4	4	
10343	Hermiston Glass	1895 N 1st Pl, Hermiston, 97838	1		1
10123	Hermiston Irrigation District	366 E Hurlburt, Hermiston, 97838	2		2
4154	Hermiston Shell Bulk Plant	615 N 1st Pl Box 865, Hermiston, 97838			2
6224	Hermiston Soc - 010446	999 E Elm, Hermiston, 97838	3	3	
8962	Hermiston Texaco	710 Hermiston Ave W, Hermiston, 97838	4	4	
8390	Hermiston, City of WWTP	205 N 1st Pl, Hermiston, 97838	1	1	
5854	Hermiston, City of - Public Safety	330 S 1st, Hermiston, 97838	2		2
10520	Housing Authority of Umatilla County	155 SW 10th St, Hermiston, 97838	1	1	
4425	JR Simplot - Food Division	Hinkle Jct Rd, Hermiston, 97838	4	4	
7507	JR Simplot Maint & Trucking	Box 1000 Buttercreek Hwy, Hermiston, 97838	4	4	
3031	Kasari Trucking Inc	200 NE 7th Butter Creek, Hermiston, 97838	2		2
4040	Lamb Weston Inc - Hermiston Plant	Westland Rd, Hermiston, 97838	2		2
4275	Leathers Oil Co	1655 N 1st St, Hermiston, 97838	4	4	
2809	Mull Tin Shop Inc	290 W Marie Dr, Hermiston, 97838	1		1
6132	Netarts Bay Inc	1235 N 1st, Hermiston 97838	3	3	
7836	New Holland Inc	Feedville Rd, Hermiston 97838	1		1
5334	NW Agricultural Coop Assoc	NACA Terminal N - 1 Blk, Hermiston 97838	1		1
930	OR State Hwy 5 -12 Hermiston	450 S 1st & 1840 Hwy 390S, Hermiston 97838	4	4	4

7832	Oregon Bearing Supply Co	435 NW 11th St, Hermiston 97838	1		1
4199	Oregon Bushops Central Storehouse	455 E Feedville Rd, Hermiston 97838	2	2	
518	Pacific Power & Light	705 S 1st St, Hermiston 97838			1
772	Parks, Hat Rock	Hat Rock, Hermiston 97838	1		1
6154	Pendleton Grain Growers Inc	101 Orchard, Hermiston 97838	5	4	1
6161	Pendleton Grain Growers Inc	101 Orchard, Hermiston 97838	1		1
6158	Pendleton Grain Growers Inc	200 SW 1st Pl, Hermiston 97838	1		1
6153	Pendleton Grain Growers Inc	Feedville Rd, Hermiston 97838	5	5	
6152	Pendleton Grain Growers Inc	Feedville Rd - Feedville, Hermiston 97838	2		2
2693	Phipps Chevron Service	200 N Hwy 395, Hermiston 97838	6	3	3
3679	Pioneer Implement Corp	Buttercreek Hwy, Hermiston 97838	2		2
5559	Public Works	1100 NE 4th, Hermiston 97838	3	3	
9833	Quimby Trucking Inc	1350 E Airport Rd, Hermiston 97838	1	1	
10699	Ramona Brown	1835 N 1st Pl, Hermiston 97838			3
4456	Reher's Service	205 S Hwy 395, Hermiston 97838	4	4	
3144	Rohrman Motor Co	555 S Hwy 395, Hermiston 97838	3		3
10120	Ross Machine & Iron Works Inc	1585 N 1st, Hermiston 97838	1	1	
3021	Royale Columbia Farms Inc	P.O. Box 93, Hermiston 97838	1		1
7990	Sanitary Disposal Inc	Hwy 395, Hermiston 97838	2		2
10142	Sherrell Chevrolet	296 E Main, Hermiston 97838	3		3
9494	Short Stop #1	Punkin Center & Diagonal, Hermiston 97838	3	3	3
4312	Sun Mart	1430 N 1st, Hermiston 97838	3	3	
10092	Superior Farms Inc	Rt 3 Box 3734 B, Hermiston 97838	2	2	

8893	T & J Kosmos Farms	Hwy 37 MP 4, Hermiston 97838	2	2	
6475	Umatilla Electric Coop Assoc	1725 N 1st, Hermiston 97838	4		4
6477	Umatilla Electric Coop Assoc	750 W Elm St, Hermiston 97838	5	4	1
9998	Union Pacific Railroad	Hinkle Yard, Hermiston 97838	3	10	
8307	Union Pacific Railroad - Cold Springs S	Tool House, Hermiston 97838	1		1
4767	U.S. Army Umatilla Depot Activity	Umatilla Depot, Hermiston 97838	3	3	3
5564	Van Schoiack Oil Inc	505 N 1st Pl, Hermiston 97838	2		2
10328	Walchli, Patrick	Rt 5, Box 5192, Hermiston 97838	3	3	
7944	Walchli, John F	Rt 3, Box 3342, Hermiston 97838	4	4	
8388	Westside Pump Station	W Madrona & 13th, Hermiston 97838	1	1	
9477	Wondrack Distributing	55 W Elm, Hermiston 97838	4	4	
4894	AC Houghton Elem School	Main St Irrigon 97844			2
8815	Boardman Farm - Feed Lot	Paterson Ferry Road, Irrigon 97844	2	2	
8814	Boardman - Main	Paterson Ferry Road & Hwy 7, Irrigon 97844	2	2	
1331	Browns Auto & Truck Shop	300 SE Hwy 730, Irrigon 97844	5	5	
2506	Comino American Inc	Rt 2 Box 241, Irrigon 97844		1	
1580	D Jorgenson Trucking Inc	2nd St & Hwy 730, Irrigon 97844		1	
4264	Eastern Oregon Farming Co	Paterson Ferry Rd at I 84, Irrigon 97844	11		11
515	Irrigon Fish Hatchery	Riverside Ave W, Irrigon 97844	3	3	
368	Irrigon TD-2 IRGNORQ1160	Pole Line Rd - LON 119-32, Irrigon 97844	1		1
22	Irrigon, City of	520 SE Southmain Ave, Irrigon 97844	2		2
6485	Morrow County Grain Growers	Paterson Ferry Rd, Irrigon 97844			1
11268	Morrow County Road Dept - Irrigon	215 Main St, Irrigon 97844	2		2

7760	U.S. Fish & Wildlife Service Shop	W of Paterson Ferry Rd, Irrigon 97844	2	2	
4336	West Extension Irrigation District	P.O. Box 465, Irrigon 97844	1		1
5552	Western Alfalfa, Inc	Rt 2, Box 242, Irrigon 97844	1		1
9186	Western Empires HQ	Paterson Ferry Rd, Irrigon 97844	2	2	
10895	Moyer, Del	Boulder Rd & Hwy 395, Power City 97882			2
3040	Mikami Brothers	Despain Gulch Rd, Stanfield 97875	3	3	
3042	Mills Mint Farm, Inc.	Rt 1 Box 84, Stanfield 97875	2	2	
10326	Shirley, Geraldine	Rt 1 Box 157, Stanfield 97875	1	1	
6526	Stanfield Bonoco	310 S Main St, Stanfield 97875	5	3	2
3133	Stanfield Hardware	165 S Main, Stanfield 97875			2
25	Stanfield Sewer Treatment Plant	245 Old Hinkle Road, Stanfield 97875	2		2
2209	Time Oil Co	Main & Harding, Stanfield 97875	4	4	
9066	Umatilla County Road Dept	Box 22, Stanfield 97875	2		2
10186	AM/PM Arco of Umatilla	1800 6th St, Umatilla 97882	5	5	
7384	Arrowhead Truck Plaza	Hwy 84 & Exit 216, Umatilla 97882		8	
3274	BN RR - Athena 358	MP 13 LS 451 15th Sub, Umatilla 97882			1
3361	C & B Livestock Inc	Powerline Rd, Umatilla 97882	2	2	
4744	Cenex Soil Service Center	621 5th St, Umatilla 97882	2		2
11045	Corps of Engineers, McNary Project	2 miles E of Umatilla McNary, Umatilla 97882			2
9630	Crossroads Truck Stop Inc	Hwy 730 & Bridge Jct, Umatilla 97882	7	3	4
6629	Fletchers Oil Co	6th & 'G' St, Umatilla 97882	3	3	
10082	Forest Recovery Inc	Port of Umatilla Industry, Umatilla 97882			2
6333	G & S Chevron	1010 6th St, Umatilla 97882	4	4	

4251	Leathers Oil Co	700 "G' St, Umatilla 97882	7	4	3
11363	McNary Grocery	205 Willamette, Umatilla 97882			3
8021	McNary Substation	1910 3rd St, Umatilla 97882			1
10163	Orton, Don	1803 SW Emigrant, Umatilla 97882			4
1739	Pure Gro Co	321 5th St, Umatilla 97882			2
9803	Two Over Par, dba Umatilla Golf	705 Willamette St, Umatilla 97882	1	1	
6524	Umatilla Bonoco	1251 6th St, Umatilla 97882	4	4	
164	Umatilla Marina	Foot of Quincy St, Umatilla 97882	5	2	3
5855	Umatilla School District 6-R	1400 7th St, Umatilla 97882	1		1
1466	Umatilla Texaco	1100 6th St, Umatilla 97882	5	5	
7949	Umatilla, City of	P.O. Box 130, Umatilla 97882	4		4
10870	Union Pacific RR - Juniper Station	MP 204.1, Umatilla 97882			2
939	Unocal 3316	1301 Switzler, Umatilla 97882		1	4
5370	Wilbur-Ellis Co	711 River Rd, Umatilla 97882			2

Source: Oregon Department of Environmental Quality Underground Storage Tank Facilities Database.

Table 3M.2 Underground storage tanks in the Lower Umatilla Basin with a petroleum product release reported.

Log Number	Facility Name	Address, City, Zip	Cleanup Start	End Date	Site Work Comp Date
25-94-0293	Taggares Farms Inc	Rt 1 Box 1120, Boardman 97818			
25-90-0002	Lamb-Weston	Columbia Ave & Olson Road - Box, Boardman 97818	07 Mar 90		
25-90-0003	Boardman School Bus Shed	Unknown, Boardman 97818			
30-91-0004	Circle 'C' Cubing	Echo	30 Jan 91	31 Jan 91	31 Jan 91
30-92-0224	Sherrell Chevrolet	296 E Main, Hermiston 97838	24 Mar 92		
30-90-0006	Buck's Corner	Hwy 375 & 700, Hermiston 97838			
30-91-0196	Former Chevron USA, Inc 96443	105 N 1st, Hermiston 97838	31 Oct 91	21 Feb 92	21 Feb 92
30-90-0017	Rohrman Motor Co	555 S Hwy 395, Hermiston, 97838			
30-90-0010	Hale Farms - Circle 'C' Cubing, Inc	Feedville & Hinkle P.O. Box 110, Hermiston 97838	21 Sep 90	21 Sep 90	21 Sep 90
30-93-5034	Scott & Michelle Treuninger Heating Oil	31 Cedar Dr, Hermiston 97838			
30-90-0003	Umatilla Electric Coop Hermiston	Hwy 395, Between Power City & Hermiston, Hermiston 97838			
30-90-0031	Umatilla Electric Coop Assoc	750 W Elm St, Hermiston 97838	17 Dec 90		
30-91-0189	Union Pacific RR Hinkle Yard	Hermiston 97838	28 Aug 91		
30-91-0200	U.S. Army Umatilla Depot Activity	Hermiston 97838	21 Nov 91		4 Nov 92
30-90-0026	Rhu Elevators	Hermiston 97838			
25-89-0002	S & K Farms	Homestead Rd, P.O. Box 714, Irrigon 97844	19 Dec 89	20 Dec 89	20 Dec 89
25-91-0198	Eastern OR Farming Co	Paterson Ferry, Irrigon 97844		25 Sep 92	25 Sep 92
30-90-0005	Umatilla Co. Main Yard	Box 22, Stanfield 97875	30 Nov 90	25 Mar 93	25 Mar 93
30-91-0003	City of Stanfield	Stanfield 97875	14 Jan 91		

30-92-0245	Stanfield Hardware	165 S Main, Stanfield 97875	17 Sep 92		
30-90-0029	Crossroads Truck Stop, Inc	Hwy 730 & Bridge Junction, Umatilla 97882	30 Nov 90	27 Dec 90	27 Dec 90
30-89-0002	Cenex (Soil Service Center)	651 Fifth Street, Umatilla 97882			
30-91-0204	Umatilla Marina	Ft of Quincy St, Umatilla 97882	11 Dec 91		

Source: Oregon DEQ Underground Storage Tank (UST) Cleanup List

Appendix 4A

Groundwater Chemistry Background Discussion

General Groundwater Chemistry

Introduction

Groundwater experiences various chemical processes or impacts during its migration from a recharge area to a well. The chemical composition of groundwater collected from a well is a summation of those processes and impacts. These processes and impacts include the chemical composition of the recharge water, evapotranspiration, interaction with gases within the unsaturated zone located between land surface and the water table, chemical reactions between water and solid material within the aquifer or unsaturated zone, and mixing with other water including groundwater, surface water, or water from human activity. Reactions involving micro-organisms are also important, but they will not be presented in this discussion. Figure 4A.1 schematically shows the relationship of these processes and impacts to groundwater.

Chemical Composition of Recharge Water

Water replenishing/recharging groundwater can come from a variety of sources including precipitation, surface water, and water related to human activity. Important sources of groundwater recharge in the Lower Umatilla Basin include precipitation, surface water seepage, and irrigation. The proportion and concentration of chemical constituents in these recharge source waters are often identifiably different. Those differences can make identifying the sources of groundwater recharge possible.

Precipitation

Precipitation generally includes small concentrations of atmospheric constituents (including minor amounts of nitrate), dissolved gases, and sodium, chloride, and other salts derived from ocean aerosols. Table 4A.1 presents representative constituent concentration ranges for precipitation as reported by Hem (1985). The amount of chemical constituents contributed to groundwater by precipitation is probably minor except for the presence and action of dissolved carbon dioxide. Precipitation in chemical equilibrium with atmospheric carbon dioxide will be slightly acidic (pH $\approx$ 5.5). This pH makes the water more aggressive and capable of dissolving constituents encountered in the subsurface. This chemical activity can increase constituent concentrations in groundwater.

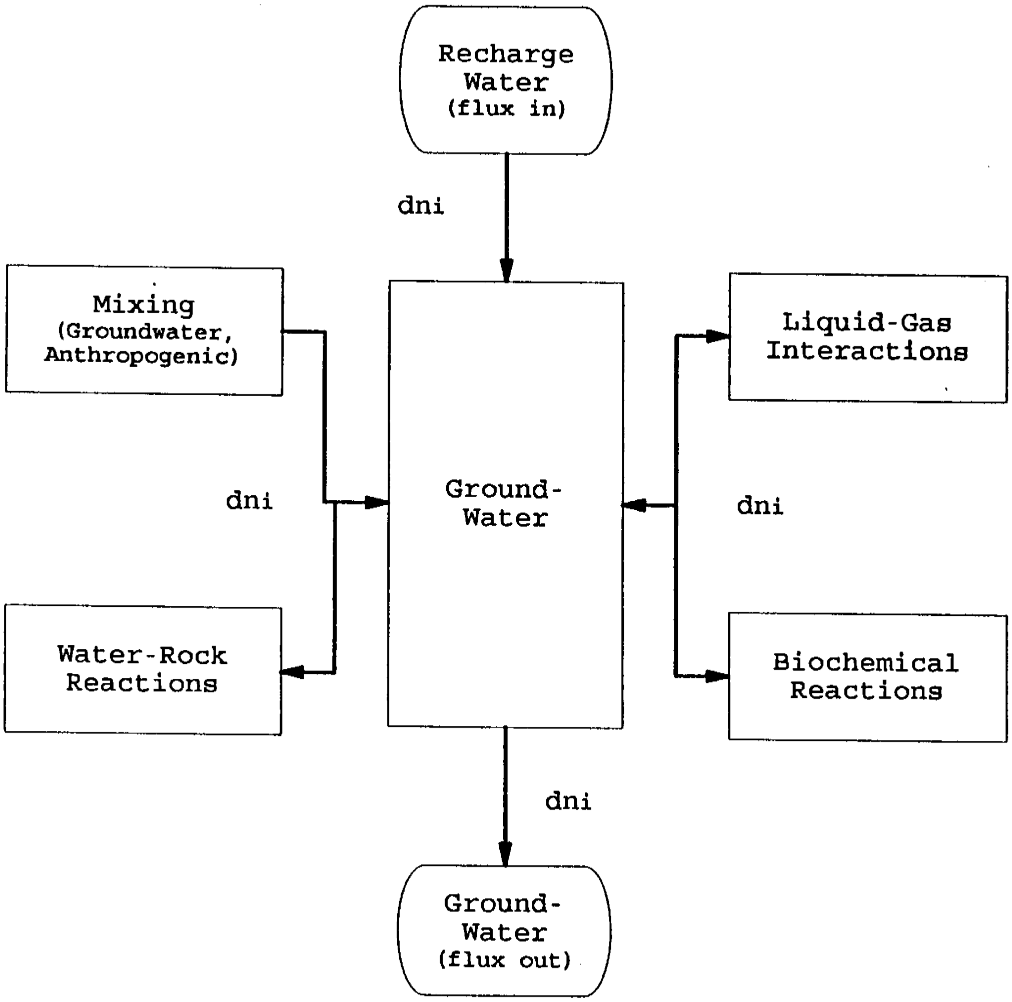


Figure 4A.1 Factors that influence the composition of groundwater.

Note: Water enters the system as recharge water, itself having previously been influenced by vadose zone processes. Groundwater may be impacted by the four general categories listed, gaining constituents through mixing, gaining or losing constituents through the other processes (arrows go both ways). The groundwater flux out has a composition that is the summation of these processes.

Table 4A.1 Reported constituent concentration ranges for precipitation

Constituent	Concentration Range in Precipitation (mg/L)
Calcium	0.0 to 1.41
Sodium	0.0 to 9.40
Sulfate	0.7 to 7.6
Chloride	0.2 to 17.0
Nitrate-Nitrogen	0.0 to 0.14
Source: Hem (1985)	

Surface Water Seepage

Surface water seepage can occur where the water level in rivers, lakes, reservoirs, conveyances, and other water bodies is higher than the water table for groundwater and downward leakage is possible. The chemistry of the surface water depends upon the mixing of various water inputs. Those water inputs include but are not limited to precipitation, runoff, return flow, waste water, and groundwater in certain areas. The type and amount of these inputs varies between surface water bodies causing the different surface water sources to have different chemical constituent proportions and concentrations.

Irrigation

Irrigation water in a basin can come from many sources. Those sources can include fresh water from various surface water bodies and/or various groundwater aquifers, wastewater, and a blending of these waters. These irrigation water sources have significantly different chemical constituent proportions and concentrations, because they have different histories. Additionally, the chemical composition of blended water may vary with time as the mixing proportions vary with time. This makes considering irrigation water chemistry important in efforts to understand the groundwater chemistry.

Evapotranspiration

Water evaporating at land surface or within the unsaturated zone and the selective uptake of water by plants can significantly impact the constituent composition of water (Drever, 1982). The impact of evapotranspiration upon water chemistry is most notable in arid regions where the evaporation rate exceeds precipitation through much of the year. For example, evaporation has been recognized as the principal process of water chemistry evolution in many of the saline lakes of western North America, including Harney, Summer, and Abert Lakes in Oregon (Eugster and Hardie, 1978; Drever, 1982).

Evaporation may also cause salts like calcite [$CaCO_3$], sepiolite [$Mg_4(Si_2O_5)_3(OH)_2 \bullet 6H_2O$], mirabilite [$Na_2SO_4 \bullet 10H_2O$], or gypsum [$CaSO_4 \bullet 2H_2O$], and halite [NaCl] to precipitate in the soil zone and the unsaturated zone, including the capillary fringe area just above the water table (Drever, 1982). For example, Law (1987), Rice and others (1989), Tedaldi and Loehr (1992), and others report salt precipitation related to irrigation water evaporation. These same authors note precipitated salts can subsequently be leached by later irrigation or precipitation. The impact on groundwater has been documented (see Tedaldi and Loehr, 1992).

Interaction With Gases

The primary gas of concern is carbon dioxide [CO_2]. Water percolating downward to groundwater may interact with carbon dioxide derived primarily from plant respiration processes or the decay of organic matter within the unsaturated zone. Water reacts with carbon dioxide [CO_2] to form carbonic acid [H_2CO_3]. That reaction substantially reduces the pH of the water to 4 or less (Krauskopf, 1967). The final pH value depends significantly on whether the infiltrating water is continually replenished with carbon dioxide from sources above (the system is open) or the water becomes isolated from the carbon dioxide sources above (the system is closed). When the system is open, the final pH will be lower which causes the total dissolved solids concentration to become higher due to water dissolving solids more aggressively (Freeze and Cherry, 1979; Drever, 1982).

Chemical Reactions With Solid Material

The discussion in this section focuses upon mineral dissolution-precipitation and solid surface reactions in the aquifer and/or the unsaturated zone. In both reactions, constituents may transfer from solids to water and vice versa. The constituents transferred and the water's final chemical composition depend upon the chemistry of the mineral solids involved, the nature of constituents located on mineral surfaces, and residence time (the length of time water is in contact with the specific mineral.

Mineral Dissolution-Precipitation Reactions

Groundwater is either undersaturated, saturated or oversaturated with respect to a specific mineral. Groundwater tends to dissolve a mineral (mineral dissolution) when groundwater is undersaturated with respect to that mineral. Minerals tend to grow from a groundwater solution (precipitation) when groundwater is oversaturated with respect to the mineral. Factors that influence the state of saturation for a mineral in groundwater are complex. Important parameters include temperature, pH and the ionic strength of the water.

The nature of mineral dissolution-precipitation reactions can make accounting the water chemistry changes difficult. This difficulty exists, because a single dissolution-precipitation reaction can involve multiple constituents, and multiple dissolution-precipitation reactions involving the same constituents can occur. For example, assume groundwater flowing through an aquifer is undersaturated with respect to gypsum [$CaSO_4 \bullet 2H_2O$], and it encounters gypsum along its flow path. The gypsum will tend to dissolve and release calcium and sulfate into the groundwater. This dissolution reaction increases the calcium and sulfate concentrations in the groundwater. Now assume the same groundwater is oversaturated with respect to calcite [$CaCO_3$]. The groundwater will precipitate that mineral, which decreases the calcium and bicarbonate concentrations in the water. This groundwater may experience other dissolution-precipitation reactions related to other minerals also.

Calculating the state of saturation of groundwater relative to various minerals is possible provided the dominant chemical ions, temperature and pH in the water are known. A computer program called WATEQF developed by Plummer and others (1976) is commonly used for these calculations. This investigation used a personal computer version of the program in conjunction with other chemical modeling.

Solid Surface Reactions

Most solids within an aquifer possess a residual surface electrical charge, due to unsatisfied chemical bonds at mineral surfaces or constituent substitution within the mineral structure. This electrical charge is influenced by pH. Under typical aquifer conditions, the common aquifer minerals have a net negative electrical charge on their surfaces. These negatively charged surfaces tend to attract and hold (sorb) positively charged ions such as calcium [Ca^{2+}], magnesium [Mg^{2+}], potassium [K^+], and sodium [Na^+] as a result. Clay minerals and iron and manganese oxides are the more important minerals participating in the sorption phenomena within aquifers.

The tendency of chemical ions in solution to sorb to a given mineral varies. Ions in solution with a greater electrical charge tend to sorb more than ions with a smaller charge. For example, divalent ions such as calcium [Ca^{2+}] and magnesium [Mg^{2+}] more readily sorb than monovalent ions such as potassium [K^+] and sodium [Na^+]. When a group of chemical elements have the same electrical charge, smaller hydrated ions sorb more strongly than larger hydrated ions. For example, calcium [Ca^{2+}] sorbs more strongly than magnesium [Mg^{2+}], and potassium [K^+] sorbs more strongly than sodium [Na^+] (Lloyd and Heathcote, 1985). Domenico and Schwartz (1990) characterized the affinity of inorganic constituents for sorption in the following sorption series:

$$Al^{3+} > Ca^{2+} > Mg^{2+} > NH_4^+ > K^+ > Na^+$$

One ion may replace another ion associated with a given mineral surface. This process is called ion exchange, and it is common when groundwater flows through a clay-bearing aquifer. Calcium and sodium ions are often involved in ion exchange. As groundwater flows through the aquifer, calcium ions typically displace sodium ions from the surfaces of clay minerals. This exchange causes the calcium concentration in groundwater to decrease while the sodium concentration increases.

It should be noted that sodium could replace calcium on the exchange sites rather than calcium replacing sodium. This is possible, because the direction of ion exchange reactions depends upon the water chemistry. For example, the governing equation for the distribution of sodium and calcium on a clay mineral surface will be in the form of:

$$[Ca_{clay}]/[Na_{clay}]^2 = K([Ca^{2+}]/[Na^+]^2)$$

where [Ca_{clay}] and [Na_{clay}] refer to the "activities" of calcium and sodium respectively on clay exchange sites and where [Ca^{2+}] and [Na^+] refer to the "activities" (related to concentrations) of calcium and sodium ions in groundwater which are in equilibrium with the clay surface (see Drever, 1982). The symbol K in the equation represents a constant that describes the equilibrium distribution of the ions between the solution and the mineral surface. If the "activity" (concentration) of sodium in groundwater is high enough, sodium may replace calcium (and magnesium) on the clay exchange sites in order to maintain equality on both sides of the equation.

Organic chemicals can undergo sorption as well. This sorption is frequently associated with organic matter in an aquifer rather than mineral surfaces. Nonpolar organic chemicals of high molecular weight sorb, because they exhibit significant hydrophobic characteristics (they cannot readily be incorporated into the polar structure of water). This hydrophobic characteristic causes these chemicals to have low solubilities and a high sorption potential (Domenico and Schwartz, 1990).

Residence Time

Reactions proceed at a finite rate whether the reaction is dissolution-precipitation or solid-surface in nature. They are not instantaneous. As a result, groundwater chemical composition evolves slowly as the groundwater moves through the aquifer. Similarly, greater groundwater composition evolution occurs when there is greater groundwater contact time with the aquifer material.

Many groundwater chemistry computer models, such as NETPATH, do not include residence time in their calculations. Instead, they assume chemical equilibrium has been reached. This may lead to model results that do not match the actual groundwater chemistry at different locations. The differences will occur when the residence time of groundwater in an aquifer is not sufficient to reach the equilibrium concentrations calculated in the model results. However, the model results remain very useful for indicating the direction in which groundwater chemical compositional evolution will occur.

Mixing

Mixing is an important process that influences the chemical composition of groundwater. Mixing occurs when groundwater moving along a specific flow path encounters other water that has evolved independently. If the mixing waters have chemical compositions different from each other, the constituent concentrations and proportions in the resulting mixture will be intermediate to the constituent concentrations and proportions of the original waters.

Water that may mix with groundwater includes groundwater from another aquifer, groundwater that has travelled along a different flow path within the same aquifer, and surface water or water related to human activity that infiltrates into the aquifer. Sources of surface water can include rivers, streams, lakes, reservoirs, canals, and ponds which can have different chemical compositions. Water related to human activity include animal, human and food processing waste water, irrigation water, and other water which have significantly different chemical compositions.

Appendix 4B

Nitrogen Isotopes Background Discussion

Nitrogen Isotopes

Introduction

The Lower Umatilla Basin groundwater investigation included chemical and data analyses of nitrogen isotopes in groundwater collected from selected sites. The isotopic analyses supplement more extensive geochemical analyses conducted to identifying the potential sources of nitrogen in local groundwater. This appendix presents a background discussion about chemical isotopes in general and nitrogen isotopes in particular for interested readers of this report.

Chemical Isotopes in General

Isotopes are chemical elements that have the same atomic number, but different atomic mass. The chemical identity of a given atom is determined by its atomic number (the number of protons in the nucleus). All carbon atoms have 6 protons, all iron atoms have 26 protons, all uranium atoms have 92 protons and so on. While the atomic number remains fixed for a given elemental (atomic) species, the number of neutrons do not. For example, nitrogen has an atomic number of 7, but the number of neutrons in the nucleus may be 7 or 8. This means different nitrogen isotopes exist which have an atomic mass (protons + neutrons) of 14 [^{14}N] and 15 [^{15}N], respectively. These isotopes behave differently during certain chemical or biochemical reactions.

Isotopes can be fractionated. Isotopic fractionation refers to a natural change in isotopic composition (the relative proportions of the various isotopes) of a chemical element during a reaction (Faure, 1986). This includes radiogenic and stable isotopes. Radiogenic isotopes are those isotopes whose abundances are primarily a function of the radioactive decay of a parent atom. Stable isotopes are those isotopes of lower atomic weight (usually less than 40) whose abundance is influenced by physical and chemical processes. The individual mass of isotopes is the principle cause of isotopic fractionation among stable isotopes. Atomic mass controls fundamental chemical behavior such as bond strengths, diffusion velocities, and vapor pressures. As a result, one isotope may be preferentially selected over another as a reaction proceeds. This causes a separation of isotopes leading to a reaction product having a different isotopic composition than the reactants.

These isotopic reactions and fractionation factors are highly predictable. So, researchers recognized very early that isotopic compositions may be useful tracers or indicators of various geochemical and biochemical processes (Faure, 1986). Research indicating the potential use of nitrogen isotopes in this manner includes Kreitler (1975), Kaplan (1983), Aravena and others (1993), and Komor and Anderson (1993).

Reporting Nitrogen Isotopic Data

Stable isotopic data are reported as "delta values" or per mil values ($^{o}/_{oo}$), which is shorthand for parts per thousand. Isotopic compositions (relative proportions of various isotopes) are reported as a deviation from a standard value. Nitrogen isotopic compositions are reported as delta ^{15}N, the deviation from standard atmosphere, using the following equation (Komor and Anderson, 1993):

$$\text{delta } ^{15}N \ (^{o}/_{oo}) = [((^{15}N/^{14}N)_{sample}/(^{15}N/^{14}N_{air})) - 1] \times 1000$$

Positive delta ^{15}N values (delta ^{15}N greater than 0) indicate that the sample has a higher $^{15}N/^{14}N$ ratio than the atmosphere standard. Negative delta ^{15}N values (delta ^{15}N less than 0) indicate a lower $^{15}N/^{14}N$ ratio than the atmosphere standard.

Factors Controlling Nitrogen Isotopic Compositions

Various influences can affect nitrogen isotopic compositions (the relative proportions of the various isotopes). These influences include the nitrogen cycle, sources of nitrogen, and other influences. A combination of factors can create composite isotopic compositions.

The Nitrogen Cycle

Chemical processes can change the nitrogen isotopic composition as nitrogen moves through the nitrogen cycle. Sometimes equilibrium conditions, such as nitrogen partitioning between ammonia in solution and ammonia vapor, control the process. At other times, kinetic processes, such as nitrification (oxidation) of ammonia to nitrate controls the process. When comparing oxidized versus reduced forms of nitrogen in the environment, it is common to observe the oxidized form being more enriched with ^{15}N over the reduced form. The amount of the enrichment depends upon the extent of the oxidation reaction.

Denitrification within the subsurface can affect nitrate delta ^{15}N values. Denitrification occurs when nitrate converts to nitrogen gas according to a reaction similar to the following (Komor and Anderson, 1993):

$$4NO_3^- + 5CH_2O = 2N_2(gas) + 5HCO_3^-$$

The reaction requires the presence of organic matter, represented by CH_2O in the reaction, anaerobic conditions, and the appropriate bacteria since the reaction is microbially mediated (Korom, 1992). The reaction leads to low delta ^{15}N compositions in the nitrogen gas, which leaves the residual nitrate enriched in ^{15}N. As a result, progressive denitrification should result in an inverse relationship between the nitrate concentration and the nitrate delta ^{15}N values. As the nitrate concentration decreases, the delta ^{15}N of the remaining nitrate increases (Komor and Anderson, 1993).

Denitrification may play an important role in influencing nitrate concentrations and its isotopic composition in environments where reducing conditions are found at shallow depths (Mariotti and others, 1988, Bottcher and others, 1990, Korom, 1992). Smith and others (1991) reported denitrification occurring with depth in nitrate-contaminated groundwater within a Cape Cod, Massachusetts sand and gravel aquifer. They observed significant decreases in nitrate (and nitrite) matched by increasing delta ^{15}N and N_2 over a 10 meter vertical section. The nitrate delta ^{15}N increased from +11.3 to +42.0 per mil. This delta ^{15}N increase could mask the original isotopic signature of the nitrate.

Denitrification may not be as prevalent in other groundwater environments. For example, Kreitler (1975) and Fogg (1994) found no evidence of denitrification with depth in their investigations. Kreitler (1975) investigated groundwater beneath a barnyard and a row-cropped field. Fogg (1994) evaluated a large number of vertical cores from the high plains of Texas to determine the effect of denitrification on nitrate concentrations. No significant variation of nitrate or isotopic composition with depth was seen in both investigations. The investigators attributed the absence of denitrification in their investigations to a deep water table. Starr and Gillham (1993) investigated two unconfined surficial sand aquifers in southern Ontario. The static water level of their "shallow" water table site was approximately one meter, while the water table for their "deep" site was approximately 4 meters. Denitrification removed nitrate to below detection levels at the shallow site, but it did not affect nitrate at the deep site. Starr and Gillham attributed the difference in denitrification to a lack of readily biodegradable (labile) organic carbon in the deeper aquifer. They noted that the presence of organic carbon is very important in allowing denitrification to occur and that organic carbon availability decreases with depth below the surface.

Sources of Nitrogen

The nitrogen source is fundamentally important in controlling the isotopic composition of nitrogen. For example, the isotopic composition of nitrogen in vascular plants is near 0 per mil (the sample $^{15}N/^{14}N$ ratio is the same as the ratio for air), because atmospheric nitrogen is the source for nitrogen fixation (Kaplan, 1983).

Soil organic nitrate-nitrogen has delta ^{15}N values ranging from +3 to +8 per mil (Kreitler, 1975, Heaton, 1986). Nitrogen contributed to groundwater by mineralized organic nitrogen is considered minimal in most agricultural areas, because most of the mineralized organic nitrogen would have been released during the first few years of cultivation (Reinhorn and Avnimelech, 1974).

Most commercial fertilizers have nearly the same isotopic composition, delta ^{15}N from -4 to +4 per mil (Heaton, 1986, Komor and Anderson, 1993), because the nitrogen used in the manufacturing of the fertilizer is derived from the atmosphere. Commercial fertilizer is routinely applied as anhydrous ammonia (NH_3). The oxidation of the ammonia to nitrate results in fractionation of the isotopes that could cause the resulting nitrate to have higher delta ^{15}N values. However, because the reaction is rapid and goes to completion (all of the ammonia converts to nitrate), the nitrate has essentially the same isotopic composition as the original ammonia (Exner and Spalding, 1994). Exner and Spalding (1994) cite several examples of delta ^{15}N of nitrate-nitrogen from agricultural sources reported by other investigators. They include less than +3.5 per mil in the Central Platte Region of Nebraska (Gormly and Spalding, 1979), a mean of +5.3 per mil in Suffolk County, Long Island (Kreitler and others, 1978), and a mean of $+4.1 \pm 2.6$ per mil in the Burbank-Wallula area of Washington (Spalding and others, 1982).

Animal wastes often have significantly higher nitrate-nitrogen delta ^{15}N values ranging from +10 to +22 per mil (Kreitler, 1975, Aravena and others, 1993, Komor and Anderson, 1993). Selective loss of ^{15}N-poor ammonia by volatilization and the incomplete oxidation of residual ammonia to nitrate contributes to the higher delta ^{15}N values. Kreitler (1975) demonstrated that gaseous ammonia (delta ^{15}N equal to -21 per mil) is approximately 38 per mil lighter than aqueous ammonia in animal waste material.

Food processing wastewater delta ^{15}N values were not found in professional literature reviewed. Assuming delta ^{15}N values are similar to animal waste may be reasonable when food processing wastewater has elevated ammonia concentrations as exists in the Lower Umatilla Basin. However, a single analysis of J.R. Simplot Company plant wastewater conducted prior to this investigation yielded a nitrate delta ^{15}N of +8.8 per mil. Why? Possibly the ammonia concentration in the sample was relatively low (within 10 mg/L as nitrogen), or the ammonia converted rapidly to nitrate with little ammonia loss, yielding a lower delta ^{15}N value for nitrate.

Some case studies have had nitrate delta ^{15}N values that clearly and conveniently match one or more sources (see Aravena and others, 1993). These cases appear to be exceptions. Most researchers note that the ranges of nitrogen isotopic composition related to different sources overlap. That makes distinguishing sources difficult or impossible when relying upon isotopic data alone. For example, it is not possible to distinguish commercial fertilizer from soil nitrogen, nor is it possible to distinguish septic system effluent from animal wastes. However it is often possible to distinguish groups. Fertilizers and/or soil nitrogen can be distinguished from septic system effluent and/or animal wastes (Wolterink and others, 1979, Exner and Spalding, 1994).

Other Factors

Another influence upon nitrate ^{15}N are other processes that may occur on the land surface,within the vadose zone, and within the groundwater system. Iqbal and others (1994) suggested that the nitrogen isotopic composition could vary with time as a function of land use, rainfall flushing, and the presence of macropores such as root channels, burrows, and cracks in clay beds. Schulmeister and MacPherson (1994) reported a large variation in the nitrate isotopic composition in groundwater sampled from varying depths in an alluvial aquifer in Kansas. The nitrate values were stratified. The values related to the geologic lithology and the oxidation-reduction potential (redox potential) in the individual layers.

Occurrence of Composite Isotopic Compositions

Composite isotopic compositions complicate nitrogen source identification. Many opportunities exist to produce composite isotopic compositions, such as water from multiple sources passing through various processes prior to merging into a particular groundwater sample (see Exner and Spalding, 1994).

Soil system complexities may cause composite isotopic compositions. Wolterink and others (1979) suggest environmental factors could influence the isotopic composition of soil nitrate by affecting the types of bacteria present and the reaction pathways leading to formation of nitrate. Kaplan (1983) cited a study of 223 measurements of nitrogen compounds in soil where the mean nitrogen delta ^{15}N was +5.0 per mil. He suggests the mean delta ^{15}N value may reflect several sub-populations of nitrogen in the system, since the soil system is dynamic, where various forms of nitrogen continually turn over and complex.

Multiple nitrogen sources can also cause composite isotopic compositions. For example, Exner and Spalding (1994) interpreted the delta ^{15}N range of +5.8 to +8.8 per mil in groundwater sampled near Sidney, Nebraska as derived from mixed agronomic leachate and animal wastes. They noted that Sidney farmers commonly use both commercial fertilizer and manure on their fields. The amount of commercial fertilizer applied is determined by a soil test conducted prior to the manure application. No credit is awarded for manure supplied nutrients.

Berndt (1990) identified sewage effluent from a sewage treatment plant and commercial fertilizer as the mixed nitrate sources yielding a +5.4 to +12.2 per mil delta ^{15}N range in Florida samples. Iqbal and others (1994) interpreted varied delta ^{15}N data from southern Indiana as a function of differing contributions from inorganic fertilizer and animal wastes. Komar and Anderson (1993) attributed changing proportions of nitrate from different sources as partly responsible for delta ^{15}N varying over time in shallow groundwater sampled from Minnesota Sand-Plain aquifers.

Appendix 4C

Groundwater and Surface Water Sampling Sites

Table 4C.1 Groundwater sampling sites.

Lower Umatilla Basin
Groundwater Sampling Sites

Sorted by DEQ Well Identification Number

Aquifer Designations
A = Alluvial
B = Basalt
CG = Coarse Grained
FG = Fine Grained
FP = Flood Plain Deposit
SU = Shallow Unconfined (generally above a saturated, alluvial, low permeability zone which confines alluvial groundwater below)
N = Unconfined But Not Shallow Unconfined
C = Confined
? = Unknown (a series of ? often implies no well log found)

	Location			Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
4N	25E	15	Acd	Connell	UMA001							?	?	?	?	?
4N	25E	15	Dab	Prag	UMA002	MORR	692				X	51	51	A	CG	N
4N	25E	15	Ddd	Nicholes	UMA003	MORR	790		X		X	104	65	B		C
4N	25E	14	Cab	Scoubo	UMA004							?	?	?	?	?
5N	26E	35	Ccd	Creason	UMA005							?	?	?	?	?
4N	26E	1	Bbb	White	UMA006							?	?	?	?	?
5N	26E	36	Bcd	Sims	UMA007							?	?	?	?	?
5N	28E	18	Cbc	Wilson	UMA008							?	?	?	?	?
5N	27E	13	Cda	Cooney	UMA009							?	?	?	?	?
4N	26E	3	Daa	Acock	UMA010							?	?	?	?	?
5N	27E	14	Dcb	Howard	UMA011							?	?	?	?	?
5N	27E	14	Ccd	Fox	UMA012							?	?	?	?	?
4N	25E	14	Ccd	Hansell	UMA013							?	?	?	?	?
4N	25E	14	Cdc	Baker	UMA014							?	?	?	?	?
4N	25E	14	Cdb	Hemnes	UMA015							?	?	?	?	?
4N	25E	14	Cab	Hardie	UMA016							?	?	?	?	?
4N	25E	14	Cca	Pettigrew	UMA017							?	?	?	?	?
4N	25E	15	Cda	Carlson	UMA018							?	?	?	?	?
4N	25E	22	Bad	Carlson	UMA019							?	?	?	?	?

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
4N	25E	22	Acb	Akers	UMA020							?	?	?	?	?
4N	25E	10	Dda	Glenn	UMA021							?	?	?	?	?
4N	25E	14	Bcd	Flug	UMA022							?	?	?	?	?
4N	25E	13	Dbb	Dawson	UMA023							?	?	?	?	?
4N	25E	13	Cab	Gantenbein	UMA024							?	?	?	?	?
4N	25E	14	Cbc	Walker	UMA025							?	?	?	?	?
5N	27E	19	Cbb	Hurn	UMA026	MORR	1410		X		X	65	65	A	CG	N
5N	26E	27	Bbc	Kenney	UMA027				X			?	?	?	?	?
4N	25E	16	Adb	Moen	UMA028	MORR	823		X	X	X	103	20	B		C
4N	25E	21	Bbb	Alford	UMA029	MORR	873		X	X	X	100	34	B		C
4N	25E	17	Cba	Wyss	UMA030	MORR	840		X		X	103	85	B		C
4N	25E	9	Cbb	Mathewson	UMA031	MORR	696		X		X	55	55	A	CG	N
5N	26E	26	Bbb	Gillett	UMA032	MORR	1226		X		X	59	59	A	CG	N
5N	26E	23	Cca	Irwin	UMA033	LUB	14		X	X	X	83	79	A	CG	N
5N	26E	22	Daa	Froberg	UMA034	MORR	1021		X	X	X	40	40	A	CG	N
5N	26E	23	Bca	Reaves	UMA035	MORR	1026		X			60	59	A	CG	N
5N	26E	24	Cdd	Horrace	UMA036	MORR	1094		X		X	73	73	A	CG	N
5N	28E	17	Abc	Waas	UMA037	UMAT	3373		X		X	30	30	A	CG	N
5N	28E	17	Add	Vieth	UMA038	UMAT	3374		X	X	X	66	66	A	CG	N
5N	28E	35	Dcd	Powell	UMA039	UMAT	3607		X	X	X	162	162	A	CG	N
5N	28E	36	Dad	Ziegenhirt	UMA040	UMAT	3626		X		X	100	99	A	CG	N
4N	29E	6	Bdd	Phipps	UMA041	UMAT	2753		X		X	65	65	A	CG	N
4N	29E	7	Cbd	Buwalda	UMA042	UMAT	2796		X		X	105	60	A	FG	N
4N	29E	8	Bdb	Walchli	UMA043	UMAT	2807		X		X	105	100	A	FG	N
4N	29E	4	Ccb	Walchli	UMA044	UMAT	2650		X		X	70	67	A	FG	N
4N	29E	10	Aca	Winebarger	UMA045	UMAT	2830		X		X	45	30	A	FG	N
4N	29E	17	Bba	Burnett	UMA046	UMAT	2863		X	X	X	110	60	A	FG	N
4N	29E	31	Daa	Burnett	UMA047	UMAT	2963		X	X	X	145	68	B		C
4N	29E	32	Bda	Otzenberger	UMA048	UMAT	2953		X	X	X	85	59	A	FG	N
4N	29E	32	Adb	Allen	UMA049	UMAT	2965		X		X	43	43	A	CG	SU
4N	29E	33	Bcc	May	UMA050	UMAT	2983		X			50	40	A	FG	N
4N	29E	32	Ddd	Drtina	UMA051	UMAT	2969		X		X	213	42	B		C
4N	29E	33	Cdd	Burkett	UMA052	UMAT	2986		X		X	83	58	A	FG	N
5N	26E	25	Abd	Cooley	UMA053	LUB	4		X		X	55	54	A	CG	N
5N	27E	21	Bad	Legner	UMA054	MORR	1441		X		X	110	20	B?		C?

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
5N	28E	26	Dbc	Wolfe	UMA055	UMAT	3424		X		X	60	60	A	CG	N
4N	29E	14	Cad	Hansen	UMA056	UMAT	2855		X	X	X	72	29	A	FG	N
5N	28E	25	Daa	Bloodsworth	UMA057	UMAT	3405		X		X	69	69	A	CG	N
4N	28E	27	Ccb	J.R. Simplot Co.	UMA058	UMAT	2578		X	X	X	230	198	A	FG	N
5N	27E	19	Cbb	City of Irrigon	UMA059	MORR	1398		X		X	68.5	56.5	A	CG	N
4N	28E	2	Cdc	Normandin	UMA060				X		X	50	50	A	CG	N
4N	28E	19	Cac	Lamb-Weston, Inc.	UMA061	UMAT	2402		X			137	135.1	A	CG	N
4N	28E	19	Aad	Westland Estates Water Co.	UMA062	UMAT	2338		X			125	96	A	CG	N
4N	28E	18	Bba	Moltman	UMA063	UMAT	2373		X		X	78	78	A	FG?	N
4N	28E	11	Bac	Dun Rollin MHP	UMA064	UMAT	2063		X		X	32	31	A	CG	N
5N	29E	15	Adb	McNary Yacht Club	UMA065	UMAT	3662		X		X	95	95	A	CG	N
5N	29E	15	Dcb	Hat Rock MHP	UMA066	UMAT	3657		X	X	X	74	74	A	CG	N
3N	29E	4	Cbc	Wheatland Dairy & Cafe	UMA067				X			?	?	?	?	?
4N	28E	3	Bad	Brown	UMA068	UMAT	1779		X		X	51	51	A	CG	N
4N	28E	16	Ddd	Stewart	UMA069	UMAT	2307		X		X	53	53	A	CG	N
4N	28E	15	Bbc	Gianakopoulos	UMA070	UMAT	2188		X		X	61	56	A	CG	N
4N	28E	8	Aab	Bellinger	UMA071	UMAT	1862		X			130	95	A?	FG	N
4N	28E	10	Dbc	Helms	UMA072	UMAT	2028		X		X	50	50	A	CG	N
4N	28E	20	Daa	Challis	UMA073	UMAT	2424		X		X	70	70	A	CG	N
4N	28E	1	Dda	Kane	UMA074	UMAT	1710		X		X	51	51	A	CG	N
4N	28E	12	Ccb	Martin	UMA075	UMAT	2114		X			81	57	A	CG	N
4N	28E	11	Add	Parrill	UMA076	UMAT	2068		X		X	56	46	A	CG	N
4N	28E	4	Ddd	Rogers	UMA077	UMAT	1832		X	X	X	65	40.5	A	CG?	N
4N	28E	17	Cbc	Huston	UMA078	UMAT	2331		X		X	97	96	A	CG	N
4N	28E	31	Cba	Noble	UMA079	UMAT	2606		X		X	150	97	B?		C
4N	28E	33	Bcc	Rowe	UMA080	UMAT	2628		X		X	94	85	A	FG	N
4N	28E	28	Abb	Pioneer Implement Corp.	UMA081	UMAT	2591		X		X	118	114	A	CG	N
4N	28E	15	Dad	Church	UMA082	UMAT	2211		X		X	80	69	A	FG	N
4N	28E	15	Cbd	Lanphear	UMA083	UMAT	2218		X			92	60	A?	FG	N
4N	28E	21	Dbb	King	UMA084	UMAT	2453		X	X	X	80	80	A	CG?	N
4N	25E	13	Bcc	Rea	UMA085	MORR	733		X	X	X	74	74	A	CG	N
4N	25E	9	Aca	J&D Electric	UMA086	MORR	740		X		X	57	57	A	CG	N
4N	29E	5	Cdb	Murray	UMA087	UMAT	2700		X			110	100	B&A?		
4N	28E	17	Dda	Quick	UMA088	UMAT	2348		X	X	X	33	33	A	CG	N
4N	28E	21	Aab	Gray	UMA089	UMAT	2448		X		X	60	60	A	CG	N

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
5N	28E	35	Add	Crabtree	UMA090				X			?	?	?	?	?
4N	28E	17	Abb	Ralston	UMA091	UMAT	2360		X			131	92	B&A		
4N	28E	19	Ada	Marsh	UMA092	UMAT	2391		X		X	79	79	A	CG	N
4N	28E	23	Bdb	OSU Agric. Exp. Station	UMA093	UMAT	2510		X			875	232	B		C
4N	28E	18	Add	McClune	UMA094				X	X	X	101	101	A	CG	N
5N	28E	18	Cac	Shady Rest MHP	UMA095	UMAT	5441		X		X	225	77	B		C
5N	27E	13	Cac	Andrews	UMA096	UMAT	3271		X	X	X	57	57	A	CG	N
5N	27E	13	Cbc	Kurz	UMA097	UMAT	3306		X		X	97	96	A	CG	N
5N	26E	24	Dad	Johnson	UMA098				X			?	?	?	?	?
5N	26E	23	Bdd	Warner	UMA099	MORR	1345		X		X	60	59	A	CG	N
5N	27E	19	Ccc	Byrd	UMA100	MORR	1403		X		X	63	63	A	CG	N
4N	28E	24	Abd	Sickelstiel	UMA101	UMAT	2523		X		X	100	75	A	FG	N
5N	26E	23	Dda	Seeger	UMA102	MORR	1065		X		X	84.5	83	A	CG	N
5N	27E	21	Aab	Yates	UMA103	MORR	1431		X	X	X	40	40	A	CG	N
5N	29E	31	Bcc	Petty	UMA104	UMAT	3785		X		X	96	96	A	CG	N
4N	28E	1	Acb	Angell	UMA105	UMAT	1673		X			129	129	A	CG	N
4N	29E	4	Aab	Cripe	UMA106	UMAT	2645		X	X	X	115	58	B		C
4N	29E	5	Bbb	Hermiston RFPD	UMA107	UMAT	2653		X			94	65	B&A		
5N	29E	19	Ddc	Thornburg	UMA108				X			?	?	?	?	?
5N	29E	29	Bcd	Beck	UMA109	UMAT	3727		X	X	X	45	44	A	CG	N
4N	29E	10	Bbd	Picker	UMA110	UMAT	2829		X	X	X	42	31	A	FG	N
4N	29E	19	Bbb	Walchli	UMA111	UMAT	5307		X		X	175	159	A	FG	N
3N	27E	1	Bcd	McFarlane	UMA112	MORR	630		X	X	X	185	18	A	FG	N
5N	29E	32	Dba	Bruce	UMA113	UMAT	3820		X			55	55	?	?	?
5N	29E	32	Aac	Leitch	UMA114	UMAT	3821		X			68	65	B&A		
4N	28E	1	Aba	Smith	UMA115				X			?	?	?	?	?
5N	29E	32	Dcc	Anson	UMA116	UMAT	3824		X	X	X	52	50	A	CG	N
5N	29E	29	Bca	Stoneburner	UMA117				X		X	?	?	?	?	?
3N	28E	1	Add	Stanfield Rest Area	UMA118	UMAT	5476		X		X	95	79	B?		C?
4N	28E	16	Ddb	Lemmon	UMA119	UMAT	2305		X	X	X	40	40	A	CG	N
3N	28E	5	Abc	Horn	UMA120	UMAT	2620		X		X	130	130	A	FP	N
4N	28E	16	Dda	Utt	UMA121	UMAT	2299		X		X	45	45	A	CG	N
4N	28E	33	Bba	Mueller	UMA122	UMAT	2622		X	X	X	73	71	A	FG	N
4N	28E	33	Bcd	Parrish	UMA123	UMAT	2630		X		X	58	56	A	FG	N
4N	28E	24	Bab	Culp	UMA124	UMAT	2525		X		X	107	107	A	FG	N

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
4N	29E	9	Aab	Aichele	UMA125	UMAT	2810		X	X	X	100	28	B		C
4N	28E	3	Bcd	Walker	UMA126	UMAT	1775		X		X	339	40	B		C
4N	27E	27	Dad	Hansell Brothers Farms	UMA127	UMAT	1574		X			547	526	B		C
4N	27E	27	Dbd	Hansell Brothers Farms	UMA128				X			?	?	?	?	?
4N	25E	16	Adc	Kanyid	UMA129	MORR	824		X		X	173	35	B		C
4N	25E	16	Adc	Shoemake	UMA130	MORR	829		X			105	26	A&B		
4N	24E	23	Acd	Tatone	UMA131				X			?	?	?	?	?
4N	28E	7	Add	Reuter	UMA132				X			?	?	?	?	?
3N	27E	4	Ada	Key	UMA133				X	X	X	80	?	A	FG	N
4N	28E	21	Aad	Lambier	UMA134	UMAT	2490		X		X	70	68	A	FG?	N
4N	28E	21	Aad	Linder	UMA135				X			?	?	?	?	?
4N	27E	13	Ddd	Skinner	UMA136	UMAT	1539		X		X	111	104	A	CG	N
4N	28E	33	Bcd	Parrish	UMA137				X			?	?	?	?	?
4N	28E	7	Aaa	Reuter	UMA138	UMAT	1867		X		X	135	40	B&A		C
4N	28E	5	Bdd	Bryson	UMA139				X			?	?	?	?	?
4N	28E	7	Acc	Wadekamper	UMA140	UMAT	1875		X			286	80	B&A		C
4N	28E	17	Aba	Ridgeway	UMA141				X			?	?	?	?	?
4N	28E	17	Aab	Hunsinger	UMA142				X			?	?	?	?	?
4N	28E	17	Aaa	Lerfald	UMA143				X					Spring		
5N	26E	25	Cba	Kellar	UMA144	MORR	1178		X	X	X	57	57	A	CG	N
5N	26E	25	Dac	Hovinghoff	UMA145				X			?	?	?	?	?
5N	26E	36	Bbd	Hovinghoff	UMA146				X			?	?	?	?	?
5N	26E	25	Cca	Gale	UMA147	MORR	1189		X			110	51	B&A		
5N	27E	13	Daa	Cross	UMA148				X			?	?	?	?	?
5N	29E	32	Ccd	Fetterhoff	UMA149				X			?	?	?	?	?
4N	29E	6	Daa	Jacques	UMA150				X			?	?	A?		
4N	29E	5	Cca	Baldwin	UMA151	UMAT	2708		X			200	95	B&A		
4N	29E	5	Cca	Kennen	UMA152				X			?	?	Spring		
5N	29E	26	Cba	Marks	UMA153				X			?	?	?	?	?
5N	29E	30	Adc	Landers	UMA154				X			?	?	?	?	?
4N	29E	7	Add	McAllister	UMA155				X			?	?	?	?	?
4N	29E	7	Ccd	Furrer	UMA156	UMAT	2797		X	X	X	54	47	A	FG	N
4N	28E	7	Abc	Casey	UMA157				X			?	?	?	?	?
5N	28E	15	Ccd	Meyers	UMA158				X			?	?	?	?	?
4N	26E	4	Bac	Western Empire	UMA159	MORR	917		X		X	92	92	A	CG	N

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling							
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Well Depth	Deepest Casing/Liner	Aquifer System	Aquifer Unit	Aquifer Type
5N	26E	33	Ddd	Western Empire	UMA160	MORR	1257		X	X	X	86?	75.8?	A?	CG?	N?
5N	26E	27	Cba	Western Empire	UMA161	MORR	1250		X		X	133	133	A	CG	N
5N	26E	35	Bbb	Western Empire	UMA162	MORR	1321		X		X	87	87	A	CG	N
5N	26E	16	Acb	U.S. Fish & Wildlife	UMA163	MORR	1005		X		X	77	77	A	CG	N
5N	26E	24	Cad	Murray	UMA164	MORR	1120		X	X	X	175	88	B		C
4N	28E	31	Cdd	Curtis	UMA165	UMAT	2607		X		X	204	147	B		C
3N	26E	13	Dcd	Big River Farms	UMA166	MORR	606		X		X	200	200	A	FG	N
3N	27E	2	Bba	Hampton	UMA167	UMAT	1162		X		X	110	82	A	FG	N
4N	27E	29	Bbb	Salono	UMA168	MORR	946		X	X	X	173	171.5	A	CG	N
3N	23E	9	Dda	Taggares Farms, Inc.	UMA169	MORR	1528		X			650	542	B		C
3N	25E	4	Daa	U.S. Navy	UMA170	MORR	587		X		X	310	310	B		C
3N	24E	15	Bab	Boeing Aerospace Co.	UMA171	MORR	576		X			730	510	B		C
3N	26E	22	Aab	Sabre Farms	UMA172	MORR	609		X		X	243	213	B		C
5N	26E	33	Aac	Western Empire	UMA173	MORR	1264		X		X	124	124	A	CG	N
5N	26E	32	Abc	Western Empire	UMA174	MORR	1254		X		X	151	150	A	CG	N
5N	26E	31	Acb	Western Empire	UMA175	MORR	1252		X		X	111	109	A	CG	N
4N	25E	1	Baa	Port of Morrow	UMA176	MORR	679		X		X	96	96	A	CG	N
4N	25E	12	Bba	Port of Morrow	UMA177	MORR	772		X		X	87.9	88	A	CG	N
4N	25E	2	Caa	Port of Morrow	UMA178	MORR	684		X		X	93	92	A	CG	N
4N	24E	13	Bcc	Wilson	UMA179	MORR	647		X		X	100	20	B		C
5N	26E	36	Bca	Bond	UMA180	MORR	1325		X	X	X	47	47	A	CG	N
4N	27E	25	Dab	Johnson	UMA181	UMAT	1552		X		X	89	58.83	A	FG	N
4N	27E	26	Bcb	Hansell Brothers, Inc.	UMA182	UMAT	1560		X		X	105	104	A	CG	N
4N	27E	27	Bdc	Hansell Brothers, Inc.	UMA183	UMAT	1565		X		X	127	125	A	CG	N
4N	27E	30	Ddd	Key	UMA184	MORR	962		X		X	120	118	A	CG	N
3N	28E	17	Baa	Brown	UMA185	UMAT	1201		X	X	X	112	80	A	FP	N
3N	27E	26	Dac	Madison	UMA186	UMAT	1168		X		X	330	324	A	FG	N
3N	27E	36	Add	Madison Ranch	UMA187	UMAT	1169		X	X	X	100	25	A	FP	N
3N	28E	27	Bcc	Levy	UMA188	UMAT	1217		X		X	450	85	B		C
3N	29E	17	Dba	Spike	UMA189	UMAT	1317		X		X	30	25	A	FP	N
3N	29E	21	Bad	Spike	UMA190	UMAT	1325		X	X	X	25	25	A	FP	N
3N	29E	8	Aca	City of Echo	UMA191	UMAT	1274		X	X	X	22.5	17.5	A	FP	N
3N	29E	7	Cdc	Prior	UMA192	UMAT	1269		X		X	33	33	A	FP	N
3N	28E	11	Dbb	Correa	UMA193	UMAT	1194		X		X	50	50	A	FP	N
3N	26E	3	Aaa	Big River Farms, Inc.	UMA194	MORR	589		X		X	324	138	B		C

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well Depth	Deepest Casing/Liner	Aquifer System	Aquifer Unit	Aquifer Type
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic					
4N	29E	9	Bbd	Kopacz	UMA195	UMAT	2813		X		X	103	77	A	FG	N
3N	28E	14	Ada	Taylor	UMA196	UMAT	5373		X		X	100	43	B?		C?
4N	24E	17	Adc	Union Pacific Railroad	UMA197	MORR	669		X			216	130	B		C
4N	27E	12	Ada	Lamb-Weston, Inc.	UMA198	UMAT	1536	MW-1	X	X	X	110	104	A	FG	N
3N	27E	9	Ada	Hansell	UMA199	MORR	628		X		X	125	61	A	FG	N
4N	29E	27	Abc	Pomeroy	UMA200	UMAT	2925		X		X	80	80	A	FG	N
4N	25E	2	Dcc	Port of Morrow	UMA201	MORR	1469			X	X	85	80	A	CG	N
4N	27E	6	Ccb	U.S. Army	UMA202	LUB	113	18-2			X	91	88.75	A	FG	N
4N	26E	12	Aac	U.S. Army	UMA203	LUB	121	38-2			X	87	85.25	A	FG	N
4N	26E	1	Acc	U.S. Army	UMA204	LUB	143	46			X	46	44.5	A	FG	N
4N	26E	1	Dad	U.S. Army	UMA205	LUB	153	57-5			X	76	74	A	FG	N
4N	26E	13	Aad	U.S. Army	UMA206	LUB	152	57-4			X	86	84.5	A	FG	N
4N	27E	13	Cdd	U.S. Army	UMA207	LUB	94	MW-11			X	103	99	A	CG	N
4N	27E	2	Dca	U.S. Army	UMA208	LUB	95	11-1			X	169	167	A	FG	N
4N	27E	15	Dbb	U.S. Army	UMA209	LUB	135	4-4			X	122	118.5	A	CG	N
4N	27E	15	Cbb	U.S. Army	UMA210	LUB	162	MW-26			X	60.5	60.5	A	CG	N
4N	27E	21	Daa	U.S. Army	UMA211	LUB	103	12-3			X	110	108.7	A	CG	N
4N	27E	22	Cbd	U.S. Army	UMA212	LUB	104	12-4			X	104.5	104.18	A	CG	N
4N	27E	6	Bcc	U.S. Army	UMA213	LUB	115	19-2			X	84	82.5	A	FG	N
4N	26E	12	Acb	U.S. Army	UMA214	LUB	122	38-3			X	101	99.75	A	FG	N
4N	26E	12	Dbd	U.S. Army	UMA215	LUB	123	38-4			X	80	78.75	A	FG	N
4N	27E	8	Dac	U.S. Army	UMA216	LUB	88	MW-5			X	140	136	A	FG	N
4N	26E	12	Add	U.S. Army	UMA217	LUB	110	16-2			X	108	106.5	A	FG	N
4N	27E	4	Ccb	U.S. Army	UMA218	LUB	87	MW-4			X	170	170	A	FG	N
4N	27E	12	Bbb	U.S. Army	UMA219	LUB	97	11-3			X	123	122.5	A	FG	N
4N	27E	1	Cbc	U.S. Army	UMA220	LUB	98	11-4			X	140	137.75	A	FG	N
4N	27E	15	Bdb	U.S. Army	UMA221	LUB	133	4-2			X	80	77.31	A	CG	N
4N	27E	11	Adb	U.S. Army	UMA222	LUB	96	11-2			X	151	142.5	A	FG	N
4N	27E	11	Bac	U.S. Army	UMA223	LUB	100	11-6			X	166	164.75	A	FG	N
4N	27E	15	Bcd	U.S. Army	UMA224	LUB	124	4-1			X	97	97	A	CG	N
4N	27E	15	Bcd	U.S. Army	UMA225	LUB	132	4-18			X	73	71.75	A	CG	N
4N	27E	15	Cca	U.S. Army	UMA226	LUB	134	4-3			X	58	55.81	A	CG	N
4N	27E	15	Dcb	U.S. Army	UMA227	LUB	136	4-5			X	118	116	A	CG	N
4N	27E	9	Ddb	U.S. Army	UMA228	LUB	130	4-16			X	115	114.7	A	FG	N
4N	27E	22	Bcc	U.S. Army	UMA229	LUB	101	12-1			X	111	110.9	A	CG	N

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
4N	27E	22	Bbb	U.S. Army	UMA230	LUB	106	12-6			X	97	94.5	A	CG	N
4N	26E	6	Add	Port of Morrow	UMA231	MORR	689	MW-2			X	98	95	A	CG	N
4N	26E	7	Bbc	Port of Morrow	UMA232	MORR	1549	MW-7			X	84.5	86	A	CG	N
4N	25E	24	Ddd	Port of Morrow	UMA233	MORR	1559	MW-15			X	90	90	B		C
4N	27E	1	Acc	Lamb-Weston Inc.	UMA234	UMAT	1524	MW-3			X	180	150	A	FG	N
4N	27E	1	Aaa	Lamb-Weston Inc.	UMA235	UMAT	1523	MW-4			X	180	150	A	FG	N
4N	28E	6	Acd	Lamb-Weston Inc.	UMA236	UMAT	5364	MW-6			X	100	100	A	FG	N
4N	28E	6	Acc	Lamb-Weston Inc.	UMA237	UMAT	1854	MW-8			X	30	28	A	FG	SU
4N	27E	1	Acd	Lamb-Weston Inc.	UMA238	LUB	19	MW-10			X	105	105	A	CG	SU
3N	27E	1	Caa	Lamb-Weston Inc.	UMA239	UMAT	5571	MR-MW-4			X	61	61	A	FG	N
3N	27E	16	Aba	Lamb-Weston Inc.	UMA240	UMAT	5570	MR-MW-3			X	39	38.33	A	FG	N
3N	27E	23	Bdb	Lamb-Weston Inc.	UMA241	UMAT	5594	MR-MW-2			X	172	172	A	FG	N
3N	28E	17	Cba	Lamb-Weston Inc.	UMA242	UMAT	5569	MR-MW-5			X	18	17.5	A	FP	SU?
4N	28	6	Aba	Lamb-Weston Inc.	UMA243	UMAT	5365	MW-5			X	152	150	A	FG	N
4N	29E	31	Dbd	A.E. Staley Mfg. Co.	UMA244	UMAT	5286	MW-3S			X	25	25	A	FP	SU?
4N	28E	28	Dba	J.R. Simplot Co.	UMA245	LUB	43	MW-11D			X	200	187	A	FG	N
4N	28E	28	Dcd	J.R. Simplot Co.	UMA246	LUB	45	MW-13S			X	178		A	CG	P
4N	28E	28	Dcd	J.R. Simplot Co.	UMA247	LUB	46	MW-13D			X	178	178	A	FG	N
4N	28E	26	Ccc	J.R. Simplot Co.	UMA248	LUB	50	MW-17			X	20	19	A	FP	SU?
4N	28E	32	Daa	J.R. Simplot Co.	UMA249	LUB	64	MW-31			X	27.5	27.5	A	FP	SU?
4N	28E	27	Cdd	J.R. Simplot Co.	UMA250	LUB	44	MW-12			X	85	75	A	CG	SU
3N	28E	5	Daa	J.R. Simplot Co.	UMA251	LUB	55	MW-22			X	86		A	?	?
3N	28E	4	Bda	J.R. Simplot Co.	UMA252	LUB	47	MW-14			X	142	109	A	CG	N
3N	28E	4	Ddd	J.R. Simplot Co.	UMA253	LUB	73	MW-40			X	75.5	75.5	A	CG	N
3N	28E	18	Cda	J.R. Simplot Co.	UMA254	LUB	77	MW-44			X	27.5	27.5	A	FP	SU?
3N	28E	7	Ada	J.R. Simplot Co.	UMA255	LUB	63	MW-30			X	34	33.5	A	FP	SU?
3N	28E	6	Add	J.R. Simplot Co.	UMA256	LUB	58	MW-25			X	21.5	19	A	FP	SU?
3N	28E	5	Bad	J.R. Simplot Co.	UMA257	LUB	57	MW-24			X	26.5	23.5	A	FP	SU?
4N	28E	27	Ddb	J.R. Simplot Co.	UMA258	LUB	53	MW-20			X	20	19	A	FP	SU?
4N	29E	31	Dbd	A.E. Staley Mfg. Co.	UMA259	UMAT	5290	MW-3D			X	65	65	A	FP	N
4N	29E	31	Daa	A.E. Staley Mfg. Co.	UMA260	UMAT	5287	MW-1S			X	26.5	26	A	FP	SU?
4N	28E	28	Dba	J.R. Simplot Co.	UMA261	LUB	42	MW-11S			X	200		A	CG	SU
4N	29E	31	Daa	A.E. Staley Mfg. Co.	UMA262	UMAT	5292	MW-1D			X	65	65	A	FP	N
4N	29E	19	Ddd	Hermiston Foods, Inc.	UMA263	UMAT	5525	MW-1			X	71.5	66	A	FG	N
4N	29E	19	Abb	Hermiston Foods, Inc.	UMA264	UMAT	5526	MW-2			X	87	87	A	FG	N

Table 4C.1 Groundwater sampling sites.

Location				Owner	Well Identification Number				Well Use for Sampling			Well	Deepest	Aquifer	Aquifer	Aquifer
Township	Range	Section	Qtr-Sections		DEQ	OW	RD	Facility	Recon.	Bimonthly	Synoptic	Depth	Casing/Liner	System	Unit	Type
4N	29E	19	Aaa	Hermiston Foods, Inc.	UMA265	UMAT	5528	MW-4			X	108.2	108	A	FG	N
5N	27E	19	Dad	City of Irrigon	UMA266	LUB	9	UB			X			A	CG	N
5N	27E	19	Dad	City of Irrigon	UMA267	LUB	11	DB4			X			A	CG	N
5N	27E	19	Dab	City of Irrigon	UMA268	LUB	1	DC			X			A	CG	N
5N	27E	20	Ccc	McNamee	UMA269	MORR	1564				X	203	203	B		C
4N	26E	18	Add	Eastern Oregon Farming Co.	UMA270	MORR	930				X	52	38	A	CG	N
3N	24E	31	Bbb	Portland General Electric	UMA271	LUB	32	107			X	43.5	41	B?		?
3N	24E	33	Acc	Portland General Electric	UMA272	MORR	574	1			X	564.5	30	B?		?
3N	24E	20	Ddc	Portland General Electric	UMA273	LUB	29	104			X	55.1	55.1	B?		?
4N	24E	30	Cdb	Portland General Electric	UMA274	LUB	27	101			X	25	19.4	A	CG	N
3N	24E	16	Bda	Portland General Electric	UMA275	LUB	28	103			X	67.7	65.2	A	CG	N
4N	27E	7	Ccc	U.S. Army	UMA276	LUB	151	57-3			X	99	97.5	A	FG	N
3N	27E	4	Ada	Key	UMA277	MORR	613				X	80	80	A	FG	N
4N	28E	14	Ccb	Rankin	UMA278	UMAT	2151				X	145	144	A	FG	N
5N	29E	29	Bca	Stoneburner	UMA279	UMAT	3743				?	40	40	A	CG	N

Table 4C.2 Surface water sampling sites.

Location				Owner	Site ID DEQ	Description
Township	Range	Section	Qtr Sections			
4N	28E	3	Bcb		404474	Hermiston Ditch at 11th Street Crossing
4N	28E	4	Aac		404475	Umatilla River below Hermitson Ditch and Hermiston STP outfall
5N	28E	28	Cbc	West Extension Irrigation District	404476	Three Mile Falls Diversion (Umatilla River)
4N	28E	30	Abc		404477	Umatilla River at Union Pacific Railroad Crossing
4N	27E	1	Ddd	Lamb-Weston, Inc.	404478	Lamb-Weston Wastewater Lagoon
4N	28E	19	Bbc	Stanfield-Westland Irrigation District	404479	Westland Canal at Walker Road
3N	27E	10	Bdc	Stanfield-Westland Irrigation District	404480	High Line Canal at County Line Recharge Project Diversion
3N	27E	10	Bcc		404481	Lost Lake
4N	29E	19	Cad	Hermiston Foods	404482	Hermiston Foods Surge Basin
4N	29E	32	Bdb	Stanfield-Westland Irrigation District	404483	Feed Canal at Hwy 395
4N	29E	14	Cdd	Stanfield-Westland Irrigation District	404484	Furnish Ditch at Stanfield Loop Road
4N	29E	3	Acb	Stanfield-Westland Irrigation District	404485	Cold Springs Reservoir at Outlet Tower
4N	28E	27	Cdd	J.R. Simplot Co.	404486	Simplot Surge Pond
3N	28E	5	Ddc	J.R. Simplot Co.	404487	Simplot Wastewater Irrigation Lagoon
4N	28E	28	Cdd		404488	Umatilla River at Hwy 207 Crossing

3N	23E	18	Aba	Taggares Farm, Inc.	404489	Simtag Booster Pumps (pumps water diverted from Columbia River/Willow Creek confluence)
3N	24E	33	Dcb	Portland General Electric	404490	Carty Reservoir
4N	25E	11	Abd	City of Boardman	404491	City of Boardman Sewage Lagoons
4N	25E	2	Abb	Columbia Improvement District	404492	Columbia Improvement District Columbia River Station
4N	25E	13	Bda	Hillview Dairy	404493	Feedlot Washout Lagoon
4N	26E	7	Dba	West Extension Irrigation District	404494	West Extension Irrigation Canal at Hwy 730
3N	26E	15	Aaa	Columbia Improvement District	404495	Sabre Ditch
3N	29E	21	Bad	Stanfield-Westland Irrigation District	404498	Hunt Ditch
3N	29E	8	Adb	Stanfield-Westland Irrigation District	404499	Feed Canal at Echo STP Driveway
3N	29E	8	Ada	Stanfield-Westland Irrigation District	404500	Furnish Ditch at Echo STP Driveway
4N	28E	8	Ddd		404504	Umatilla River at Westland Road Crossing

Appendix 4D

Reconnaissance Groundwater Sampling Plan

Lower Umatilla Basin
Groundwater Assessment
Sampling and Analysis
Project Plan
9-4-90

Project Officer: ________________
Greg Pettit

Lab QA Officer: ________________
Claude Shinn

Summary: The groundwater assessment in the northern parts of Morrow and Umatilla counties is in response to elevated levels of nitrates in the groundwater which were detected during assessment work conducted by the Department in 1986 and 1987. During that study, 25 wells were tested for nitrates and 12 wells were tested for pesticides. 11 wells were found to contain nitrate levels over the 10 mg/l nitrate-nitrogen public water supply drinking water standard. Concentrations as high as 80 mg/l nitrate-nitrogen were detected. Information from several other sources, such as: point source monitoring, public water supplies, and locally conducted surveys also indicate high nitrate levels are common in the area.

Under the Oregon Groundwater Quality Protection Act of 1989, areas which have nitrate levels exceeding 100% of adopted Maximum Measurable Levels of Contaminants in Groundwater (10 mg/l for nitrate-nitrogen) are to be declared groundwater management areas. This study is being undertaken to better ascertain the extent and pattern of groundwater contamination in the area. This information will be used by the Department, other agencies, and a local groundwater management committee to determine the impacts of contamination on existing and future beneficial uses of groundwater, and will be used to help develop a groundwater management plan for the area.

Initial efforts of this study will concentrate on developing an adequate data base to establish the areal extent of the contamination. This will be done by sampling a large number of different wells for the first seven months of the project. Sampling runs will be conducted every other month. 30 to 35 well samples, plus QA samples, will be collected during the first four sampling runs. In the second phase of the monitoring program, a network of 30 to 35 wells be established for routine bimonthly monitoring. These wells will be used to identify seasonal variability and trending.

The DEQ lab will collect the samples and perform inorganic, volatile organics, COD, and TOC analyses. The Department of Agriculture lab will perform pesticide screening analyses on samples collected during the first six months. After initial screening samples have been analyzed, pesticide analyses will be cut back to any pesticides that have been detected, and a annual screen for pesticides using EPA NPS Screening methods 1,2,3, and 5.

Fund Code: 3560

Special Handling: To document and track samples, a sample request form will categorize the samples and the required analysis. The form will identify the sample container, well number, owners name, and the lab to receive the sample. As case numbers are assigned, monitoring personnel will phone the number to the OSU and ODA Labs to be referred to when reporting the data to the monitoring personnel. Samples will be delivered to the Portland Greyhound station, packaged in ice chests, to be retrieved by DEQ lab personnel. Pesticide samples will be delivered to the Salem and Corvallis Greyhound stations, packaged in ice chests, to be retrieved by ODA and OSU laboratory personnel, respectively. Bacteria samples will be shipped to Coffey lab in Pendleton. Bacteria samples will be tracked by and reported to OSHD. Samples are considered non-hazardous. 40 samples will be collected for each event. For each well sampled, 6 containers will be collected for DEQ analyses, and one each for OSU, ODA, and OSHD analyses.

Parameter Codes:
Physical (DEQ)....F ALK, F pH, F COND, TEMP
Organic (DEQ)....COD, TOC, M8260
Inorganic (DEQ)...TKN, NH3-N, NO3&NO2-N, TPO4-P, IP Mn, IP Na, IP K, IP Ca, Cl, SO4, G As, IP Fe, IP Mg, IP Al, IP Cu, IP Zn, IP Si, IP B
Bacteria (Coffey).Total Coliform
Pesticides........EPA Pesticide Screening Procedures -
(ODA Lab) Methods 1,2,3, and 5; and special OSU Dacthal procedure. Pesticide analytes will be reevaluated January 1991.

Report Data To: Greg Pettit:WQ-GW, Marvin McGlothlin:Lab-GWM, & Dennis Nelson: Health Division - Portland, within 6 to 8 weeks of receiving the samples.

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Tables

1.0 Project Description

1.1 Background

Groundwater samples were collected in 1986 and 1987 from 25 domestic water supply wells located in an irrigated agricultural area of Northeastern Morrow County and Northwestern Umatilla County in 1986 and 1987. These samples were collected as part of a statewide assessment of agricultural chemicals in groundwater. 380 wells were sampled statewide during the survey. Samples were analyzed for inorganics, including nitrates, as well as a list of leachable pesticides that was developed for each area. Of the 25 samples collected and analyzed for nitrates in the study area, 11 exceeded the 10 mg/l drinking water standard. Levels as high as 80 mg/l were reported. 12 wells were analyzed for pesticides. No pesticides were detected above reporting values.

In 1989 the Oregon Legislature passed the Oregon Groundwater Quality Protection Act of 1989. This law provides the framework for establishing and coordinating State groundwater quality protection activities. It requires that when contaminants are found at levels exceeding 50% (100% for nitrates first two years) of established Maximum Levels for Contaminants in groundwater, and when these contaminants result at least in part from non-point source activities, that the area shall be declared a groundwater management area. Based upon the nitrate levels found in the region's groundwater, the Northern Umatilla and Morrow County areas have been declared as groundwater management areas by the Department.

When an area is declared a groundwater management area, the Groundwater Act requires that a local groundwater management committee be appointed by the Strategic Water Management Group (SWMG), and that a groundwater management plan be developed and adopted by the SWMG. DEQ has been designated as the lead agency for developing the groundwater management plan.

1.2 Project Boundaries

Interim project area boundaries have been established as follows: The northern boundary is the Columbia river; the western boundary is the Gilliam/Morrow County line; the southern boundary is line between townships 2N and 3N; and the eastern boundary is the line between ranges 29E and 30E.

1.3 Purpose

This project will characterize the region's shallow groundwater resources and evaluate public health and the environmental risks. Wells to be sampled are both private and public water supply sources and will be evaluated utilizing current drinking water standards and health advisories.

1.4 Data Usage

Data will be used to determine the nature and full extent of the identified contamination and to establish a data base to monitor seasonal and cyclic water quality trends and to identify aquifer characteristics.

1.5 Monitoring Network Design And Rationale

Existing public and private domestic and irrigation wells within the study area will be used. A total of 120 to 140 wells will be screened to select 35 wells to use for ongoing monitoring. 30 to 35 wells will be sampled during each event until all 120 to 140 have been sampled. Once the initial screening has been completed, 35 wells will be selected to compose the monitoring network. Wells have been selected and will be further screened based on; location, depth, well log availability, accessibility, and previous sample analysis results. The wells will be identified by a unique number assigned randomly within a drainage basin. The drainage basin abbreviation will compose the first three letters of the identification. The well number will also be the secondary STORET station number to be used in data reporting.

1.6 Parameters and Frequency

Sampling will be conducted every other month beginning July 1990 and continue through June 1993. The analytical parameters, the analytical methods and techniques, and the minimum reportable value to be utilized for this project are listed in Table 1.

Samples collected during the first six months (screening phase of survey) will be analyzed by the ODA lab for pesticides using the five screening procedures developed by EPA for the National Pesticide Survey. Special attention will be given to the 42 pesticides identified as being of particular concern (Table 2). In March 1991 the pesticide analytes will be reevaluated with additional pesticide analyses run only for those pesticides which have been detected.

Wells will be screened annually each July for pesticides by OSU and ODA labs. OSU will analyze approximately 10% of the samples for QA purposes. The analytical methodology and pesticides of concern are listed in the Project Plan and will be attached as a supplement to this plan.

2.0 Project Organization and Responsibility

This is a interagency project with participants from DEQ, OSHD, ODA, and WRD.

Greg Pettit	DEQ WQ Groundwater Section, 229-6065 Project management, design,and planning.

Marvin McGlothlin	DEQ Lab Monitoring Section, 229-5983. To insure properly performed field monitoring.
Ron McCartney	DEQ Lab Inorganic Section, 229-5983. To insure inorganic chemical analyses are properly performed.
Rick Gates	DEQ Lab Organic Section, 229-5983. To insure organic chemical analyses are properly performed.
Claude Shinn	DEQ Lab Quality Assurance Section, 229-5983. To insure laboratory quality assurance requirements are met.
Dennis Nelson	OSHD Drinking Water Program, 229-5846. To provide health risk assessment and notify well owners of health risks.
Mike Wehr	ODA Laboratory Services Division, 378-3793. To provide pesticide analyses and data interpretation.
Ian Tinsley	OSU Department of Agricultural Chemistry, 754-3791. To assist and support ODA in pesticide analyses and data interpretation.
Ken Lite	WRD Hydrogeology, 378-3671. To provide hydrogeology information and evaluation.

3.0 Data Quality Objectives

Table 3 lists the data quality objectives for this project. Data analyses for parameters with drinking water standards will be used for health risk assessments.

4.0 Sampling Procedures

Samples will be collected from a tap located closest to the wellhead. Wells will be purged for a minimum of five minutes and monitored for temperature stabilization prior to sampling. Wherever possible, samples will be collected upstream from the pressure tank, and the well will be purged until ambient groundwater temperatures are obtained and the temperature has stabilized for two minutes. If the well is not being used on a daily basis, the casing volume will be calculated and three casing volumes will be purged. Samples will be collected using standard DEQ operating procedures in accordance with the established DEQ Water Monitoring Section SOP.

Field notes will be made documenting sample collection procedures. At a minimum, field notes should contain: verified name and address of the resident at the well location, and the well owner if different; purging method; location of sample collection; and activities or structures which may influence the analytical results or sample collection procedures. For wells sampled for the first time a Well Identification Record shall be completed, and the location of the well shall be marked on a 7.5 minute USGS Quad map. The location on the map shall be identified with the well owners name and unique well number (UMA---) assigned to that well, and the well number shall be recorded in the field notes.

5.0 Sample Documentation and Custody

Routine chain of custody procedures will be adequate for this project. To track samples, the Sample Analysis Request Form will categorize the samples and summarize the required analyses. The form will identify each sample container by number and list the well number, the users or owners name, and the lab to receive the sample and perform the analysis. As DEQ Lab Case Numbers are assigned to the samples, monitoring personnel will phone that number to the ODA and OSU lab personnel to be referred to when reporting the data. The sample container size, type, quantity, the parameter to be analyzed, the preservative to be used and the laboratory to receive the sample are listed in Table 4.

6.0 Equipment Calibration and Maintenance

The established DEQ Laboratory Standard Operating Procedures will be followed along with the manufacturers' recommendations for calibrating, maintaining, and operating equipment.

7.0 Analytical Procedures

All analyses will be performed according to U.S. Environmental Protection Agency or Standard Methods procedures. Table 1 lists parameters, method, and minimum reporting value to be utilized for this project.

8.0 Data Reduction, Validation and Reporting

Each participating laboratory will review the data they generate to evaluate and report whether the data meets the quality assurance objectives. The report along with the data will be sent to the DEQ project manager and the laboratory groundwater monitoring coordinator. Monitoring personnel will transfer the data from the LIMS system to the STORET system for data storage and manipulation. Latitude and longitude coordinates will be determined by Groundwater Section GIS staff and given to Lab Monitoring Section staff for STORET station entry.

If data objectives are not met, a meeting will be scheduled by the laboratory QA personnel to determine potential causes and to recommend subsequent action. OSHD may attend the meeting depending on the nature and extent of the problem.

9.0 Quality Control Procedures

Routine quality assurance procedures will be employed as listed in the DEQ laboratory Quality Assurance Manual. Acceptable limits for the laboratory quality assurance objectives are listed in Table 3. In addition to the QA manual requirements the following procedures will be performed. Duplicate samples will be analyzed to measure the analytical precision on 10% of the samples collected. For each sampling run a transport and a transfer blank will be analyzed to detect interferences introduced during sampling or transport. Reagent blanks will be analyzed to detect interferences introduced during analysis and to verify method detection limits.

10.0 Performance and System Audits

The DEQ laboratory participates in the EPA Water Pollution Performance Evaluation Studies for the parameters included in their portion of this project. DEQ is a certified drinking water laboratory for inorganic and volatile organic analysis.

ODA coordinates the Pesticide Analytical Response Center and is authorized under the FIFRA program to perform pesticide analyses. ODA is also a certified drinking water lab for pesticides and herbicides. The OSU lab is recognized to perform analyses for the registration of pesticides under the USDA minor crop program.

11.0 Data Assessment

Each laboratory is responsible for maintaining the quality of the data generated. Data will be evaluated for precision and accuracy by the laboratory prior to reporting to the DEQ project manager.

The general acceptance criteria for accuracy and precision is listed in Table 3. Accuracy is determined by the percent recovery of spiked samples. Precision is determined by the difference between duplicate analysis divided by the mean. Complete procedures for assessing precision and accuracy are detailed in the DEQ Quality Assurance Manual.

12.0 Validation Analyses

For analytical results which are at or near the drinking water standard for the parameter being assessed, additional analysis may be requested.

Prior to confirmatory analysis, a complete review of the data and the analytical methodology available will be performed by the project manager and the laboratory QA officer to determine the applicable methodology to be used in the confirmatory analysis.

13.0 Data Distribution

Data reports from all participating labs (DEQ, ODA, Coffey, and OSU) shall be sent to the DEQ laboratory sample tracker. When the sample tracker has assembled all data for each run, he will forward copies to the DEQ project manager (Greg Pettit), the lab groundwater monitoring coordinator (Marvin Mc Glothlin), and the Health Division (Dennis Nelson). The lab groundwater monitoring manager will be responsible for insuring all data is entered into STORET and verified within 60 days of release by the sample tracker. The Health Division will be responsible for insuring that each individual well owner receives analytical results from their well along with appropriate health and treatment information within 60 days of the data release by the sample tracker. The Project coordinator will maintain a mailing list of persons interested in receiving data from the project, and will insure that monitoring reports are sent to individuals on that list within 90 days of the data release by the sample tracker.

14.0 Corrective Action

Corrective action will be initiated at the first indication of nonconformance with the project's quality assurance objectives. Prior to initiating corrective action the personnel initiating corrective action will flag the data in question and inform the laboratory QA officer, the monitoring section coordinator, and the project manager. If warranted, a meeting will be held to determine the causative factors and to recommend subsequent action.

15.0 Quality Assurance Reports

At the time of reporting the annual pesticide screening results, in the fall of each year, a meeting will be scheduled to allow the QA representatives from each participating laboratory to discuss any concerns they have and the analytical program they are charged with. At this time a report will be generated by each lab summarizing the integrity of the analytical data generated as well as any significant aspects of the program which has affected, or may affect, the quality of data generated by this project.

16.0 Health and Safety

All personnel participating in this project will conform to the Occupation Safety and Health Administration regulations governing personal protection in the work place. The sampling stations in this project are existing domestic and irrigation water wells. Samples obtained from these sources are not considered hazardous, however, unknown constituents or concentrations may be present in the media to be collected. Personnel should be aware that the samples could contain potentially hazardous materials. Personnel should be aware also of the potential hazards associated with the collection, handling, analysis, and disposal of the samples. It is the responsibility of the participating personnel to initiate and follow all necessary safety measures related to the project in accordance with the established Water Monitoring Sections Mode of Operations Manual.

Field conditions which may require additional precautions are listed below.

1. Severe temperature extremes.
2. Unaccessible potable water.
3. Exposure to such pests as insects, reptiles and rodents.
4. Hazards associated with extended travel in very primitive and remote terrain during severe weather conditions.

17.0 Schedule of Activities

July 1990 to June 1993 - Interagency meetings will be held to coordinate and schedule details of project activities. Meetings will be held periodically as needed.

July 1990 to June 1993 - Groundwater sampling will be conducted every other month. Sampling will begin July 1990 and continue through May 1993.

November 1990 - A local Groundwater management committee will be appointed by SWMG and begin work on developing a groundwater management plan for the area.

March 1991 - Routine groundwater monitoring well network will be established in the area.

July 1991 to July 1993 - Annual pesticide screening, to coincide with the July monitoring well sample collection.
Annual QA meeting and report.

November 1990 to June 1993 - Citizen Advisory Committee meetings will be held periodically as needed. Committee will be presented with a review of the project activities.

July 1991 to June 1993 - Development of Best Management Practices research and implementation of BMP field tests.

18.0 Anticipated Resources

Project Design and QA Plan Development	120 hrs.
Sample Collection and data entry	4320 hrs.
Laboratory Analyses *DEQ	5760 hrs.
*ODA & OSU	6480 hrs
Quality Assurance Summaries and Meetings	500 hrs.
Total Lab Resources	17180 hrs.

Table 1
Laboratory Analyses

Parameter	Reference	Analytical Technique	Minimum Report Value, mg/l
Organics			
COD	R2-410.4	Dichro. Spectro	5.0
TOC	R2-415.2	UV/sulfate oxidation	1.0
Volatiles	EPA 8260	Purge & Trap, GC/MS	0.0005
Total Ions & Metals			
Ca	R2-200.7	ICP	0.2
Mn	R2-200.7	ICP	0.02
Na	R2-200.7	ICP	0.5
K	R2-200.7	ICP	0.5
Cl	R2-325.1	Auto Ferricyanide	0.1
SO4	R2-375.2	Auto Methyl Thymol	0.5
As	R2-206.3	Gaseous Hydride	0.005
Fe	R2-200.7	ICP	0.05
Mg	R2-200.7	ICP	0.5
Si as SiO2	R2-200.7	ICP	0.3
B	R2-200.7	ICP	0.03
Al	R2-200.7	ICP	0.1
Cu	R2-200.7	ICP	0.05
Zn	R2-200.7	ICP	0.05
Nutrients			
TKN	R2-351.1	Block Digestion	0.2
NH3-N	R2-350.1	Auto Phenate	0.02
NO3+NO2-N	R2-353.2	Auto Cd Reduction	0.02
Total Phos	R1-424F	Ascorbic Acid Reduct.	0.01
Pesticides			
Dacthal	NPS 515	OSU Modified App. D	0.0001
Screens	NPS	Methods 1,2,&3	0.001
Carbamate Screen	NPS	Method 5	0.005
Physical			
Alkalinity	R2-310.1	Titration	1.0
pH	R2-150.1	Electrode	0-14 SU
Conductivity	R2-120.1	Wheatstone bridge	1umho/cm

Referenced methodologies are detailed in the following publications. Method modifications unique to this project are listed in Appendix D.

R1,	Standard Methods For The Examination Of Water And Wastewater 16th edition, APHA, AWWA, WPCF, 1985.
R2,	Methods For Chemical Analysis Of Water And Wastes EPA/4-79-020.
EPA,	SW-846 Test Methods For Evaluating Solid And Hazardous Wastes 3rd ed, 1986. Conforms with EPA Drinking Water Method 524.1
NPS,	National Pesticide Survey Methodology, EPA Technical Support Division, Office of Drinking Water

Table 2

Pesticide Screening Analytical Methods

Pesticides screens shall be conducted utilizing the EPA standard screening methods developed for the National Pesticide Program. These methods have been developed by the EPA technical Support Division, Office of Drinking Water.

Methods:

1) Determination of Nitrogen-and Phosphorus-Containing Pesticides by Gas Chromatography with a Nitrogen-Phosphorus Detector.

2) Determination of Chlorinated Pesticides by Gas Chromatography with an Electron Capture Detector.

3) Determination of Chlorinated Phenoxy Acids by Chromatography with an Electron Capture Detector.

4) Method 4 will not be used.

5) Measurement of Pesticides by Direct Aqueous Injection HPLC with Post Column Derivatization.

6) DCPA Special Method developed by OSU and verified by EPA Manchester lab, and ODA Lab Services.

When using these methods special attention shall be given to the following pesticides.

EPA PRIORITY LEACHERS USED IN OREGON

Alachlor
Aldicarb
Aldicarb Sulfone
Aldicarb Sulfoxide
Atrazine
Bentazon
Bromacil
Butylate
Carbaryl
Carbofuran
Carboxin
Chloramben
Chlorothalonil
Cyanazine
2,4-D
Dalapon
Dibromochloropropane (DBCP)
Diazinon
Dicamba
1,2-Dichloropropane
cis-1,3-Dichloropropene
tran-1,3-Dichloropropene
Dinoseb
Diphenamid
Disulfoton
Diuron
Fenamiphos
Hexazinone
Methomyl
Methoxychlor
Metolachlor
Metribuzin
Oxamyl
Pichloram
Pronamide
Propachlor
Propham
Simazine
Terbacil
Terbufos
Trifluralin
DCPA

Table 3

Quality Assurance Objectives

Parameter	Concentration Range	Precision Range or	RPD	100%+ Accuracy
Physical				
Conductivity	≥25 umhos/cm3		±5%	±5%
pH	0 - 14 SU	±0.2 SU		±0.1 SU
Alkalinity	≥10 mg/l		±5%	NA
Nutrients				
TKN	0.2-1.0 mg/l	±0.1 mg/l		
	≥1.0 mg/l		±20%	±20%
NH3-N	0.02-0.2 mg/l	±0.05 mg/l		
	≥0.2 mg/l		±20%	±20%
NO3+NO2-N	0.02-0.2 mg/l	±0.05 mg/l		
	≥0.2 mg/l		±10%	±15%
Total Phos.	0.01-0.1 mg/l	±0.05 mg/l		
	≥0.1 mg/l		±20%	±20%
Organics				
COD	5.0-10.0 mg/l	±0.5 mg/l		
	≥10.0 mg/l		±20%	±20%
TOC	1.0-5.0 mg/l	±0.5 mg/l		
	≥5.0 mg/l		±20%	±20%
VOC (8260)	0.0005-0.010 mg/l	±0.001 mg/l		
	≥0.01		±15%	±15%
Total Ions and Metals				
Mn	0.02-0.10	±0.01 mg/l		
	≥0.10		±15%	±15%
Ca,Na,K Mg,SiO2	0.2-10.0 mg/l	±1.0 mg/l		
	≥10.0 mg/l		±15%	±15%
Cl,Al	0.1-5.0 mg/l	±1.0 mg/l		
	≥5.0 mg/l		±15%	±15%
SO4	0.5-5.0 mg/l	±1.0 mg/l		
	≥5.0 mg/l		±15%	±15%
Fe,Cu,Zn,B	0.05-0.5 mg/l	±0.05 mg/l		
	≥0.5 mg/l		±15%	±15%
As	0.005-0.1 mg/l	±0.001 mg/l		
	≥0.1 mg/l		±15%	±15%

Table 4

Containers and Preservation*

Laboratory	Container	Preservative	Analysis
DEQ	(1) 250 ml DP poly	refrig	Ions
	(2) 40 ml glass vials	refrig	volatiles
	(1) 250 ml TM poly	refrig,HNO3,pH<2	metals
	(1) 500 ml R poly	refrig,H2SO4,pH<2	nutr./org.
	(1) 1000 ml P poly	refrig	Physical
DOA	(1) 2000 ml glass	refrig	Pesticides
OSU**	(1) 2000 ml glass	refrig	Dacthal
Coffee***	(1) 250 ml glass	refrig	Bact.

* Per sample
** OSU laboratory will receive approximately 10% of the samples delivered to the DOA laboratory.
*** Samples to be shipped to Coffee Labs in Pendleton, containers and proper forms supplied by Coffee Labs.

Appendix 4E

Bimonthly Groundwater Sampling Plan

LOWER UMATILLA BASIN GROUND WATER QUALITY ASSESSMENT

WELL NETWORK FIELD WORK PLAN

ADDENDUM TO SAMPLING AND ANALYSIS PROJECT PLAN 9/4/90

FUND CODE: 3560D

SIGNATURE:

Water Quality Monitoring Manager

Date

November 1991.

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SUMMARY

Phase I (reconnaissance phase) of the ground water quality assessment project focused upon developing sufficient data to preliminarily: 1) understand the general chemistry of local groundwater; 2) identify the list and concentration range of contaminants present in local groundwater; 3) identify the extent of groundwater contamination; and 4) help establish the project boundary limits. Phase II has been established to monitor 35 to 40 wells, bi-monthly, to determine seasonal variability and trends.

WELL NETWORK

A. The network bi-monthly was established after reviewing water chemistry and well construction data collected from 198 wells in the lower Umatilla basin during the 15 month reconnaissance project. Thirty-five bi-monthly wells were chosen for routine sampling, along with 5 wells to be sampled, if field time allows (attachment I).

Phase II (bi-monthly) wells were chosen for their hydrogeological placement, geographic location, and groundwater water chemistry characteristics.

The selection of bi-monthly network wells used a two step process of pre-determined criteria.

In step 1, a list of candidate wells was compiled using the following criteria:

1. The wells were located and observed by OWRD and/or DEQ staff during Phase I.
2. The wells is completed in alluvium only or were completed in a single basalt water bearing zone.
3. The wells appear accessible throughout the year for sampling.

In step 2, a final list of wells was selected if the well met one or more of the following:

4. The well is a member of a group of wells positioned along ground water flow path.
5. The well provides data for an isolated geographic location.
6. Ground water from the well has had moderate to high levels of nitrate.

7. Wells that had confirmed levels of pesticide or volatile organic detections were included in the sampling program.

B. A list of well owner's addresses will be included in the field notebook and available to inter/intra agency staff (attachment I - list of wells).

C. Well Identification Records are to be kept in the field notebook. WIR's contain information about the well, including associated plumbing, purging information, and location of the well in relation to the property boundary or structures.

D. Maps (including 7.5 minute quadrangle maps) will be carried into the field to assist in locating the wells. New sampling sites will be marked and identified on the map.

PROJECT SAMPLING DURATION & FREQUENCY

A. Phase I of the project started in July 1990 and continued until October 1991. Phase II began in September 1991, and it will continue through 1993. After the adoption of a management plan, groundwater sampling may continue as established by the plan.

In preparation for scheduling bi-monthly sampling events in the Lower Umatilla Basin, the DEQ laboratory ground water monitoring section has prepared and will make available, a tentative schedule for the remainder of November 1991 through 1992. A copy of the bi-monthly sampling schedule will be sent to participating laboratories.

B. Sampling will be bimonthly, starting September 1991. Sample scheduling will allow participating laboratories time to schedule logistics, supplies, and target dates as to when samples will be sent to them (attachment II - tentative schedule for 1991-1993).

C. During the project, a synoptic survey will be conducted, encompassing a large number of wells (approx. 150 in number), and a limited number of surface water samples (approximately 25), for a pre-determined set of indicator parameters. The synoptic will be have different goals than the established Phase II sampling program and will require a separate project work plan.

SAMPLING LOGISTICS, SAMPLE SHIPPING, AND CONTACTS

A. Field work will require five days to complete, including travel. Overtime can be expected on occasion, to complete unscheduled or scheduled project requirements. Field staff will leave a contact phone number with the office in case of unscheduled sampling needs or emergencies.

B. Laboratories require samples to be sent before the end of thursday of the sampling week. Samples will be sent from the most convenient bus location and sent on the first available bus. If shipping is unavailable, the affected laboratories should be contacted to alleviate undue concern over holding times or late arrivals.

C. Well owners will be notified by mail that their well has been selected for the bi-monthly sampling program. An initial site visit letter will be written and delivered by field staff indicating when the well was sampled, who sampled the well, when the next scheduled sampling event will occur, and who the well owner may contact for questions and concerns. Both letters will be written by the project manager.

A list of contacts will be carried in the field notebook. Contacts will include the participating laboratories, key project staff, and project area contacts such as, SCS office, bus station, key committee members, etc. (attachment IV - contact list).

SAMPLE PARAMETERS

Sample parameters were chosen at the beginning of Phase I and several changes have been made in Phase II. Parameters were chosen to identify potential contaminants, characterize the chemistry of ground water from individual wells, monitor seasonal trends, and chemically identify ground water recharge sources (attachment III - list of parameters). All parameters are reported as total recoverable unless otherwise stated.

The parameter Bromide may be added to the parameter list at a later time. Iron will be reported as total recoverable and dissolved. Selenium has been added to Phase II and will be reported as total recoverable.

Phase II network well samples will be collected in the same manner as established during Phase I to maintain consistency in the sampling program. Sampling will be conducted by experienced ground water unit staff, knowledgeable in monitoring protocol.

No special sample handling has been added to Phase II sampling.

FIELD PARAMETERS

Temperature, conductivity, and pH readings are to be continued in Phase II. Temperature is an unstable parameter, which is influenced by variables in sampling that are difficult to control. Water line plumbing, pressure tank, and ambient air temperature can affect the reading of an accurate groundwater temperature. Temperature has not been identified as a critical parameter. Common sense needs to be used at any given well location, on how much time should be spent obtaining a temperature reading.

Temperature should be monitored during purging and is most useful as an indicator of when "fresh" groundwater is being obtained. It is not always practible for a representative groundwater to be obtained, therefore, a five minute purge is considered adequate for collecting samples.

Instruments will be calibrated and maintained according to manufactures specifications and or to water quality section manual procedures.

QUALITY ASSURANCE & QUALITY CONTROL

Components of quality assurance and quality control will include data quality objectives, equipment calibration, analytical procedures and reporting levels, quality control procedures, data reduction, validation, and reporting, performance and systems audits, data assessment, corrective action, and quality assurance reports. Both DEQ and ODA laboratories will maintain their own QA/QC programs. OSU will not continue to be a participant in the analytical QC program.

Quality control samples will include:

a. Transport blanks for organic (VOA) and pesticide samples, field blanks for inorganic samples (filtered and un-filtered), transfer blank for organic (VOA) samples, and duplicate well samples taken at random during a sampling event. Blank water for inorganic can be taken from any inorganic tap that is ASTM type II (reverse osmosis/de-ionized, double filtered). Blank water for organic (VOA) samples will be taken from boiled ASTM type II water kept in the organic section, room L71a.

b. Duplicate samples will be taken simultaneously (split sample) or one after another (co-sample) from a continuous flow.

c. Quality control samples will represent 10% of the total number of samples collected in a sampling event.

CORRECTIVE ACTION

Any changes at the well site, deviation from the Water Quality Section Manual procedures, or the work plan, will be documented in the field report and brought to the attention of the project manager. Significant changes or corrective action to the sampling plan needs to be well documented.

Non conformance with the project's quality assurance objectives needs to be followed through by flagging the data in question and inform the laboratory QA officer, the monitoring section coordinator, and the project manager. If warranted, a meeting will be held to determine the causative factors and to recommend subsequent action.

FIELD DOCUMENTATION & DATA REPORTING

A. Field documentation will be the same as in Phase I. Some of the standard forms have been updated, such as the WIR, for the purpose of gathering addition information about the well.

B. Data maintenance includes monitoring the upload of inorganic data from the Laboratory LIMS to ORACLE. At the time of inorganic data transfer, other data not handled by LIMS needs to be uploaded within a reasonable period of time. Associated data includes DEQ organic laboratory section, ODA data, and possibly other data from independent laboratories. The monitoring section is responsible for entering data, except inorganic data (electronic transfer by LIMS), into the ORACLE and STORET systems. A "Data Tracking Log" is to be kept and used to ensure data transfer from laboratories to the data base.

C. Data distribution is the function of the lab front office. A list of data recipients will be up-dated by the monitoring staff and given to office staff for data distribution (attachment V - distribution list).

HEALTH & SAFETY

All personnel participating in this project will follow the safety requirements contained in the "Section Manual", which conform to the Occupational Safety and Health Administration regulations. The sampling stations in this project are existing domestic and irrigation water wells. Samples obtained from these sources are not considered hazardous, but personnel should be aware of the potential hazards associated with the collection, handling, analysis, and disposal of the samples. It is the responsibility of the participating personnel to follow all necessary safety measures or to bring to the attention of the Agency Safety officer, through the section, issues concerning safety.

ATTACHMENT I

LOWER UMATILLA BASIN PROJECT

PRIMARY NETWORK WELLS/ALLUVIAL

PROJECT #	WELL OWNER	ADDRESS	PHONE #
UMA033	Clayton Irwin	Rt.2,Box 178 Irrigon 97844	922-3164
UMA034	Henry Froberg	Rt.2,Box 160 Irrigon 97844	922-3121
UMA038	Clyde Vieth	Rt.1,Box 73 Umatilla 97882	922-3936
UMA039	John Powell	Rt.2,Box 2884 Hermiston 97838	567-5326
UMA046	Verle Burnett	Rt.1,Box 205 Stanfield 97875	567-6738
UMA048	W. Otzenberger	P.O. Box 717 Stanfield 97875	449-3462
UMA056	Harry Hansen	Rt.1,Box 141 Stanfield 97875	567-2606
UMA058	Simplot #3	P.O. Box 850 Hermiston 97838	567-9733
UMA066	Hat Rock MHP	Rt.3, Box 3780 Hermiston 97838	567-4188
UMA077	Richard Rodgers	Rt.2, Box 2317 Hermiston 97838	567-6692
UMA085	Terrell Rea	Rt.1, Box 70A Boardman 97818	-
UMA088	Norma Quick	Rt.6,Box 6046 Hermiston 97838	-
UMA094	Duke McClune	Rt.1,Box 1352 Hermiston 97838	-

UMA096	Vern Andrews	Rt.2,Box 129 Umatilla 97882	-
UMA103	Don Yates	Rt.2,Box 606 Irrigon 97844	922-3522
UMA110	Wayne Picker	Rt.1,Box 171 Stanfield 97875	-
UMA112	Ellen McFarlane	Rt.1,Box 1886 Hermiston 97838	-
UMA116	Albert Anson	Rt.3,Box 3446 Stanfield 97875	567-8231
UMA117	Sanoi Stoneburner	Rt.3,Box 3854C Hermiston 97838	567-2540
UMA119	Marvin Lemmon	Rt.4,Box 4295 Hermiston 97838	567-6304
UMA122	Frank Mueller	Rt.1,Box 1944 Hermiston 97838	567-5615
UMA144	Artie Kellar	Rt.2,Box 393 Irrigon 97844	-
UMA156	Ron Furrer	Rt.1,Box 218 Stanfield 97875	567-8169
UMA168	Jose Salano	-	567-2835
UMA177	Port of Morrow #2	P.O. Box 216 Boardman 97818	481-2901
UMA185	Louise S. Brown	57 Ramona Rd. Danville,Ca.	415-837-9548
UMA187	Madison Ranch	Butter Cr. Hwy. Echo	376-8347
UMA190	Robert Spike	Rt.1,Box 4 Echo 97826	376-8203
UMA191	City of Echo	City Hall 20 S. Bonanza Echo 97	376-8411

UMA198	Lamb-Weston #1 (Circle 6)	-	567-2211

PRIMARY NETWORK WELLS/BASALT

UMA028	Les Moen	P.O. Box 665 Boardman 97818	481-4351
UMA029	William Alford	Rt.1,3 Mountain Boardman 97818	481-5246
UMA106	Edwin Cripe	Rt.3,Box 3382 Hermiston 97838	567-8476
UMA125	Vic Aichele	Rt.1,Box 185 Stanfield 97875	567-5313
UMA164	Dewey Murray	Rt.2,Box 83 Irrigon 97844	922-4301

OPTIONAL WELLS

UMA047	Mr. Burnett 875 E. Highland	Box 365 Stanfield 97875	449-3652
UMA084	Ruby King Lloyd & Lloyd Rds.	Rt.4,Box 4228 Hermiston 97838	567-3212
UMA133	Don Key County Line Rd.	Rt.1,Box 1844 Hermiston 97838	567-5917
UMA180	Danny Bond Wagon Wheel Est.	Rt. 2,Box 540 Irrigon 97844	922-5271
UMA160	Western Empire Farm	Rt. 2 Box 230 Irrigon 97844	481-2061

PROJECT #	WELL LOCATION	7.5 MINUTE MAP
Alluvial:		
UMA033	Washington & 7th	Paterson
UMA034	-	Paterson
UMA038	off Brownell Rd.(Cherry)	Umatilla
UMA039	Punkin Center Road	Stanfield
UMA046	off East Highland	Stanfield
UMA048	off Harding Ave.	Stanfield
UMA056	Stanfield Loop Rd.	Stanfield
UMA058	Butter Creek Hwy.(Hwy 207)	Hermiston
UMA066	Hat Rock MHP/Mike Jewett/sp.26	Hat Rock
UMA077	11th & Elm	Hermiston
UMA085	Wilson Rd./Root Ln.	Boardman
UMA088	Tom Quick Rd.	Hermiston
UMA094	Agnon Rd.	Hermiston
UMA096	South Shore Dr.	Irrigon
UMA103	Hwy. 730 & 23rd	Irrigon
UMA110	Stanfield Loop Rd.	Stanfield
UMA112	off Jordon Rd.	Ordnance
UMA116	Punkin Court Rd.	Stanfield
UMA117	off W.Locust Rd.	Hat Rock
UMA119	Lemmon Rd./off Butter Cr.Rd.	Hermiston
UMA122	Lower Meadows Rd.	Hermiston
UMA144	County Rd. & West 3rd	Paterson
UMA156	East Highland	Stanfield
UMA168	-	Ordnance
UMA177	#1 Marine Dr.	Boardman
UMA185	off Hwy. 207/Heffernan-renter	Service Buttes
UMA187	off Hwy. 207	Service Buttes
UMA190	off Lexington Rd.	Echo
UMA191	-	Stanfield
UMA198	off Walker Rd.,N. of gravel pit S. of Lamb-Weston storage lagoon	Hermiston
Basalt:		
UMA028	off Olson Rd.	Boardman
UMA029	off Knuse Rd.	Boardman
UMA106	Punkin Center Rd.	Stanfield
UMA125	off Stanfield Loop Rd.	Stanfield
UMA164	off Washington St.	Irrigon (?)
Optional Wells:		
UMA047	875 East Highland	Stanfield
UMA084	Lloyd & Lloyd Rds.	Hermiston
UMA133	County Line Rd.	Ordnance
UMA180	Wagon Wheel Estates	Clarke
UMA160	between Hwy 730 and Patterson Ferry Rd.	Clarke

ATTACHMENT II

LOWER UMATILLA BASIN PROJECT

1991-1993 TENTATIVE SAMPLING SCHEDULE

This schedule was written for both DEQ and ODA laboratories. This schedule is for routine sampling parameters outlined in Attachment III.

YEAR	MONTH										
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov Dec
1991.										X	
1992.	X		Xp		X		O		Xp		X
1993.	X		Xp		X		X		Xp		X

Key: X = DEQ-Inorganic/Organic, ODA-Atrazine,Terbacil
p = full pesticide screen
0 = Synoptic

SAMPLE DATES:

11/18-22/91.

1/14-18/92.
3/11-15/92.(full screen)
5/13-17/92.
7/15-19/92.(synoptic)
9/16-20/92.(full screen)
11/18-22/92.
l/11-15/93.
3/8-12/93.(full screen)
5/10-14/93.
7/12-16/93.
9/13-17/93.(full screen)
11/15-19/93.

NOTE:

One or more synoptic surveys will be conducted during the project sampling program, but were not included in this schedule. The dynamics of a synoptic require special needs and will be scheduled separately. Advance notice to participating laboratories will accompany a separate work plan.

ATTACHMENT III

LOWER UMATILLA BASIN PROJECT

PARAMETER LIST

The bi-monthly network sampling program encompasses the following water quality parameters, by analytical grouping. Selection of parameters in Phase II was based on project requirements established in Phase I. Parameter values (minimum reporting detection levels) remain the same for the project objectives outlined in the initial project plan. Selenium was added to Phase II and will be reported as total recoverable. Iron is reported both as total recoverable and dissolved. It will be necessary during the sampling program, to investigate the possibility of suspended solids transport in the groundwater matrix. The identification of solids transport will be done by analysis of total recoverable metals along with dissolved metals, used in identifying the composition of ions.

Cost saving in running certain parameter groups will include parameters not pertinent to project objectives, and are highlighted in the parameter list. A brief explanation for selection of each analytical group is given:

Key: * Project parameter selection.
\+ Additional parameters that will be reported with requested parameters.

DEQ reporting "units" and "minimum limits" are contained in the "Field Sampling Reference Guide", pages 45-50. The following list of parameter minimum reporting limits are reported in mg/l units, unless otherwise noted:

Aluminum <0.1
Calcium <0.1
Copper <0.02
Fluoride <0.1
Potassium <0.5
Silica <0.3
Zinc <0.02
TKN <0.2
Turbidity <5 NTU
VOA screen <0.0005

Arsenic <0.005
Chromium <0.03
Chloride <0.5
Magnesium <0.5
T. Phosphate <0.01
Sodium <0.5
Ammonia <0.02
TDS 1
Alkalinity 1
Pesticides(ref ODA)

Barium <0.03

Iron <0.04
Manganese <0.01
Selenium <0.005
Sulfate <0.5
Nitrate+Nitrite <0.02
COD <5
Hardness <3
Bact./TC,FC,EC

AUTOMATED Cd REDUCTION/R1-353.2 (total recoverable)

* Nitrate-Nitrite as N

indicator of contamination, data comparability with Phase I data and, trend, drinking water standard.

ICP/INDICATOR METALS/GROUP I (total recoverable/dissolved on request/ dissolved Iron required on all samples)

* Aluminum
* Manganese
+ Lanthanum
* Calcium
* Sodium
+ Lithium
* Iron
* Hardness (calc.)
* Potassium
* Magnesium

natural ground water characteristics, aquifer unit typing, detection of contamination, trends, data comparability with Phase I.

PRIORITY POLLUTANTS/GROUP I (total recoverable)

* Barium
+ Beryllium
+ Molybdenum
* Chromium
+ Cadmium
+ Silver
* Copper
+ Cobalt
+ Vanadium
* Zinc
+ Nichel

natural ground water characteristics, aquifer unit typing (ions), detection of contamination, drinking water standards, trends, data comparability with Phase I.

AA Furnace (total recoverable)

* Arsenic

natural ground water characteristics, health risk assessment, detection of contamination, drinking water standard, trend, data comparability with Phase I.

AUTOMATED FERRICYANIDE/R1-325.1

* Chloride

AUTOMATED METHYL THYMOL BLUE/R1-375.2

* Sulfate

natural ground water characteristics, detection of contamination, trend, data comparability with Phase.

AUTOMATED COMPLEXONE

* Fluoride

natural ground water characteristics, data comparability with Phase I, trend, drinking water standard.

COLORIMETRIC, ASCORBIC ACID/modified R1-424F

* Total Phosphate

detection of contamination, trend, data comparability with Phase I.

AUTOMATED PHENATE/R1-350.1

* Nitrogen Ammonia

detection of contamination, trend, data comparability with Phase I.

SEMI AUTOMATED BLOCK DIGESTION/R1-351.2

* Total Kjeldahl Nitrogen

detection of contamination, trend, data comparability with Phase I.

GRAVIMETRIC, DRIED 180 DEGREES C./R1-160.1

* Filterable residue (total dissolved solids)

detection of contamination, trend, data comparability with Phase I.

OIC SPECTROPHOTOMETRIC/R1-410.4

* Chemical Oxygen Demand

detection of contamination, trend, data comparability with Phase I.

NEPHELOMETRIC/R1-180.1

* Turbidity

detection of poorly constructed wells, sample alteration, drinking water standard, data comparability with Phase I, trend.

PURGE/TRAP/GC/MS/R2-8260 R3-524.2

* Volatile Organics

detection of contamination, data comparability with Phase I, drinking water standards, trends.

PESTICIDE/HERBICIDE SCREENS

* Agricultural chemicals
detection of chemicals in ground water, data comparability with Phase I, trend.

IM-ICP #2 (dissolved)

* Silica + Boron

natural ground water characteristics, comparability with Phase I data, trend.

Note: method requires a dissolved sample be collected; total analysis digests silica from the lab glassware.

AA-Furnace/R1-270.2 R2-7740

* Selenium
natural ground water characteristics, comparability with Phase I data, drinking water standard, trend.

* BROMIDE - Ion Chromatography/Titration methods are not currently available.

BACTERIA (on request)

* Total coliform * Fecal coliform * Enterococus

FIELD PARAMETERS

* Temperature * Conductivity
* pH * Alkalinity

purge effectiveness, natural ground water characteristics, detection of contamination, hydrologic data, data comparability between Phase I & Phase II.

ATTACHMENT IV

LOWER UMATILLA BASIN PROJECT

CONTACT LIST

OREGON DEPARTMENT OF AGRICULTURE - LABORATORY
635 Capital Street N.E.
Salem, Oregon 97310
Phone: 378-3710
Contact: Norma Corristan

OREGON STATE UNIVERSITY - Agriculture Chemistry Department
Corvallis, Oregon 97331
Phone: 737-3791

COFFEY LABORATORIES, INC.
20 S.W. Emigrant
Pendleton, Oregon 97801
Office hours: 0800-1600, Mon-Fri
Phone: 276-0385 (after hours - 276-3283)
Contact: Sally or Bryce Haynie

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
1712 S.W. 11th Ave.
Portland, Oregon 97201
Phone: 229-5983
Contact: Bob McCoy, Sample Receiver

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY - Eastern Region
700 S.E. Emigrant
Pendleton, Oregon 97801
Phone: 276-4063
Contact: Bruce Hammon, Manager

OREGON HEALTH DIVISION - Water Section, Pendleton Office
700 S.E. Emigrant
Pendleton, Oregon 97801
Phone: 276-8006
contact: Gary Burnett

DEPARTMENT OF WATER RESOURCES
3850 Portland Road
Salem, Oregon 97310
Phone: 378-8456
Contact: Ken Lite

OREGON DEPARTMENT OF HEALTH - Drinking Water Section
708 State Office Building
Portland, Oregon 97201
Phone: 229-6357

Contact: Chuck Stahl

OSU AGRICULTURAL EXTENSION SERVICE
P.O. BOX 105
Hinkle Road
Hermiston, Oregon 97838
Phone: 567-8321
Contact: Luther Fitch

ATTACHMENT V

LOWER UMATILLA BASIN PROJECT

DATA DISTRIBUTION LIST

NAME	MAILING ADDRESS
Jerry Grondin	DEQ:WQ:Non-point source
Greg Pettit	DEQ:Lab:WQM
David Cole	DEQ:Lab:WQM
Chuck Stahl	OSHD:Drinking Water Section 708 State Office Bldg. Portland, Oregon 97201
Luther Fitch	OSU extension Service P.O. Box 105 Hermiston, Oregon 97838
Norma Coristan	ODA Laboratory 635 Capital Street N.E. Salem, Oregon 97310
Bruce Hammond	DEQ Eastern Region 700 S.E. Emigrant Pendleton, Oregon 97801

Appendix 4F

Project Sampling Data
Selected Inorganic Constituents
(July 1990 - March 1993)

LOWER UMATILLA BASIN GROUNDWATER MANAGEMENT AREA

All Project Wells and Surface Water Sites Sampled by DEQ
July 1990 through March 1993
Selected Inorganic Constituents

Site-ID	date	Arsenic Total As mg/L	Arsenic Diss. As mg/L	Bicarbonate HCO3 mg/L	Boron Diss. B mg/L	Bromide Br mg/L	Calcium Total Ca mg/L	Calcium Diss. Ca mg/L	Cloride Cl mg/L	Iron Total Fe mg/L	Iron Diss. Fe mg/L	Manganese Total Mn mg/L	Manganese Diss. Mn mg/L	Magnesium Total Mg mg/L	Magnesium Diss. Mg mg/L	Nitrate NO3+NO2-N mg/L	Phosphate Tot.PO4-P mg/L	Potassium Total K mg/L	Potassium Diss. K mg/L	Sodium Total Na mg/L	Sodium Diss. Na mg/L	Sulfate SO4 mg/L	TDS mg/L	Vanadium Total V mg/L	Vanadium Diss. V mg/L
UMA002	06/23/92	0.008	NA	309.6806	NA	0.32	77.0	78.0	61.0	<0.04	<0.04	<0.01	<0.01	41.0	42.0	15.00	0.02	4.5	4.4	45.0	46.0	54.0	540	0.03	<0.03
UMA003	05/14/91	0.008	NA	213.3626	<0.03	NA	110.0	NA	190.0	<0.04	NA	<0.01	NA	59.0	NA	40.00	0.02	5.8	NA	63.0	NA	130.0	820	0.03	NA
UMA003	06/23/92	0.009	NA	162.1556	NA	0.51	110.0	110.0	140.0	0.04	<0.04	<0.01	<0.01	56.0	56.0	40.00	0.02	5.7	5.6	58.0	56.0	120.0	850	0.03	0.03
UMA026	07/19/90	0.008	NA	267.0080	0.04	NA	64.0	NA	14.0	0.06	NA	<0.02	NA	16.0	NA	3.80	0.19	7.1	NA	26.0	NA	22.0	NA	NA	NA
UMA026	06/24/92	0.008	NA	284.0771	NA	0.07	74.0	69.0	19.0	0.05	<0.04	<0.01	<0.01	18.0	17.0	4.80	0.11	7.6	7.2	28.0	27.0	29.0	360	<0.03	<0.03
UMA027	07/19/90	<0.005	NA	207.2665	0.07	NA	6.5	NA	14.0	<0.05	NA	<0.02	NA	2.5	NA	0.15	0.08	7.4	NA	75.0	NA	2.2	NA	NA	NA
UMA028	07/19/90	<0.005	NA	410.8754	<0.03	NA	67.0	NA	16.0	<0.05	NA	<0.02	NA	44.0	NA	1.90	0.07	5.6	NA	26.0	NA	25.0	NA	NA	NA
UMA028	10/01/91	<0.005	NA	404.7793	<0.03	NA	66.0	66.0	17.0	<0.04	<0.04	<0.01	<0.01	45.0	44.0	2.20	0.03	5.6	5.6	25.0	25.0	23.0	420	<0.03	NA
UMA028	11/19/91	<0.005	<0.005	392.5872	0.03	NA	64.0	58.0	16.0	<0.04	<0.04	<0.01	<0.01	43.0	43.0	2.20	0.02	5.3	5.1	26.0	22.0	24.0	400	<0.03	<0.03
UMA028	01/14/92	<0.005	<0.005	388.9295	0.03	NA	65.0	60.0	16.0	<0.04	<0.04	<0.01	<0.01	45.0	42.0	2.10	0.02	5.7	4.6	26.0	24.0	23.0	E 410	<0.03	<0.03
UMA028	03/11/92	<0.005	NA	391.3680	<0.03	NA	62.0	59.0	15.0	<0.04	<0.04	<0.01	<0.01	42.0	41.0	2.20	0.02	5.6	5.5	24.0	24.0	23.0	410	0.03	<0.03
UMA028	05/20/92	<0.005	<0.005	408.4370	<0.03	NA	65.0	63.0	18.0	<0.04	<0.04	<0.01	<0.01	43.0	41.0	2.40	0.01	4.7	4.2	26.0	25.0	25.0	430	0.03	0.03
UMA028	06/24/92	<0.005	NA	418.1907	NA	0.11	68.0	68.0	17.0	<0.04	<0.04	<0.01	<0.01	44.0	43.0	2.40	0.02	5.4	5.5	27.0	26.0	25.0	430	0.03	<0.03
UMA028	07/14/92	<0.005	NA	414.5330	0.04	NA	66.0	66.0	19.0	<0.04	<0.04	<0.01	<0.01	41.0	42.0	2.20	0.02	5.0	5.1	24.0	24.0	24.0	440	0.03	NA
UMA028	09/22/92	<0.005	NA	408.4370	0.04	NA	67.0	65.0	16.0	<0.04	<0.04	<0.01	<0.01	45.0	44.0	2.00	0.02	5.8	5.6	27.0	.26.0	23.0	420	<0.03	<0.03
UMA028	11/17/92	<0.005	0.007	396.2448	0.03	NA	65.0	68.0	16.0	<0.04	<0.04	<0.01	<0.01	43.0	45.0	2.00	0.02	4.9	5.2	26.0	27.0	23.0	400	0.04	<0.03
UMA028	01/12/93	<0.005	<0.005	397.4640	0.03	NA	63.0	64.0	15.0	<0.04	<0.04	<0.01	<0.01	42.0	43.0	1.90	0.02	5.9	5.6	24.0	24.0	23.0	420	0.03	0.04
UMA028	01/12/93	<0.005	<0.005	388.9295	0.03	NA	63.0	63.0	15.0	<0.04	<0.04	<0.01	<0.01	41.0	41.0	1.80	0.01	5.6	5.9	23.0	24.0	23.0	410	0.03	0.04
UMA028	03/23/93	<0.005	<0.005	423.0675	<0.03	NA	70.0	69.0	19.0	<0.04	<0.04	<0.01	<0.01	44.0	44.0	2.10	0.02	5.7	5.2	25.0	25.0	27.0	450	<0.03	<0.03
UMA028	03/23/93	<0.005	<0.005	431.6020	0.03	NA	69.0	68.0	19.0	<0.04	<0.04	<0.01	<0.01	45.0	43.0	2.10	0.02	5.5	5.6	26.0	26.0	27.0	450	<0.03	<0.03
UMA029	07/19/90	0.006	NA	249.9390	<0.03	NA	98.0	NA	110.0	0.16	NA	<0.02	NA	65.0	NA	32.00	0.07	9.8	NA	85.0	NA	200.0	NA	NA	NA
UMA029	10/01/91	0.006	NA	227.9932	<0.03	NA	110.0	120.0	150.0	<0.04	<0.04	<0.01	<0.01	77.0	79.0	37.00	0.01	11.0	12.0	92.0	99.0	280.0	1100	<0.03	NA
UMA029	11/19/91	<0.005	<0.005	225.5547	<0.03	NA	110.0	110.0	140.0	<0.04	<0.04	<0.01	<0.01	77.0	79.0	44.00	0.01	12.0	12.0	96.0	100.0	290.0	1000	<0.03	<0.03
UMA029	01/14/92	<0.005	<0.005	234.0892	0.03	NA	130.0	110.0	150.0	<0.04	<0.04	<0.01	<0.01	87.0	80.0	64.00	0.02	13.0	13.0	110.0	100.0	280.0	1100	<0.03	<0.03
UMA029	03/11/92	<0.005	NA	225.5547	<0.03	NA	120.0	110.0	150.0	<0.04	<0.04	<0.01	<0.01	80.0	78.0	44.00	0.02	13.0	12.0	100.0	100.0	260.0	1100	0.03	0.03
UMA029	05/20/92	0.006	0.006	234.0892	<0.03	NA	100.0	100.0	110.0	<0.04	<0.04	<0.01	<0.01	66.0	66.0	33.00	0.02	9.0	8.5	85.0	83.0	220.0	890	<0.03	<0.03
UMA029	06/24/92	0.007	NA	271.8849	NA	0.54	84.0	84.0	75.0	<0.04	<0.04	<0.01	<0.01	53.0	52.0	24.00	0.02	6.1	5.7	60.0	58.0	130.0	750	<0.03	<0.03
UMA029	07/14/92	0.006	NA	235.3085	0.03	NA	100.0	100.0	130.0	<0.04	<0.04	<0.01	<0.01	63.0	64.0	31.00	0.03	8.6	8.6	75.0	74.0	230.0	890	<0.03	NA
UMA029	09/22/92	<0.005	NA	219.4587	0.04	NA	120.0	120.0	135.0	<0.04	<0.04	<0.01	<0.01	81.0	78.0	43.00	0.02	12.0	11.0	100.0	100.0	260.0	1100	<0.03	<0.03
UMA029	11/17/92	<0.005	0.006	215.8010	0.03	NA	130.0	120.0	160.0	<0.04	<0.04	<0.01	<0.01	84.0	83.0	49.00	0.02	13.0	13.0	110.0	110.0	290.0	1100	0.03	<0.03
UMA029	01/12/93	0.005	<0.005	207.2665	0.03	NA	120.0	120.0	160.0	<0.04	<0.04	<0.01	<0.01	81.0	81.0	48.00	0.01	12.0	13.0	98.0	100.0	290.0	1100	0.03	<0.03
UMA029	03/23/93	<0.005	<0.005	218.2395	<0.03	NA	120.0	120.0	160.0	<0.04	<0.04	<0.01	<0.01	79.0	79.0	47.00	0.02	12.0	12.0	100.0	99.0	270.0	1100	<0.03	<0.03
UMA030	07/19/90	0.006	NA	296.2692	<0.03	NA	29.0	NA	19.0	0.06	NA	0.07	NA	18.0	NA	<0.02	0.06	6.4	NA	74.0	NA	38.0	NA	NA	NA
UMA030	06/23/92	0.007	NA	290.1731	NA	0.16	31.0	32.0	21.0	0.34	0.33	0.08	0.08	18.0	19.0	0.03	<0.01	6.6	6.7	73.0	77.0	47.0	370	<0.03	<0.03
UMA031	07/19/90	0.008	NA	291.3923	0.03	NA	86.0	NA	45.0	<0.05	NA	<0.02	NA	27.0	NA	17.00	0.06	9.1	NA	55.0	NA	48.0	NA	NA	NA
UMA031	06/23/92	0.010	NA	277.9810	NA	0.28	88.0	91.0	55.0	<0.04	<0.04	<0.01	<0.01	27.0	28.0	21.00	0.03	8.7	9.2	49.0	52.0	57.0	550	<0.03	<0.03
UMA032	07/19/90	0.007	NA	265.7888	<0.03	NA	65.0	NA	14.0	0.38	NA	<0.02	NA	17.0	NA	5.80	0.13	6.8	NA	25.0	NA	25.0	NA	NA	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA032	06/23/92	0.007	NA	275.5426	NA	0.05	71.0	72.0	16.0	<0.04	<0.04	<0.01	<0.01	18.0	18.0	6.60	0.04	7.0	7.3	25.0	26.0	27.0	360	<0.03	<0.03
UMA033	07/18/90	0.006	NA	264.5696	<0.03	NA	75.0	NA	10.0	1.90	NA	0.07	NA	18.0	NA	16.00	0.08	6.8	NA	76.0	NA	21.0	NA	NA	NA
UMA033	10/01/91	0.007	NA	268.2273	<0.03	NA	67.0	71.0	10.0	0.11	<0.04	<0.01	<0.01	17.0	17.0	10.00	0.04	6.7	6.5	23.0	24.0	21.0	350	<0.03	NA
UMA033	11/19/91	0.006	0.006	276.7618	<0.03	NA	73.0	65.0	11.0	0.07	<0.04	<0.01	<0.01	17.0	16.0	12.00	0.04	6.8	6.2	24.0	22.0	22.0	360	<0.03	<0.03
UMA033	01/14/92	0.006	<0.005	269.4465	0.07	NA	71.0	73.0	11.0	0.06	<0.04	<0.01	<0.01	17.0	18.0	11.00	0.04	6.9	6.9	24.0	25.0	21.0	380	<0.03	<0.03
UMA033	03/12/92	0.005	NA	263.3504	<0.03	NA	67.0	68.0	11.0	<0.04	<0.04	<0.01	<0.01	16.0	16.0	10.00	0.04	6.7	6.4	22.0	22.0	21.0	350	<0.03	<0.03
UMA033	05/21/92	0.006	0.006	267.0080	<0.03	NA	68.0	69.0	11.0	<0.04	<0.04	<0.01	<0.01	16.0	16.0	8.00	0.04	6.0	6.6	24.0	23.0	21.0	340	<0.03	<0.03
UMA033	06/25/92	0.006	NA	268.2273	NA	<0.05	66.0	65.0	10.0	<0.04	<0.04	<0.01	<0.01	15.0	16.0	7.70	0.04	6.3	6.4	23.0	23.0	21.0	330	<0.03	<0.03
UMA033	07/14/92	0.006	NA	258.4735	0.03	NA	64.0	64.0	10.0	<0.04	<0.04	<0.01	<0.01	15.0	15.0	7.60	0.05	6.4	6.4	22.0	22.0	20.0	330	<0.03	NA
UMA033	09/22/92	0.006	NA	256.0351	0.04	NA	71.0	70.0	10.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	10.00	0.04	6.7	6.6	26.0	25.0	20.0	360	<0.03	<0.03
UMA033	11/17/92	0.006	0.007	256.0351	<0.03	NA	69.0	67.0	10.0	<0.04	<0.04	<0.01	<0.01	16.0	16.0	9.90	0.04	5.8	6.1	24.0	23.0	21.0	340	<0.03	<0.03
UMA033	01/15/93	0.007	0.006	256.0351	<0.03	NA	68.0	66.0	10.0	2.80	<0.04	0.03	<0.01	16.0	16.0	10.00	0.04	7.0	6.8	24.0	23.0	20.0	350	<0.03	<0.03
UMA033	01/15/93	0.007	0.007	259.6928	<0.03	NA	69.0	66.0	10.0	2.30	<0.04	0.02	<0.01	16.0	16.0	11.00	0.04	6.8	6.7	25.0	23.0	20.0	350	<0.03	<0.03
UMA033	03/23/93	0.006	0.006	262.1312	<0.03	NA	68.0	65.0	10.0	0.13	<0.04	<0.01	<0.01	17.0	16.0	11.00	0.04	6.7	6.3	24.0	23.0	20.0	360	<0.03	<0.03
UMA034	07/18/90	0.005	NA	208.4857	<0.03	NA	49.0	NA	5.0	<0.05	NA	<0.02	NA	12.0	NA	2.30	0.11	5.4	NA	11.0	NA	14.0	NA	NA	NA
UMA034	10/01/91	0.006	NA	210.9242	<0.03	NA	54.0	53.0	4.7	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.50	0.11	5.0	5.1	11.0	11.0	16.0	240	<0.03	NA
UMA034	10/01/91	0.006	NA	212.1434	<0.03	NA	54.0	53.0	4.8	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.50	0.11	5.0	5.0	11.0	10.0	15.0	240	<0.03	NA
UMA034	11/19/91	0.005	0.005	213.3626	<0.03	NA	56.0	51.0	5.3	0.09	<0.04	<0.01	<0.01	13.0	12.0	2.70	0.12	5.2	4.7	12.0	11.0	16.0	250	<0.03	<0.03
UMA034	01/14/92	0.005	0.005	210.9242	<0.03	NA	55.0	55.0	6.4	0.10	<0.04	<0.01	<0.01	13.0	13.0	3.10	0.13	5.2	5.5	11.0	12.0	16.0	270	<0.03	<0.03
UMA034	03/12/92	0.006	NA	236.5277	<0.03	NA	58.0	61.0	8.5	0.18	<0.04	<0.01	<0.01	14.0	14.0	4.20	0.11	5.3	5.7	12.0	13.0	20.0	290	<0.03	<0.03
UMA034	05/21/92	0.005	<0.005	213.3626	<0.03	NA	52.0	55.0	6.3	0.12	<0.04	<0.01	<0.01	13.0	13.0	2.80	0.10	4.9	5.0	12.0	12.0	17.0	250	<0.03	<0.03
UMA034	06/25/92	0.005	NA	214.5818	NA	<0.05	52.0	51.0	5.2	<0.04	<0.04	<0.01	<0.01	12.0	12.0	2.40	0.11	5.1	5.0	12.0	12.0	16.0	250	<0.03	<0.03
UMA034	06/25/92	0.005	NA	212.1434	NA	<0.05	52.0	52.0	5.2	<0.04	<0.04	<0.01	<0.01	12.0	12.0	2.40	0.11	4.8	4.9	12.0	12.0	16.0	240	<0.03	<0.03
UMA034	07/14/92	0.005	NA	208.4857	<0.03	NA	51.0	50.0	4.6	0.23	<0.04	<0.01	<0.01	12.0	11.0	2.00	0.12	4.9	4.9	11.0	11.0	15.0	240	<0.03	NA
UMA034	09/22/92	0.006	NA	214.5818	<0.03	NA	55.0	52.0	4.0	0.47	<0.04	<0.01	<0.01	13.0	12.0	2.00	0.13	5.3	5.1	11.0	11.0	14.0	250	<0.03	<0.03
UMA034	11/17/92	0.005	0.006	217.0202	<0.03	NA	55.0	53.0	5.2	0.04	<0.04	<0.01	<0.01	12.0	12.0	2.30	0.11	4.2	4.6	11.0	11.0	16.0	240	<0.03	<0.03
UMA034	01/12/93	0.006	0.005	225.5547	<0.03	NA	57.0	58.0	6.0	0.09	<0.04	<0.01	<0.01	13.0	13.0	3.00	0.10	5.6	5.6	12.0	12.0	16.0	270	<0.03	<0.03
UMA034	03/23/93	0.005	0.005	227.9932	<0.03	NA	58.0	56.0	8.0	0.48	<0.04	0.01	<0.01	14.0	13.0	3.80	0.12	5.2	5.6	13.0	13.0	18.0	290	<0.03	<0.03
UMA035	07/18/90	0.005	NA	184.1014	<0.03	NA	42.0	NA	5.1	<0.05	NA	<0.02	NA	10.0	NA	2.00	0.07	4.9	NA	11.0	NA	15.0	NA	NA	NA
UMA036	07/18/90	0.006	NA	254.8159	0.03	NA	63.0	NA	18.0	<0.05	NA	<0.02	NA	16.0	NA	5.70	0.05	7.0	NA	27.0	NA	30.0	NA	NA	NA
UMA036	06/23/92	0.006	NA	256.0351	NA	0.08	67.0	66.0	17.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	6.30	0.05	7.2	7.2	28.0	27.0	30.0	350	<0.03	<0.03
UMA037	07/19/90	0.005	NA	304.8037	0.08	NA	69.0	NA	28.0	<0.05	NA	<0.02	NA	23.0	NA	4.10	0.11	7.5	NA	50.0	NA	77.0	NA	NA	NA
UMA037	07/19/90	0.005	NA	299.9268	0.08	NA	68.0	NA	28.0	<0.05	NA	<0.02	NA	23.0	NA	4.20	0.13	7.2	NA	50.0	NA	79.0	NA	NA	NA
UMA037	06/25/92	0.006	NA	259.6928	NA	0.20	56.0	53.0	28.0	<0.04	<0.04	<0.01	<0.01	18.0	17.0	3.40	0.08	6.7	6.8	54.0	52.0	59.0	400	<0.03	<0.03
UMA038	07/19/90	0.005	NA	302.3653	0.06	NA	75.0	NA	24.0	2.80	NA	0.04	NA	26.0	NA	1.70	0.14	8.0	NA	45.0	NA	75.0	NA	NA	NA
UMA038	10/02/91	0.005	NA	310.8998	0.04	NA	66.0	60.0	18.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	1.60	0.08	7.6	6.9	43.0	39.0	41.0	370	<0.03	NA
UMA038	11/19/91	0.005	0.005	309.6806	0.05	NA	68.0	60.0	20.0	<0.04	<0.04	<0.01	<0.01	23.0	21.0	2.30	0.08	7.8	6.7	43.0	39.0	50.0	380	<0.03	<0.03
UMA038	01/15/92	0.005	<0.005	329.1880	0.05	NA	73.0	79.0	24.0	<0.04	<0.04	<0.01	<0.01	25.0	27.0	3.00	0.08	7.9	8.4	45.0	48.0	58.0	440	<0.03	<0.03
UMA038	03/12/92	0.005	NA	320.6535	0.05	NA	74.0	73.0	26.0	0.14	<0.04	<0.01	<0.01	25.0	25.0	3.90	0.07	7.8	7.6	42.0	43.0	66.0	450	<0.03	<0.03
UMA038	05/21/92	0.005	0.006	316.9959	0.05	NA	81.0	77.0	24.0	<0.04	<0.04	<0.01	<0.01	28.0	27.0	2.90	0.07	8.3	7.9	44.0	44.0	84.0	470	<0.03	<0.03
UMA038	06/25/92	<0.005	NA	315.7766	NA	0.10	72.0	71.0	20.0	<0.04	<0.04	<0.01	<0.01	22.0	23.0	2.90	0.08	6.7	6.9	37.0	39.0	58.0	420	<0.03	<0.03
UMA038	07/14/92	<0.005	NA	315.7766	0.05	NA	73.0	73.0	22.0	<0.04	<0.04	<0.01	<0.01	23.0	22.0	3.00	0.08	7.1	6.9	38.0	36.0	62.0	410	<0.03	NA
UMA038	09/22/92	<0.005	NA	353.5723	0.07	NA	79.0	74.0	20.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	2.30	0.08	8.1	7.9	45.0	43.0	51.0	430	<0.03	<0.03
UMA038	11/17/92	<0.005	0.006	365.7644	0.06	NA	81.0	79.0	21.0	0.38	0.04	<0.01	<0.01	26.0	26.0	3.70	0.08	6.8	7.4	46.0	45.0	56.0	440	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA038	01/13/93	0.005	<0.005	351.1339	0.06	NA	79.0	79.0	22.0	<0.04	<0.04	<0.01	<0.01	26.0	26.0	3.80	0.07	8.0	8.0	43.0	42.0	61.0	460	<0.03	<0.03
UMA038	03/23/93	0.005	0.005	340.1609	0.06	NA	75.0	73.0	24.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	3.60	0.08	7.6	7.3	44.0	42.0	63.0	470	<0.03	<0.03
UMA039	07/18/90	0.009	NA	224.3355	<0.03	NA	50.0	NA	10.0	<0.05	NA	<0.02	NA	13.0	NA	2.20	0.11	7.5	NA	18.0	NA	17.0	NA	NA	NA
UMA039	10/03/91	0.010	NA	220.6779	<0.03	NA	53.0	52.0	10.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.10	0.11	7.6	7.9	19.0	19.0	18.0	260	<0.03	NA
UMA039	11/18/91	0.010	0.010	209.7050	<0.03	NA	54.0	52.0	10.0	<0.04	<0.04	<0.01	<0.01	14.0	13.0	2.30	0.12	8.0	7.7	19.0	19.0	17.0	260	<0.03	<0.03
UMA039	11/18/91	0.010	0.010	213.3626	<0.03	NA	53.0	50.0	10.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.30	0.11	7.9	7.7	19.0	18.0	18.0	260	<0.03	<0.03
UMA039	01/13/92	0.009	0.010	217.0202	0.03	NA	49.0	49.0	11.0	<0.04	0.06	<0.01	<0.01	12.0	13.0	2.10	0.10	7.1	7.3	18.0	18.0	18.0	270	<0.03	<0.03
UMA039	03/09/92	0.010	0.009	215.8010	0.03	NA	48.0	47.0	9.4	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.00	0.11	7.2	7.4	18.0	17.0	16.0	260	<0.03	<0.03
UMA039	05/18/92	0.012	0.012	208.4857	<0.03	NA	45.0	41.0	8.5	<0.04	<0.04	<0.01	<0.01	11.0	11.0	0.32	0.13	6.2	6.2	17.0	17.0	15.0	250	<0.03	<0.03
UMA039	06/22/92	0.010	NA	219.4587	NA	0.07	48.0	45.0	9.5	<0.04	<0.04	<0.01	<0.01	12.0	11.0	1.10	0.11	7.6	7.1	18.0	17.0	16.0	270	<0.03	<0.03
UMA039	07/13/92	0.010	NA	217.0202	0.04	NA	47.0	47.0	10.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.30	0.11	6.9	6.9	17.0	17.0	18.0	270	<0.03	NA
UMA039	09/21/92	0.010	NA	218.2395	<0.03	NA	51.0	51.0	10.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.00	0.11	7.7	7.8	18.0	18.0	16.0	260	<0.03	<0.03
UMA039	09/21/92	0.010	NA	219.4587	<0.03	NA	51.0	51.0	10.0	<0.04	<0.04	<0.01	<0.01	13.0	12.0	2.00	0.11	8.2	7.9	19.0	18.0	16.0	270	<0.03	<0.03
UMA039	11/16/92	0.010	0.010	221.8971	0.03	NA	51.0	50.0	10.0	0.04	<0.04	<0.01	<0.01	12.0	13.0	2.20	0.11	6.9	7.0	18.0	18.0	17.0	260	<0.03	<0.03
UMA039	01/11/93	0.009	0.008	202.3897	0.04	NA	49.0	48.0	11.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.60	0.09	7.4	6.8	18.0	18.0	16.0	260	<0.03	<0.03
UMA039	01/11/93	0.009	0.008	207.2665	0.04	NA	50.0	49.0	11.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.60	0.09	7.3	7.1	18.0	18.0	17.0	270	<0.03	<0.03
UMA039	03/22/93	0.009	0.009	224.3355	0.03	NA	51.0	50.0	11.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.10	0.11	7.4	7.2	18.0	18.0	17.0	280	<0.03	<0.03
UMA040	07/18/90	0.007	NA	217.0202	<0.03	NA	40.0	NA	7.2	0.52	NA	0.23	NA	11.0	NA	<0.02	0.32	7.4	NA	17.0	NA	7.1	NA	NA	NA
UMA040	06/23/92	0.008	NA	215.8010	NA	<0.05	41.0	41.0	7.5	0.56	0.54	0.26	0.25	12.0	12.0	<0.02	0.29	7.3	7.2	16.0	16.0	7.1	240	<0.03	<0.03
UMA040	06/23/92	0.008	NA	214.5818	NA	<0.05	42.0	41.0	7.2	0.57	0.53	0.26	0.25	12.0	12.0	<0.02	0.30	7.5	7.3	17.0	17.0	7.3	240	<0.03	<0.03
UMA041	07/17/90	0.010	NA	173.1285	<0.03	NA	41.0	NA	10.0	<0.05	NA	<0.02	NA	9.7	NA	1.00	0.10	5.1	NA	15.0	NA	14.0	NA	NA	NA
UMA041	06/23/92	0.011	NA	175.5669	NA	0.07	41.0	41.0	8.7	<0.04	<0.04	<0.01	<0.01	9.1	9.5	1.00	0.09	4.7	4.8	15.0	16.0	12.0	230	<0.03	0.03
UMA042	07/17/90	0.008	NA	221.8971	<0.03	NA	51.0	NA	6.3	<0.05	NA	<0.02	NA	14.0	NA	4.10	0.05	4.6	NA	17.0	NA	17.0	NA	NA	NA
UMA042	06/23/92	0.008	NA	237.7469	NA	0.06	67.0	64.0	11.0	<0.04	<0.04	<0.01	<0.01	19.0	18.0	10.00	0.05	4.8	4.6	19.0	18.0	29.0	350	<0.03	<0.03
UMA043	07/17/90	<0.005	NA	224.3355	<0.03	NA	36.0	NA	16.0	<0.05	NA	<0.02	NA	14.0	NA	4.90	0.01	6.2	NA	52.0	NA	25.0	NA	NA	NA
UMA043	07/17/90	<0.005	NA	229.2124	<0.03	NA	36.0	NA	17.0	<0.05	NA	<0.02	NA	15.0	NA	4.90	0.02	6.5	NA	52.0	NA	25.0	NA	NA	NA
UMA043	06/23/92	<0.005	NA	229.2124	NA	0.13	34.0	35.0	15.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	5.10	0.01	5.7	5.9	49.0	50.0	24.0	330	0.04	0.05
UMA044	07/17/90	<0.005	NA	335.2841	<0.03	NA	64.0	NA	19.0	<0.05	NA	<0.02	NA	34.0	NA	14.00	0.02	6.0	NA	57.0	NA	51.0	NA	NA	NA
UMA044	10/10/90	<0.005	NA	373.0797	<0.03	NA	63.0	NA	19.0	<0.04	NA	<0.01	NA	38.0	NA	16.00	0.02	4.3	NA	58.0	NA	54.0	NA	0.05	NA
UMA044	10/10/90	<0.005	NA	349.9147	<0.03	NA	66.0	NA	19.0	<0.04	NA	<0.01	NA	37.0	NA	15.00	0.02	4.5	NA	57.0	NA	54.0	NA	0.04	NA
UMA044	06/23/92	<0.005	NA	324.3111	NA	0.12	61.0	62.0	16.0	<0.04	<0.04	<0.01	<0.01	29.0	29.0	12.00	0.01	5.4	5.5	42.0	43.0	47.0	450	0.04	0.05
UMA044	06/26/92	<0.005	NA	280.4194	NA	0.18	62.0	62.0	21.0	0.36	<0.04	<0.01	<0.01	42.0	43.0	16.00	0.03	4.3	4.2	61.0	61.0	58.0	560	0.05	0.04
UMA044	09/22/92	<0.005	NA	401.1217	0.04	NA	60.0	61.0	20.0	0.09	<0.04	<0.01	<0.01	49.0	47.0	16.00	0.02	3.0	3.2	71.0	67.0	53.0	550	0.05	0.05
UMA045	07/18/90	0.005	NA	354.7915	0.03	NA	61.0	NA	12.0	<0.05	NA	<0.02	NA	37.0	NA	3.80	0.01	5.0	NA	22.0	NA	15.0	NA	NA	NA
UMA045	07/18/90	0.005	NA	352.3531	0.04	NA	58.0	NA	12.0	<0.05	NA	<0.02	NA	36.0	NA	3.80	0.01	4.0	NA	21.0	NA	15.0	NA	NA	NA
UMA045	06/23/92	0.006	NA	335.2841	NA	<0.05	55.0	56.0	6.1	<0.04	<0.04	<0.01	<0.01	33.0	34.0	2.30	0.01	4.3	4.4	20.0	20.0	13.0	350	0.06	0.06
UMA046	07/17/90	<0.005	NA	148.7442	<0.03	NA	24.0	NA	4.3	0.26	NA	<0.02	NA	15.0	NA	0.58	0.01	3.0	NA	12.0	NA	7.2	NA	NA	NA
UMA046	10/03/91	<0.005	NA	157.2787	<0.03	NA	25.0	26.0	7.4	0.05	<0.04	<0.01	<0.01	16.0	17.0	1.40	0.01	2.8	2.9	12.0	13.0	9.7	200	0.06	NA
UMA046	11/21/91	<0.005	<0.005	149.9634	<0.03	NA	26.0	24.0	5.7	0.09	<0.04	<0.01	<0.01	16.0	16.0	1.10	0.01	2.9	2.5	13.0	13.0	8.5	200	0.07	0.06
UMA046	11/21/91	<0.005	<0.005	148.7442	<0.03	NA	25.0	25.0	5.7	<0.04	<0.04	<0.01	<0.01	16.0	16.0	1.10	0.01	2.5	2.7	12.0	12.0	8.5	190	0.06	0.07
UMA046	03/11/92	<0.005	NA	152.4019	<0.03	NA	24.0	21.0	4.6	<0.04	<0.04	<0.01	<0.01	15.0	14.0	0.84	0.02	2.6	2.7	12.0	11.0	7.0	190	0.06	0.06
UMA046	05/20/92	<0.005	<0.005	145.0866	<0.03	NA	21.0	20.0	3.3	<0.04	<0.04	<0.01	<0.01	14.0	13.0	0.49	0.02	2.1	2.0	11.0	11.0	5.9	170	0.07	0.07
UMA046	06/23/92	<0.005	NA	143.8673	NA	<0.05	20.0	20.0	3.6	<0.04	<0.04	<0.01	<0.01	13.0	13.0	0.48	<0.01	2.3	2.4	9.9	10.0	6.1	180	0.07	0.07
UMA046	07/16/92	<0.005	NA	113.3870	<0.03	NA	20.0	20.0	3.7	<0.04	<0.04	<0.01	<0.01	13.0	13.0	0.47	<0.01	2.3	2.7	10.0	11.0	6.1	200	0.07	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA046	09/24/92	<0.005	NA	146.3058	0.03	NA	22.0	22.0	3.7	<0.04	<0.04	<0.01	<0.01	14.0	14.0	0.50	0.01	2.4	2.3	11.0	11.0	6.7	180	0.06	0.06
UMA046	11/19/92	<0.005	<0.005	134.1136	<0.03	NA	22.0	21.0	3.7	<0.04	<0.04	<0.01	<0.01	14.0	13.0	0.49	0.01	2.7	2.9	11.0	10.0	6.0	180	0.07	0.06
UMA046	01/14/93	0.005	0.005	136.5521	<0.03	NA	21.0	21.0	4.0	0.05	<0.04	<0.01	<0.01	13.0	13.0	0.47	0.01	2.6	2.9	10.0	11.0	6.0	180	0.07	0.07
UMA046	03/25/93	<0.005	<0.005	138.9905	<0.03	NA	21.0	20.0	3.9	0.04	<0.04	<0.01	<0.01	13.0	12.0	0.50	0.01	2.3	2.1	9.6	9.8	6.1	180	0.08	0.07
UMA047	07/17/90	0.006	NA	175.5669	0.03	NA	43.0	NA	18.0	<0.05	NA	<0.02	NA	9.5	NA	2.40	0.04	4.5	NA	31.0	NA	26.0	NA	NA	NA
UMA047	10/03/91	0.005	NA	179.2246	<0.03	NA	45.0	2.0	19.0	<0.04	<0.04	<0.01	<0.01	10.0	<0.5	2.50	0.04	4.4	1.7	33.0	98.0	30.0	280	0.03	NA
UMA047	11/21/91	0.006	0.005	169.4709	0.04	NA	43.0	42.0	20.0	<0.04	<0.04	<0.01	<0.01	9.3	9.3	2.60	0.04	3.8	3.9	30.0	30.0	29.0	280	<0.03	<0.03
UMA047	03/10/92	VOID	NA	175.5669	<0.03	NA	VOID	25.0	19.0	VOID	<0.04	VOID	<0.01	VOID	5.5	2.60	0.04	VOID	2.7	VOID	55.0	29.0	280	VOID	<0.03
UMA047	05/19/92	0.005	0.007	187.7591	<0.03	NA	45.0	42.0	17.0	<0.04	<0.04	<0.01	<0.01	9.8	9.8	2.60	0.04	4.3	4.3	31.0	31.0	27.0	280	0.04	0.04
UMA047	06/23/92	0.006	NA	178.0054	NA	0.18	41.0	40.0	19.0	<0.04	<0.04	<0.01	<0.01	8.8	8.3	2.60	0.04	3.7	3.6	33.0	34.0	28.0	280	0.04	0.04
UMA047	07/16/92	0.006	NA	190.1975	<0.03	NA	23.0	36.0	16.0	<0.04	<0.04	<0.01	<0.01	5.1	8.2	2.60	0.04	2.3	3.6	60.0	41.0	27.0	280	0.04	NA
UMA047	09/23/92	<0.005	NA	185.3207	0.04	NA	27.0	42.0	20.0	<0.04	<0.04	<0.01	<0.01	6.1	9.3	2.60	0.05	2.7	4.3	53.0	29.0	29.0	280	<0.03	<0.03
UMA047	11/19/92	0.005	<0.005	164.5940	<0.03	NA	39.0	38.0	20.0	<0.04	<0.04	<0.01	<0.01	8.5	8.5	2.60	0.04	3.8	4.0	38.0	37.0	28.0	270	0.03	<0.03
UMA047	01/14/93	0.006	0.006	167.0324	<0.03	NA	0.2	0.2	19.0	<0.04	<0.04	<0.01	<0.01	<0.5	<0.5	2.60	0.04	<0.5	<0.5	98.0	98.0	28.0	300	0.03	0.03
UMA047	03/25/93	0.005	0.005	170.6901	<0.03	NA	43.0	40.0	20.0	<0.04	<0.04	<0.01	<0.01	9.2	8.6	2.70	0.04	3.2	3.5	28.0	28.0	28.0	270	0.03	<0.03
UMA048	07/16/90	0.009	NA	215.8010	0.04	NA	33.0	NA	7.3	<0.05	NA	<0.02	NA	8.6	NA	1.60	0.05	3.4	NA	40.0	NA	17.0	280	NA	NA
UMA048	10/03/91	0.006	NA	218.2395	<0.03	NA	34.0	32.0	6.4	0.04	<0.04	<0.01	<0.01	8.7	8.1	1.80	0.04	4.6	4.2	48.0	46.0	15.0	250	0.04	NA
UMA048	11/21/91	0.007	0.006	212.1434	<0.03	NA	32.0	33.0	6.2	<0.04	<0.04	<0.01	<0.01	8.4	8.4	1.90	0.04	3.7	4.1	45.0	46.0	15.0	260	0.04	0.03
UMA048	01/17/92	0.006	0.006	215.8010	<0.03	NA	34.0	33.0	6.1	<0.04	<0.04	<0.01	<0.01	8.7	8.7	1.80	0.04	4.6	4.2	48.0	46.0	15.0	270	0.04	0.05
UMA048	03/10/92	0.009	NA	203.6089	0.03	NA	31.0	30.0	7.3	<0.04	<0.04	<0.01	<0.01	7.8	7.9	1.30	0.05	3.3	3.3	40.0	41.0	17.0	250	0.05	0.04
UMA048	05/19/92	0.011	0.011	210.9242	<0.03	NA	33.0	30.0	7.5	<0.04	<0.04	<0.01	<0.01	8.3	7.9	1.30	0.05	3.4	3.2	39.0	38.0	17.0	250	0.07	0.06
UMA048	06/23/92	0.011	NA	214.5818	NA	0.05	33.0	32.0	7.2	<0.04	<0.04	<0.01	<0.01	8.4	8.1	1.50	0.04	3.1	3.0	40.0	40.0	16.0	250	0.05	0.05
UMA048	07/16/92	0.010	NA	195.0744	<0.03	NA	32.0	31.0	6.6	<0.04	<0.04	<0.01	<0.01	8.1	7.9	1.20	0.05	3.0	2.8	40.0	39.0	16.0	250	0.06	NA
UMA048	09/23/92	0.010	NA	209.7050	0.04	NA	32.0	32.0	6.2	<0.04	0.05	<0.01	<0.01	8.2	8.1	1.50	0.05	3.6	3.3	41.0	40.0	15.0	250	0.06	0.05
UMA048	11/20/92	0.006	0.005	213.3626	<0.03	NA	32.0	31.0	6.3	<0.04	<0.04	<0.01	<0.01	8.2	8.1	1.80	0.06	4.1	4.1	45.0	46.0	15.0	260	0.04	0.04
UMA048	01/14/93	0.006	0.006	212.1434	<0.03	NA	31.0	31.0	6.0	<0.04	<0.04	<0.01	<0.01	8.1	7.7	1.80	0.04	4.2	4.1	44.0	44.0	14.0	260	0.04	0.04
UMA048	03/25/93	0.007	0.007	212.1434	<0.03	NA	30.0	29.0	6.6	<0.04	<0.04	<0.01	<0.01	7.7	7.6	1.60	0.04	3.3	3.2	41.0	39.0	15.0	250	0.05	0.04
UMA049	07/16/90	0.008	NA	271.8849	0.04	NA	57.0	NA	6.2	<0.05	NA	<0.02	NA	19.0	NA	1.30	0.05	3.6	NA	19.0	NA	11.0	310	NA	NA
UMA049	06/24/92	0.007	NA	242.6238	NA	<0.05	51.0	48.0	6.2	<0.04	<0.04	<0.01	<0.01	16.0	15.0	2.10	0.05	2.9	2.9	19.0	17.0	10.0	270	0.05	0.04
UMA050	07/16/90	<0.005	NA	279.2002	0.04	NA	42.0	NA	18.0	<0.05	NA	<0.02	NA	12.0	NA	4.10	0.03	6.7	NA	63.0	NA	31.0	390	NA	NA
UMA051	07/16/90	<0.005	NA	195.0744	<0.03	NA	19.0	NA	15.0	<0.05	NA	<0.02	NA	7.0	NA	0.14	0.01	15.0	NA	57.0	NA	43.0	300	NA	NA
UMA051	06/24/92	<0.005	NA	170.6901	NA	0.13	19.0	17.0	15.0	<0.04	<0.04	<0.01	<0.01	6.9	6.1	0.18	0.01	15.0	13.0	59.0	52.0	38.0	280	0.05	0.05
UMA052	07/16/90	0.014	NA	199.9512	0.03	NA	33.0	NA	12.0	<0.05	NA	<0.02	NA	14.0	NA	1.60	0.02	4.2	NA	29.0	NA	16.0	290	NA	NA
UMA052	06/25/92	0.015	NA	179.2246	NA	0.11	33.0	33.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	1.30	0.02	3.6	3.4	25.0	25.0	16.0	260	0.19	0.19
UMA053	07/18/90	0.010	NA	292.6116	<0.03	NA	73.0	NA	23.0	<0.05	NA	<0.02	NA	20.0	NA	4.30	0.04	9.2	NA	29.0	NA	37.0	NA	NA	NA
UMA053	06/24/92	0.009	NA	293.8308	NA	0.09	78.0	74.0	25.0	<0.04	<0.04	<0.01	<0.01	20.0	19.0	4.90	0.04	9.1	8.5	31.0	29.0	34.0	400	<0.03	<0.03
UMA054	07/19/90	<0.005	NA	207.2665	0.05	NA	12.0	NA	28.0	<0.05	NA	<0.02	NA	3.7	NA	0.28	0.09	10.0	NA	100.0	NA	51.0	NA	NA	NA
UMA054	06/24/92	<0.005	NA	210.9242	NA	0.20	9.7	9.1	25.0	<0.04	<0.04	<0.01	<0.01	2.7	2.6	0.15	0.02	8.7	8.5	92.0	88.0	29.0	320	<0.03	<0.03
UMA055	07/18/90	0.006	NA	185.3207	0.03	NA	41.0	NA	12.0	1.80	NA	0.04	NA	11.0	NA	3.00	0.18	5.3	NA	22.0	NA	23.0	NA	NA	NA
UMA055	06/23/92	0.006	NA	203.6089	NA	0.08	58.0	59.0	18.0	<0.04	<0.04	<0.01	<0.01	15.0	16.0	9.10	0.16	5.7	6.0	27.0	27.0	39.0	350	<0.03	<0.03
UMA056	07/17/90	<0.005	NA	165.8132	0.03	NA	50.0	NA	110.0	<0.05	NA	<0.02	NA	20.0	NA	6.70	0.02	7.4	NA	20.0	NA	66.0	NA	NA	NA
UMA056	10/03/91	<0.005	NA	157.2787	<0.03	NA	52.0	52.0	110.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	6.40	0.01	7.8	7.6	82.0	79.0	71.0	460	0.03	NA
UMA056	11/21/91	<0.005	<0.005	158.4979	0.04	NA	54.0	54.0	100.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	6.90	0.01	7.3	7.2	77.0	79.0	80.0	490	<0.03	<0.03
UMA056	03/10/92	<0.005	NA	157.2787	0.04	NA	51.0	49.0	100.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.80	0.01	7.4	7.3	77.0	74.0	72.0	480	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA056	05/19/92	<0.005	<0.005	165.8132	<0.03	NA	55.0	51.0	97.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	6.50	0.01	7.7	7.3	74.0	72.0	78.0	490	0.03	0.03
UMA056	06/23/92	<0.005	NA	158.4979	NA	0.81	50.0	49.0	110.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.30	<0.01	7.0	6.8	76.0	76.0	65.0	480	0.03	<0.03
UMA056	07/16/92	<0.005	NA	152.4019	<0.03	NA	48.0	50.0	110.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.60	0.01	6.8	7.2	77.0	80.0	70.0	490	<0.03	NA
UMA056	09/24/92	<0.005	NA	164.5940	0.04	NA	51.0	52.0	100.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	7.00	0.02	7.2	7.8	80.0	79.0	72.0	490	<0.03	<0.03
UMA056	11/19/92	<0.005	<0.005	156.0595	<0.03	NA	52.0	51.0	110.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	7.00	0.02	7.5	7.6	77.0	76.0	72.0	480	0.03	<0.03
UMA056	01/14/93	<0.005	<0.005	154.8403	<0.03	NA	51.0	51.0	97.0	0.14	<0.04	<0.01	<0.01	20.0	20.0	7.00	0.01	7.2	7.3	73.0	74.0	75.0	490	0.03	0.03
UMA056	01/14/93	<0.005	<0.005	157.2787	<0.03	NA	51.0	51.0	97.0	0.14	<0.04	<0.01	<0.01	20.0	20.0	7.30	0.01	7.6	7.5	74.0	73.0	76.0	490	0.04	0.03
UMA056	03/25/93	<0.005	<0.005	152.4019	<0.03	NA	49.0	48.0	96.0	<0.04	<0.04	<0.01	<0.01	20.0	19.0	6.70	0.01	6.3	6.8	68.0	66.0	73.0	450	0.03	0.03
UMA057	07/18/90	0.008	NA	210.9242	0.04	NA	54.0	NA	16.0	0.15	NA	<0.02	NA	15.0	NA	8.20	0.07	6.3	NA	28.0	NA	22.0	NA	NA	NA
UMA057	06/22/92	0.008	NA	241.4045	NA	0.05	63.0	59.0	17.0	0.10	<0.04	<0.01	<0.01	17.0	16.0	9.90	0.06	6.8	6.7	28.0	27.0	33.0	380	<0.03	<0.03
UMA058	10/08/90	<0.005	NA	292.6116	0.08	NA	68.0	NA	34.0	<0.04	NA	<0.01	NA	26.0	NA	160.00	0.08	6.1	NA	53.0	NA	27.0	NA	<0.03	NA
UMA058	11/26/90	<0.005	NA	407.2178	0.11	NA	95.0	NA	46.0	<0.04	NA	<0.01	NA	31.0	NA	22.00	0.10	7.3	NA	75.0	NA	42.0	590	<0.03	NA
UMA058	10/02/91	<0.005	NA	298.7076	0.04	NA	71.0	70.0	33.0	<0.04	<0.04	<0.01	<0.01	24.0	24.0	13.00	0.08	6.4	5.6	50.0	48.0	31.0	450	<0.03	NA
UMA058	11/20/91	<0.005	<0.005	281.6386	0.03	NA	65.0	66.0	30.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	13.00	0.08	5.4	5.4	47.0	47.0	30.0	440	<0.03	<0.03
UMA058	03/09/92	<0.005	<0.005	315.7766	0.08	NA	73.0	71.0	36.0	<0.04	<0.04	<0.01	<0.01	24.0	24.0	15.00	0.09	5.8	6.0	51.0	50.0	28.0	480	<0.03	<0.03
UMA058	05/18/92	<0.005	<0.005	290.1731	0.06	NA	67.0	63.0	31.0	0.15	<0.04	<0.01	<0.01	23.0	22.0	10.00	0.08	5.3	4.9	46.0	44.0	27.0	430	<0.03	<0.03
UMA058	06/22/92	<0.005	NA	496.2204	NA	0.35	110.0	120.0	68.0	<0.04	<0.04	<0.01	<0.01	36.0	37.0	23.00	0.12	7.8	8.3	84.0	86.0	40.0	770	<0.03	<0.03
UMA058	07/15/92	<0.005	NA	448.6711	0.18	NA	110.0	110.0	57.0	<0.04	<0.04	<0.01	<0.01	35.0	34.0	23.00	0.11	7.4	7.1	81.0	81.0	39.0	700	<0.03	NA
UMA058	09/23/92	<0.005	NA	271.8849	0.06	NA	58.0	57.0	26.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	9.70	0.08	5.2	5.1	39.0	40.0	23.0	380	<0.03	<0.03
UMA058	11/18/92	<0.005	<0.005	274.3233	0.03	NA	57.0	56.0	24.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	8.20	0.08	5.2	5.3	40.0	39.0	23.0	370	0.03	0.03
UMA058	03/24/93	<0.005	<0.005	285.2963	0.06	NA	65.0	63.0	32.0	<0.04	<0.04	<0.01	<0.01	20.0	21.0	9.70	0.09	5.3	5.6	39.0	39.0	24.0	410	<0.03	0.03
UMA059	10/08/90	0.010	NA	277.9810	0.05	NA	64.0	NA	15.0	<0.04	NA	<0.01	NA	18.0	NA	3.90	0.18	7.5	NA	29.0	NA	23.0	NA	<0.03	NA
UMA059	06/23/92	0.009	NA	285.2963	NA	0.10	69.0	69.0	17.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	5.50	0.15	7.4	7.6	28.0	28.0	29.0	370	<0.03	<0.03
UMA060	10/09/90	0.010	NA	302.3653	0.05	NA	62.0	NA	15.0	<0.04	NA	<0.01	NA	20.0	NA	1.70	0.09	7.6	NA	35.0	NA	24.0	NA	<0.03	NA
UMA060	06/25/92	0.012	NA	282.8578	NA	0.07	57.0	53.0	14.0	<0.04	<0.04	<0.01	<0.01	17.0	16.0	1.90	0.15	6.7	6.8	30.0	27.0	20.0	310	<0.03	<0.03
UMA061	10/09/90	<0.005	NA	215.8010	0.03	NA	41.0	NA	7.3	0.05	NA	<0.01	NA	14.0	NA	2.70	0.09	4.6	NA	26.0	NA	14.0	NA	<0.03	NA
UMA061	11/21/91	0.010	?	208.4857	?	?	41.0	?	45.0	<0.04	?	?	?	22.0	?	16.00	0.01	4.9	?	57.0	?	23.0	<1	<0.03	?
UMA062	10/09/90	<0.005	NA	379.1758	0.04	NA	100.0	NA	24.0	<0.04	NA	<0.01	NA	34.0	NA	13.00	0.08	6.3	NA	24.0	NA	23.0	NA	<0.03	NA
UMA062	11/28/90	<0.005	NA	380.3950	0.05	NA	110.0	NA	24.0	0.08	NA	<0.01	NA	31.0	NA	13.00	0.08	6.6	NA	21.0	NA	23.0	450	<0.03	NA
UMA063	10/09/90	0.015	NA	215.8010	<0.03	NA	37.0	NA	8.5	<0.04	NA	<0.01	NA	24.0	NA	2.60	0.02	2.3	NA	21.0	NA	14.0	NA	0.07	NA
UMA063	10/09/90	0.015	NA	215.8010	<0.03	NA	36.0	NA	8.5	<0.04	NA	<0.01	NA	23.0	NA	2.60	0.02	2.1	NA	20.0	NA	14.0	NA	0.07	NA
UMA063	06/24/92	0.014	NA	254.8159	NA	0.06	45.0	43.0	11.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	5.00	0.03	2.4	2.3	22.0	22.0	11.0	300	0.07	0.07
UMA064	10/09/90	0.007	NA	318.2151	0.04	NA	67.0	NA	18.0	<0.04	NA	<0.01	NA	24.0	NA	1.60	0.09	8.8	NA	38.0	NA	28.0	NA	<0.03	NA
UMA064	06/25/92	0.007	NA	340.1609	NA	0.09	70.0	71.0	17.0	<0.04	<0.04	0.04	0.04	22.0	23.0	2.50	0.12	8.1	8.7	35.0	37.0	27.0	390	<0.03	<0.03
UMA064	06/25/92	0.007	NA	343.8186	NA	0.09	69.0	68.0	17.0	<0.04	<0.04	0.04	0.04	23.0	21.0	2.50	0.12	8.5	9.1	36.0	34.0	29.0	380	<0.03	<0.03
UMA065	10/09/90	0.013	NA	318.2151	0.06	NA	88.0	NA	76.0	<0.04	NA	<0.01	NA	32.0	NA	6.00	0.04	14.0	NA	81.0	NA	110.0	NA	<0.03	NA
UMA065	06/22/92	0.011	NA	582.7847	NA	0.28	91.0	90.0	80.0	<0.04	<0.04	<0.01	<0.01	30.0	30.0	6.10	0.02	14.0	13.0	79.0	79.0	100.0	650	<0.03	<0.03
UMA066	10/09/90	0.009	NA	270.6657	0.04	NA	62.0	NA	18.0	<0.04	NA	<0.01	NA	22.0	NA	5.70	0.10	7.2	NA	31.0	NA	32.0	NA	<0.03	NA
UMA066	09/30/91	0.010	NA	274.3233	0.06	NA	62.0	59.0	19.0	<0.04	<0.04	<0.01	<0.01	20.0	19.0	4.80	0.10	6.5	6.5	30.0	28.0	29.0	360	<0.03	NA
UMA066	11/18/91	0.009	0.009	267.0080	0.07	NA	67.0	65.0	20.0	0.05	<0.04	<0.01	<0.01	21.0	20.0	6.90	0.11	7.5	7.1	32.0	32.0	32.0	370	<0.03	<0.03
UMA066	01/13/92	0.009	0.009	249.9390	0.07	NA	62.0	63.0	19.0	<0.04	0.04	<0.01	<0.01	20.0	20.0	6.60	0.10	6.4	6.8	30.0	30.0	32.0	360	<0.03	<0.03
UMA066	03/10/92	0.009	NA	273.1041	0.04	NA	63.0	64.0	19.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.50	0.10	6.7	6.5	30.0	30.0	30.0	380	<0.03	<0.03
UMA066	03/10/92	0.008	NA	276.7618	0.06	NA	62.0	62.0	18.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.50	0.10	6.8	7.2	29.0	30.0	30.0	370	<0.03	<0.03
UMA066	05/19/92	0.010	0.011	279.2002	0.05	NA	62.0	64.0	20.0	<0.04	<0.04	<0.01	<0.01	19.0	20.0	6.50	0.10	6.2	6.5	29.0	30.0	30.0	370	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA066	06/23/92	0.009	NA	284.0771	NA	0.10	66.0	63.0	20.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	6.20	0.09	6.2	6.7	30.0	30.0	30.0	380	<0.03	<0.03
UMA066	07/13/92	0.010	NA	286.5155	0.07	NA	69.0	67.0	20.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	6.50	0.11	6.9	6.6	31.0	31.0	32.0	400	<0.03	NA
UMA066	09/21/92	0.009	NA	264.5696	0.05	NA	67.0	68.0	21.0	0.06	<0.04	<0.01	<0.01	20.0	20.0	6.20	0.10	7.2	7.7	31.0	31.0	30.0	380	0.03	<0.03
UMA066	11/16/92	0.009	0.010	277.9810	0.07	NA	64.0	63.0	20.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.70	0.10	6.6	6.5	30.0	29.0	31.0	370	<0.03	<0.03
UMA066	01/11/93	0.011	0.010	268.2273	0.07	NA	64.0	63.0	20.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	6.70	0.10	6.8	6.8	30.0	30.0	31.0	370	<0.03	<0.03
UMA066	03/22/93	0.009	0.010	280.4194	0.07	NA	63.0	62.0	20.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	6.50	0.11	6.5	6.5	30.0	29.0	30.0	370	<0.03	<0.03
UMA067	10/09/90	0.008	NA	132.8944	<0.03	NA	28.0	NA	16.0	<0.04	NA	<0.01	NA	12.0	NA	3.40	0.02	2.9	NA	23.0	NA	17.0	NA	0.09	NA
UMA068	10/09/90	<0.005	NA	175.5669	<0.03	NA	32.0	NA	9.3	0.05	NA	0.08	NA	11.0	NA	0.03	0.01	12.0	NA	46.0	NA	74.0	NA	<0.03	NA
UMA068	06/25/92	<0.005	NA	188.9783	NA	0.07	33.0	32.0	11.0	0.05	0.04	0.09	0.08	12.0	12.0	0.04	0.01	13.0	13.0	49.0	47.0	70.0	320	<0.03	<0.03
UMA069	10/10/90	0.007	NA	336.5033	0.03	NA	86.0	NA	25.0	<0.04	NA	<0.01	NA	26.0	NA	9.10	0.11	5.9	NA	22.0	NA	24.0	NA	<0.03	NA
UMA069	06/23/92	0.007	NA	398.6832	NA	0.14	100.0	100.0	33.0	<0.04	<0.04	<0.01	<0.01	32.0	33.0	14.00	0.11	7.1	6.9	25.0	25.0	30.0	510	<0.03	<0.03
UMA070	10/10/90	0.007	NA	267.0080	0.05	NA	62.0	NA	9.3	1.60	NA	<0.01	NA	16.0	NA	2.50	0.15	6.0	NA	23.0	NA	19.0	NA	<0.03	NA
UMA070	06/24/92	0.007	NA	256.0351	NA	<0.05	63.0	61.0	10.0	<0.04	<0.04	<0.01	<0.01	16.0	16.0	3.20	0.15	5.9	6.2	23.0	22.0	16.0	310	<0.03	<0.03
UMA071	10/10/90	0.014	NA	412.0946	0.05	NA	85.0	NA	20.0	<0.04	NA	<0.01	NA	35.0	NA	10.00	0.11	5.5	NA	53.0	NA	54.0	NA	0.06	NA
UMA072	10/10/90	0.009	NA	326.7496	0.05	NA	69.0	NA	16.0	0.06	NA	<0.01	NA	21.0	NA	2.40	0.09	7.4	NA	37.0	NA	36.0	NA	<0.03	NA
UMA072	06/25/92	0.009	NA	329.1880	NA	0.10	68.0	67.0	18.0	0.06	<0.04	<0.01	<0.01	22.0	22.0	3.40	0.08	7.4	7.9	42.0	41.0	43.0	400	<0.03	<0.03
UMA073	10/10/90	<0.005	NA	229.2124	0.03	NA	49.0	NA	11.0	0.05	NA	<0.01	NA	15.0	NA	7.90	0.11	4.9	NA	33.0	NA	23.0	NA	<0.03	NA
UMA073	06/23/92	<0.005	NA	221.8971	NA	0.13	44.0	44.0	12.0	0.06	<0.04	<0.01	<0.01	14.0	14.0	6.20	0.12	4.7	4.5	32.0	32.0	20.0	290	<0.03	<0.03
UMA074	10/11/90	0.011	NA	342.5994	0.10	NA	69.0	NA	15.0	<0.04	NA	<0.01	NA	26.0	NA	1.80	0.05	5.3	NA	34.0	NA	24.0	NA	0.03	NA
UMA074	06/24/92	0.010	NA	359.6684	NA	0.06	63.0	64.0	14.0	<0.04	<0.04	<0.01	<0.01	24.0	24.0	1.20	0.05	5.4	5.4	33.0	33.0	24.0	380	0.03	0.03
UMA075	10/10/90	0.009	NA	342.5994	<0.03	NA	70.0	NA	16.0	0.12	NA	<0.01	NA	24.0	NA	4.00	0.05	7.5	NA	35.0	NA	23.0	NA	0.03	NA
UMA076	10/11/90	0.006	NA	312.1190	0.08	NA	80.0	NA	19.0	0.04	NA	0.02	NA	20.0	NA	3.80	0.08	7.5	NA	35.0	NA	36.0	NA	<0.03	NA
UMA076	06/24/92	0.006	NA	330.4072	NA	0.09	70.0	72.0	18.0	<0.04	<0.04	<0.01	<0.01	18.0	19.0	3.00	0.08	7.1	7.3	34.0	36.0	29.0	380	<0.03	<0.03
UMA077	10/11/90	<0.005	NA	206.0473	0.07	NA	53.0	NA	12.0	0.08	NA	<0.01	NA	12.0	NA	2.30	0.08	4.2	NA	20.0	NA	19.0	NA	<0.03	NA
UMA077	10/02/91	<0.005	NA	219.4587	<0.03	NA	51.0	49.0	11.0	<0.04	<0.04	<0.01	<0.01	12.0	11.0	1.20	0.08	5.2	4.6	20.0	18.0	17.0	250	<0.03	NA
UMA077	11/22/91	<0.005	<0.005	191.4167	0.03	NA	44.0	42.0	7.3	<0.04	<0.04	<0.01	<0.01	10.0	9.4	1.20	0.09	4.2	3.9	19.0	17.0	13.0	230	<0.03	<0.03
UMA077	01/15/92	<0.005	<0.005	201.1704	<0.03	NA	47.0	46.0	7.9	<0.04	<0.04	<0.01	<0.01	11.0	11.0	1.40	0.09	4.3	4.0	19.0	19.0	14.0	250	<0.03	<0.03
UMA077	03/12/92	<0.005	NA	202.3897	<0.03	NA	45.0	45.0	7.3	<0.04	<0.04	<0.01	<0.01	10.0	10.0	1.30	0.08	4.4	4.4	17.0	17.0	15.0	230	<0.03	<0.03
UMA077	06/24/92	<0.005	NA	168.2516	NA	0.05	38.0	38.0	5.5	<0.04	<0.04	<0.01	<0.01	8.3	8.4	0.75	0.09	4.1	3.8	17.0	17.0	12.0	200	<0.03	<0.03
UMA078	10/11/90	<0.005	NA	310.8998	0.05	NA	84.0	NA	15.0	<0.04	NA	<0.01	NA	22.0	NA	8.20	0.07	5.7	NA	25.0	NA	23.0	NA	<0.03	NA
UMA078	06/23/92	<0.005	NA	310.8998	NA	0.07	79.0	78.0	17.0	0.04	<0.04	<0.01	<0.01	20.0	20.0	9.20	0.07	5.5	5.3	23.0	22.0	24.0	380	<0.03	<0.03
UMA079	10/11/90	<0.005	NA	149.9634	<0.03	NA	32.0	NA	8.4	<0.04	NA	<0.01	NA	9.7	NA	0.55	<0.01	3.1	NA	14.0	NA	12.0	NA	<0.03	NA
UMA079	10/11/90	<0.005	NA	152.4019	<0.03	NA	34.0	NA	8.3	<0.04	NA	<0.01	NA	10.0	NA	0.56	0.01	3.3	NA	14.0	NA	13.0	NA	<0.03	NA
UMA079	06/24/92	<0.005	NA	146.3058	NA	<0.05	32.0	33.0	8.4	<0.04	<0.04	0.02	0.02	9.9	10.0	0.25	0.01	3.2	3.4	15.0	14.0	12.0	210	<0.03	<0.03
UMA080	10/11/90	<0.005	NA	184.1014	<0.03	NA	39.0	NA	8.7	<0.04	NA	<0.01	NA	13.0	NA	2.40	0.06	3.9	NA	18.0	NA	13.0	NA	<0.03	NA
UMA080	06/22/92	<0.005	NA	187.7591	NA	0.07	39.0	37.0	9.4	0.05	<0.04	<0.01	<0.01	13.0	12.0	2.60	0.06	4.3	4.2	18.0	18.0	13.0	250	<0.03	<0.03
UMA081	10/11/90	<0.005	NA	234.0892	0.04	NA	69.0	NA	40.0	0.05	NA	<0.01	NA	23.0	NA	11.00	0.08	5.2	NA	33.0	NA	42.0	NA	<0.03	NA
UMA081	06/23/92	<0.005	NA	451.1095	NA	0.22	110.0	110.0	52.0	<0.04	<0.04	<0.01	<0.01	36.0	35.0	14.00	0.08	7.1	7.1	44.0	43.0	27.0	580	<0.03	<0.03
UMA082	11/26/90	0.005	NA	176.7861	<0.03	NA	26.0	NA	24.0	0.05	NA	0.01	NA	8.8	NA	<0.02	0.01	8.1	NA	53.0	NA	46.0	270	<0.03	NA
UMA082	06/23/92	0.006	NA	170.6901	NA	0.17	25.0	25.0	22.0	0.08	<0.04	<0.01	<0.01	8.6	8.3	0.03	0.02	7.5	7.2	53.0	52.0	42.0	280	<0.03	<0.03
UMA083	11/26/90	<0.005	NA	180.4438	0.04	NA	34.0	NA	6.4	0.28	NA	0.09	NA	12.0	NA	0.08	0.05	6.6	NA	20.0	NA	16.0	230	<0.03	NA
UMA084	11/26/90	<0.005	NA	319.4343	0.06	NA	88.0	NA	44.0	0.04	NA	<0.01	NA	29.0	NA	14.00	0.08	6.6	NA	37.0	NA	48.0	480	<0.03	NA
UMA084	10/03/91	<0.005	NA	306.0229	<0.03	NA	89.0	84.0	44.0	0.06	<0.04	<0.01	<0.01	29.0	28.0	14.00	0.08	7.0	6.7	40.0	38.0	42.0	480	<0.03	NA
UMA084	11/20/91	<0.005	<0.005	285.2963	0.03	NA	84.0	80.0	42.0	0.06	<0.04	<0.01	<0.01	26.0	25.0	15.00	0.07	6.5	6.4	38.0	36.0	41.0	470	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA084	03/09/92	<0.005	<0.005	409.6562	0.06	NA	100.0	100.0	52.0	0.07	<0.04	<0.01	<0.01	32.0	33.0	10.00	0.09	7.3	7.3	41.0	41.0	25.0	550	<0.03	<0.03
UMA084	05/18/92	<0.005	<0.005	364.5452	0.06	NA	90.0	93.0	45.0	<0.04	<0.04	<0.01	<0.01	30.0	30.0	NA	NA	6.6	6.6	41.0	41.0	30.0	510	<0.03	<0.03
UMA084	06/22/92	<0.005	NA	409.6562	NA	0.21	96.0	93.0	46.0	<0.04	<0.04	<0.01	<0.01	31.0	30.0	6.90	0.08	7.3	6.8	41.0	41.0	22.0	540	<0.03	<0.03
UMA084	07/15/92	<0.005	NA	354.7915	0.05	NA	84.0	88.0	41.0	<0.04	<0.04	<0.01	<0.01	27.0	28.0	10.00	0.08	6.2	6.4	38.0	39.0	30.0	480	<0.03	NA
UMA084	09/23/92	<0.005	NA	398.6832	0.08	NA	100.0	99.0	50.0	<0.04	<0.04	<0.01	<0.01	33.0	32.0	13.00	0.10	7.3	6.9	40.0	39.0	32.0	550	<0.03	<0.03
UMA084	11/18/92	<0.005	<0.005	426.7252	0.06	NA	100.0	110.0	49.0	0.06	<0.04	<0.01	<0.01	34.0	34.0	11.00	0.09	7.5	7.2	42.0	42.0	30.0	540	<0.03	<0.03
UMA084	01/13/93	<0.005	<0.005	419.4099	0.07	NA	110.0	110.0	52.0	<0.04	<0.04	<0.01	<0.01	34.0	33.0	9.20	0.09	7.2	7.1	40.0	40.0	30.0	560	<0.03	<0.03
UMA084	03/25/93	<0.005	<0.005	408.4370	0.06	NA	98.0	98.0	53.0	<0.04	<0.04	<0.01	<0.01	31.0	32.0	6.50	0.09	6.7	6.8	39.0	37.0	29.0	540	<0.03	<0.03
UMA085	11/27/90	0.009	NA	180.4438	<0.03	NA	69.0	NA	58.0	0.06	NA	<0.01	NA	25.0	NA	21.00	0.05	7.5	NA	50.0	NA	65.0	450	0.03	NA
UMA085	11/27/90	0.009	NA	188.9783	<0.03	NA	71.0	NA	59.0	0.05	NA	<0.01	NA	25.0	NA	21.00	0.05	7.8	NA	51.0	NA	66.0	460	0.03	NA
UMA085	10/01/91	0.010	NA	187.7591	<0.03	NA	72.0	69.0	61.0	<0.04	<0.04	<0.01	<0.01	26.0	26.0	20.00	0.05	7.7	7.7	52.0	52.0	65.0	490	0.04	NA
UMA085	11/19/91	0.009	0.009	182.8822	<0.03	NA	71.0	67.0	59.0	<0.04	<0.04	<0.01	<0.01	24.0	25.0	22.00	0.05	7.8	7.4	53.0	50.0	67.0	480	0.04	0.04
UMA085	03/11/92	0.010	NA	187.7591	<0.03	NA	65.0	67.0	58.0	0.04	<0.04	<0.01	<0.01	24.0	24.0	23.00	0.05	7.4	7.5	51.0	49.0	65.0	500	0.04	0.04
UMA085	05/20/92	0.005	<0.005	187.7591	<0.03	NA	70.0	68.0	59.0	0.10	<0.04	<0.01	<0.01	25.0	23.0	23.00	0.04	6.8	7.4	53.0	51.0	66.0	500	<0.03	<0.03
UMA085	06/24/92	0.008	NA	191.4167	NA	0.44	67.0	68.0	58.0	<0.04	<0.04	<0.01	<0.01	25.0	24.0	24.00	0.05	7.3	7.3	51.0	52.0	64.0	500	0.03	0.03
UMA085	07/14/92	0.008	NA	184.1014	<0.03	NA	68.0	68.0	57.0	0.05	<0.04	<0.01	<0.01	24.0	24.0	22.00	0.05	7.3	7.5	50.0	50.0	70.0	500	0.03	NA
UMA085	09/22/92	0.011	NA	195.0744	<0.03	NA	74.0	70.0	59.0	0.70	<0.04	0.04	<0.01	26.0	25.0	24.00	0.07	7.9	7.6	55.0	54.0	65.0	500	0.04	0.04
UMA085	09/22/92	0.011	NA	191.4167	<0.03	NA	72.0	68.0	59.0	0.72	<0.04	0.04	<0.01	26.0	25.0	24.00	0.07	7.9	7.6	55.0	53.0	66.0	510	0.04	0.04
UMA085	11/17/92	0.010	0.010	185.3207	<0.03	NA	70.0	70.0	57.0	0.14	<0.04	0.02	0.01	25.0	25.0	25.00	0.05	6.6	6.9	54.0	52.0	66.0	490	0.05	<0.03
UMA085	01/12/93	0.011	0.009	184.1014	<0.03	NA	71.0	70.0	57.0	0.48	<0.04	0.02	<0.01	25.0	25.0	25.00	0.06	7.7	7.8	50.0	50.0	67.0	510	0.04	<0.03
UMA085	03/23/93	0.009	0.009	186.5399	<0.03	NA	68.0	67.0	59.0	0.07	<0.04	<0.01	<0.01	25.0	25.0	25.00	0.06	7.3	7.6	51.0	50.0	67.0	530	0.03	<0.03
UMA086	11/27/90	0.009	NA	296.2692	0.04	NA	70.0	NA	29.0	1.90	NA	0.01	NA	27.0	NA	9.30	0.04	6.7	NA	35.0	NA	33.0	390	<0.03	NA
UMA086	06/23/92	0.010	NA	293.8308	NA	0.09	65.0	64.0	24.0	0.12	<0.04	<0.01	<0.01	25.0	25.0	7.00	0.03	6.5	6.2	32.0	32.0	28.0	400	<0.03	<0.03
UMA087	11/27/90	0.007	NA	410.8754	0.06	NA	78.0	NA	15.0	<0.04	NA	<0.01	NA	41.0	NA	20.00	0.02	4.9	NA	65.0	NA	55.0	540	0.03	NA
UMA088	11/28/90	<0.005	NA	371.8605	0.04	NA	97.0	NA	19.0	0.05	NA	<0.01	NA	27.0	NA	9.80	0.07	5.1	NA	22.0	NA	21.0	410	<0.03	NA
UMA088	10/03/91	<0.005	NA	371.8605	<0.03	NA	100.0	96.0	18.0	<0.04	<0.04	<0.01	<0.01	29.0	27.0	11.00	0.07	5.8	5.1	25.0	23.0	24.0	450	<0.03	NA
UMA088	11/20/91	<0.005	<0.005	364.5452	<0.03	NA	98.0	95.0	20.0	0.05	<0.04	<0.01	<0.01	27.0	26.0	12.00	0.06	5.2	5.0	22.0	22.0	24.0	460	<0.03	<0.03
UMA088	03/09/92	<0.005	<0.005	363.3260	0.05	NA	99.0	97.0	20.0	<0.04	<0.04	<0.01	<0.01	29.0	28.0	13.00	0.07	4.8	5.2	22.0	21.0	23.0	450	<0.03	<0.03
UMA088	05/18/92	<0.005	<0.005	364.5452	0.04	NA	100.0	96.0	22.0	<0.04	<0.04	<0.01	<0.01	29.0	28.0	13.00	0.07	4.6	4.5	22.0	22.0	27.0	480	<0.03	<0.03
UMA088	06/22/92	<0.005	NA	369.4221	NA	0.07	97.0	95.0	21.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	13.00	0.07	4.9	4.9	22.0	22.0	24.0	480	<0.03	<0.03
UMA088	07/15/92	<0.005	NA	365.7644	0.04	NA	97.0	96.0	22.0	<0.04	<0.04	<0.01	<0.01	28.0	27.0	12.00	0.06	4.5	4.4	22.0	21.0	23.0	460	<0.03	NA
UMA088	09/23/92	<0.005	NA	371.8605	0.05	NA	100.0	95.0	23.0	<0.04	<0.04	<0.01	<0.01	28.0	27.0	13.00	0.07	5.1	4.6	21.0	21.0	23.0	470	<0.03	<0.03
UMA088	11/18/92	<0.005	<0.005	368.2029	<0.03	NA	100.0	96.0	21.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	12.00	0.07	5.1	5.2	21.0	21.0	23.0	460	<0.03	<0.03
UMA088	01/13/93	<0.005	<0.005	357.2299	0.04	NA	97.0	86.0	20.0	<0.04	<0.04	<0.01	<0.01	26.0	24.0	12.00	0.07	5.0	4.9	21.0	19.0	23.0	460	<0.03	<0.03
UMA088	03/24/93	<0.005	<0.005	368.2029	0.03	NA	100.0	99.0	22.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	13.00	0.07	4.8	4.7	21.0	20.0	23.0	470	<0.03	<0.03
UMA089	11/28/90	<0.005	NA	479.1514	0.04	NA	130.0	NA	28.0	<0.04	NA	<0.01	NA	32.0	NA	5.80	0.06	7.3	NA	19.0	NA	24.0	510	<0.03	NA
UMA089	11/28/90	<0.005	NA	479.1514	0.04	NA	130.0	NA	29.0	<0.04	NA	<0.01	NA	32.0	NA	5.80	0.06	7.1	NA	18.0	NA	23.0	510	<0.03	NA
UMA089	06/23/92	<0.005	NA	455.9863	NA	0.13	110.0	120.0	24.0	0.04	<0.04	<0.01	<0.01	29.0	28.0	6.20	0.06	6.6	6.6	18.0	18.0	21.0	500	<0.03	<0.03
UMA090	11/28/90	0.011	NA	201.1704	<0.03	NA	48.0	NA	8.7	<0.04	NA	<0.01	NA	11.0	NA	0.72	0.10	6.8	NA	17.0	NA	16.0	230	<0.03	NA
UMA091	11/28/90	<0.005	NA	210.9242	0.05	NA	24.0	NA	11.0	<0.04	NA	0.03	NA	10.0	NA	<0.02	0.01	7.2	NA	62.0	NA	53.0	280	<0.03	NA
UMA091	05/19/92	<0.005	?	364.5452	?	?	55.0	?	22.0	<0.04	?	?	?	21.0	?	13.00	0.07	7.7	?	74.0	?	27.0	480	0.03	?
UMA092	11/28/90	<0.005	NA	248.7198	0.04	NA	54.0	NA	9.8	0.46	NA	0.01	NA	19.0	NA	6.10	0.08	5.9	NA	23.0	NA	19.0	290	<0.03	NA
UMA092	06/23/92	<0.005	NA	245.0622	NA	0.07	50.0	50.0	9.5	0.07	<0.04	<0.01	<0.01	18.0	17.0	5.70	0.09	5.6	5.1	22.0	22.0	18.0	310	<0.03	<0.03
UMA093	11/28/90	<0.005	NA	156.0595	<0.03	NA	18.0	NA	14.0	0.09	NA	<0.01	NA	6.4	NA	1.20	0.01	5.1	NA	48.0	NA	28.0	230	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA094	11/29/90	<0.005	NA	376.7374	0.05	NA	110.0	NA	28.0	<0.04	NA	<0.01	NA	30.0	NA	14.00	0.06	5.8	NA	19.0	NA	23.0	460	<0.03	NA
UMA094	10/03/91	<0.005	NA	392.5872	<0.03	NA	110.0	110.0	25.0	<0.04	<0.04	<0.01	<0.01	32.0	30.0	13.00	0.07	6.1	5.9	21.0	21.0	24.0	480	<0.03	NA
UMA094	11/20/91	<0.005	<0.005	385.2719	<0.03	NA	110.0	100.0	24.0	<0.04	<0.04	<0.01	<0.01	31.0	29.0	12.00	0.07	5.5	5.6	20.0	19.0	23.0	480	<0.03	<0.03
UMA094	01/16/92	<0.005	<0.005	384.0527	<0.03	NA	100.0	100.0	21.0	<0.04	<0.04	<0.01	<0.01	30.0	29.0	11.00	0.08	5.5	5.3	21.0	19.0	20.0	470	<0.03	<0.03
UMA094	03/12/92	<0.005	NA	368.2029	<0.03	NA	96.0	88.0	20.0	<0.04	<0.04	<0.01	<0.01	27.0	25.0	11.00	0.07	5.2	4.7	18.0	16.0	21.0	450	<0.03	<0.03
UMA094	05/20/92	<0.005	<0.005	370.6413	<0.03	NA	99.0	96.0	22.0	<0.04	<0.04	<0.01	<0.01	28.0	28.0	11.00	0.07	5.8	4.4	20.0	19.0	20.0	440	<0.03	<0.03
UMA094	06/24/92	<0.005	NA	366.9837	NA	0.07	99.0	97.0	21.0	<0.04	<0.04	<0.01	<0.01	28.0	27.0	11.00	0.07	5.5	5.1	20.0	19.0	21.0	440	<0.03	<0.03
UMA094	07/15/92	<0.005	NA	366.9837	0.03	NA	92.0	95.0	22.0	<0.04	<0.04	<0.01	<0.01	26.0	27.0	10.00	0.06	5.0	5.2	18.0	19.0	20.0	450	<0.03	NA
UMA094	09/23/92	<0.005	NA	384.0527	0.04	NA	91.0	86.0	18.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	9.00	0.08	5.1	5.3	18.0	17.0	18.0	430	<0.03	<0.03
UMA094	09/23/92	<0.005	NA	390.1487	0.05	NA	92.0	90.0	18.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	8.90	0.07	5.3	5.1	18.0	18.0	18.0	430	<0.03	<0.03
UMA094	11/18/92	<0.005	<0.005	359.6684	<0.03	NA	89.0	86.0	16.0	<0.04	<0.04	<0.01	<0.01	25.0	24.0	8.50	0.07	5.0	5.2	18.0	18.0	18.0	400	<0.03	<0.03
UMA094	01/13/93	<0.005	<0.005	334.0649	0.04	NA	86.0	85.0	16.0	0.13	<0.04	<0.01	<0.01	24.0	23.0	8.00	0.07	5.2	5.1	17.0	17.0	16.0	400	<0.03	<0.03
UMA094	03/24/93	<0.005	<0.005	338.9417	<0.03	NA	82.0	84.0	16.0	<0.04	<0.04	<0.01	<0.01	24.0	23.0	8.10	0.07	4.7	5.0	17.0	16.0	17.0	410	<0.03	<0.03
UMA095	11/29/90	<0.005	NA	193.8552	0.08	NA	3.4	NA	20.0	<0.04	NA	<0.01	NA	0.8	NA	<0.02	0.03	11.0	NA	77.0	NA	1.4	250	<0.03	NA
UMA095	06/23/92	<0.005	NA	192.6359	NA	0.21	3.4	3.3	21.0	<0.04	<0.04	<0.01	<0.01	0.9	0.9	0.02	0.02	10.0	11.0	80.0	79.0	8.5	280	<0.03	<0.03
UMA096	11/29/90	0.005	NA	264.5696	0.04	NA	85.0	NA	25.0	0.19	NA	<0.01	NA	29.0	NA	27.00	0.04	6.7	NA	36.0	NA	47.0	480	<0.03	NA
UMA096	11/29/90	0.006	NA	263.3504	0.03	NA	83.0	NA	25.0	0.09	NA	<0.01	NA	29.0	NA	27.00	0.04	6.8	NA	36.0	NA	49.0	490	<0.03	NA
UMA096	10/01/91	0.006	NA	243.8430	<0.03	NA	74.0	77.0	24.0	0.17	<0.04	<0.01	<0.01	27.0	28.0	25.00	0.04	6.6	6.3	37.0	37.0	50.0	470	<0.03	NA
UMA096	11/19/91	0.006	0.006	254.8159	<0.03	NA	77.0	70.0	24.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	25.00	0.05	6.2	6.0	38.0	34.0	46.0	460	<0.03	<0.03
UMA096	11/19/91	0.006	0.006	254.8159	<0.03	NA	77.0	70.0	24.0	<0.04	<0.04	<0.01	<0.01	28.0	26.0	25.00	0.05	5.8	6.1	39.0	33.0	45.0	460	<0.03	<0.03
UMA096	01/15/92	0.006	0.006	237.7469	<0.03	NA	82.0	83.0	26.0	<0.04	<0.04	<0.01	<0.01	29.0	30.0	29.00	0.03	6.7	6.8	40.0	40.0	52.0	520	<0.03	<0.03
UMA096	01/15/92	0.007	0.007	237.7469	<0.03	NA	83.0	80.0	26.0	<0.04	<0.04	<0.01	<0.01	29.0	29.0	29.00	0.06	6.3	6.6	40.0	38.0	52.0	510	<0.03	<0.03
UMA096	03/12/92	0.006	NA	223.1163	<0.03	NA	81.0	76.0	28.0	0.14	<0.04	<0.01	<0.01	30.0	28.0	35.00	0.05	6.6	6.2	37.0	36.0	58.0	530	<0.03	<0.03
UMA096	05/21/92	0.005	0.005	210.9242	<0.03	NA	80.0	77.0	27.0	0.06	<0.04	<0.01	<0.01	29.0	28.0	34.00	0.05	6.2	6.3	40.0	40.0	56.0	520	<0.03	<0.03
UMA096	06/25/92	0.005	NA	215.8010	NA	0.10	77.0	75.0	27.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	31.00	0.04	6.4	6.3	39.0	39.0	55.0	490	<0.03	<0.03
UMA096	07/14/92	0.005	NA	209.7050	<0.03	NA	74.0	77.0	27.0	0.23	<0.04	<0.01	<0.01	27.0	28.0	31.00	0.05	5.9	6.0	37.0	38.0	58.0	510	<0.03	NA
UMA096	07/14/92	0.005	NA	215.8010	<0.03	NA	73.0	74.0	27.0	0.20	<0.04	<0.01	0.02	27.0	27.0	30.00	0.05	6.3	6.5	37.0	39.0	59.0	510	<0.03	NA
UMA096	09/22/92	0.006	NA	258.4735	0.04	NA	78.0	77.0	26.0	<0.04	<0.04	<0.01	<0.01	28.0	28.0	23.00	0.05	6.3	6.3	41.0	40.0	46.0	490	<0.03	<0.03
UMA096	11/17/92	0.006	0.007	256.0351	<0.03	NA	78.0	76.0	26.0	0.08	<0.04	<0.01	<0.01	27.0	27.0	27.00	0.05	5.3	5.5	38.0	38.0	50.0	480	<0.03	<0.03
UMA096	01/14/93	0.006	0.007	231.6508	<0.03	NA	81.0	81.0	26.0	0.08	<0.04	<0.01	<0.01	29.0	28.0	32.00	0.05	6.5	6.7	38.0	38.0	55.0	540	<0.03	<0.03
UMA096	03/23/93	0.006	0.005	215.8010	<0.03	NA	80.0	77.0	29.0	0.20	<0.04	<0.01	<0.01	29.0	28.0	35.00	0.05	6.5	6.3	39.0	37.0	60.0	550	<0.03	<0.03
UMA097	11/29/90	0.008	NA	249.9390	0.03	NA	62.0	NA	16.0	0.15	NA	<0.01	NA	20.0	NA	9.80	0.05	6.2	NA	28.0	NA	31.0	350	<0.03	NA
UMA097	06/24/92	0.007	NA	202.3897	NA	0.15	63.0	62.0	21.0	0.09	<0.04	<0.01	<0.01	21.0	21.0	19.00	0.05	6.0	6.1	32.0	32.0	38.0	400	<0.03	<0.03
UMA098	11/29/90	0.010	NA	273.1041	0.04	NA	64.0	NA	14.0	0.04	NA	<0.01	NA	16.0	NA	3.80	0.14	7.2	NA	28.0	NA	23.0	310	<0.03	NA
UMA099	11/29/90	<0.005	NA	252.3775	<0.03	NA	61.0	NA	6.3	<0.04	NA	<0.01	NA	15.0	NA	3.50	0.07	5.2	NA	16.0	NA	17.0	280	<0.03	NA
UMA099	06/23/92	<0.005	NA	227.9932	NA	<0.05	57.0	56.0	6.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	3.50	0.08	5.2	5.3	14.0	14.0	17.0	270	<0.03	<0.03
UMA100	11/29/90	<0.005	NA	263.3504	0.03	NA	64.0	NA	13.0	<0.04	NA	<0.01	NA	15.0	NA	1.70	0.07	5.1	NA	22.0	NA	20.0	290	<0.03	NA
UMA100	06/24/92	<0.005	NA	236.5277	NA	0.05	57.0	59.0	11.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.50	0.08	4.9	5.1	20.0	20.0	17.0	280	<0.03	<0.03
UMA100	06/24/92	0.005	NA	235.3085	NA	0.05	58.0	59.0	11.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.50	0.08	4.9	5.0	20.0	20.0	17.0	280	<0.03	<0.03
UMA101	01/14/91	<0.005	NA	154.8403	<0.03	NA	24.0	NA	42.0	0.06	NA	<0.01	NA	9.5	NA	4.50	0.01	5.0	NA	58.0	NA	25.0	290	0.04	NA
UMA101	05/16/91	0.005	NA	153.6211	<0.03	NA	26.0	NA	43.0	<0.04	NA	<0.01	NA	10.0	NA	4.60	0.01	5.3	NA	59.0	NA	24.0	280	0.04	NA
UMA101	06/22/92	<0.005	NA	154.8403	NA	0.34	24.0	24.0	44.0	<0.04	<0.04	<0.01	<0.01	9.1	9.0	4.60	0.01	4.9	5.1	55.0	57.0	23.0	300	0.04	0.04
UMA102	01/14/91	0.006	NA	262.1312	0.03	NA	59.0	NA	12.0	0.06	NA	<0.01	NA	15.0	NA	3.00	0.04	6.4	NA	24.0	NA	22.0	310	<0.03	NA
UMA102	06/23/92	0.006	NA	251.1583	NA	0.07	61.0	60.0	12.0	<0.04	<0.04	<0.01	<0.01	15.0	15.0	4.00	0.04	6.6	6.5	25.0	24.0	26.0	310	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA103	01/14/91	0.014	NA	390.1487	0.04	NA	74.0	NA	36.0	<0.04	NA	0.01	NA	52.0	NA	12.00	0.03	6.9	NA	48.0	NA	67.0	540	0.04	NA
UMA103	10/01/91	0.012	NA	310.8998	<0.03	NA	66.0	67.0	36.0	<0.04	<0.04	<0.01	<0.01	45.0	45.0	17.00	0.02	6.6	5.9	40.0	38.0	62.0	510	0.04	NA
UMA103	11/19/91	0.012	0.012	288.9539	<0.03	NA	64.0	62.0	31.0	<0.04	<0.04	<0.01	<0.01	43.0	42.0	21.00	0.02	6.1	6.2	39.0	37.0	60.0	500	0.04	0.04
UMA103	01/15/92	0.012	0.011	269.4465	<0.03	NA	67.0	66.0	30.0	<0.04	<0.04	<0.01	<0.01	44.0	43.0	23.00	0.11	6.5	6.4	40.0	39.0	59.0	520	0.04	0.04
UMA103	03/12/92	0.014	NA	280.4194	<0.03	NA	62.0	59.0	29.0	<0.04	<0.04	<0.01	<0.01	41.0	39.0	24.00	0.02	6.0	5.7	34.0	34.0	59.0	490	0.04	0.03
UMA103	05/21/92	0.012	0.011	275.5426	<0.03	NA	67.0	67.0	29.0	<0.04	<0.04	<0.01	<0.01	44.0	43.0	23.00	0.02	6.0	6.8	37.0	34.0	57.0	500	0.04	0.04
UMA103	05/21/92	0.012	0.012	276.7618	<0.03	NA	68.0	65.0	28.0	<0.04	<0.04	<0.01	<0.01	46.0	43.0	23.00	0.02	6.3	6.8	37.0	37.0	58.0	500	0.04	0.04
UMA103	06/25/92	0.012	NA	277.9810	NA	0.15	66.0	62.0	27.0	<0.04	<0.04	<0.01	<0.01	43.0	41.0	24.00	0.02	6.4	6.1	36.0	36.0	59.0	490	0.03	0.03
UMA103	07/14/92	0.012	NA	271.8849	<0.03	NA	62.0	63.0	29.0	<0.04	0.54	<0.01	<0.01	41.0	41.0	21.00	0.03	6.3	6.4	33.0	34.0	58.0	500	0.04	NA
UMA103	09/22/92	0.014	NA	292.6116	0.04	NA	69.0	66.0	28.0	<0.04	<0.04	<0.01	<0.01	45.0	42.0	22.00	0.03	7.4	7.4	39.0	36.0	56.0	520	0.03	0.04
UMA103	11/17/92	0.016	0.015	280.4194	<0.03	NA	69.0	68.0	31.0	<0.04	<0.04	<0.01	<0.01	44.0	43.0	22.00	0.03	7.1	7.0	37.0	37.0	66.0	500	0.05	0.05
UMA103	11/17/92	0.014	0.014	282.8578	<0.03	NA	69.0	71.0	32.0	<0.04	<0.04	<0.01	<0.01	43.0	45.0	22.00	0.03	7.1	7.9	36.0	36.0	66.0	500	0.04	0.05
UMA103	01/12/93	0.016	0.015	277.9810	<0.03	NA	67.0	67.0	29.0	<0.04	<0.04	<0.01	<0.01	43.0	42.0	23.00	0.02	8.1	8.0	34.0	34.0	62.0	510	0.04	0.05
UMA103	03/23/93	0.014	0.014	274.3233	<0.03	NA	65.0	62.0	29.0	<0.04	<0.04	<0.01	<0.01	43.0	42.0	23.00	0.03	7.5	7.2	35.0	33.0	60.0	530	0.03	0.03
UMA104	01/15/91	0.010	NA	192.6359	<0.03	NA	38.0	NA	6.2	0.31	NA	0.15	NA	9.5	NA	<0.02	0.15	6.3	NA	17.0	NA	10.0	200	<0.03	NA
UMA104	06/23/92	0.009	NA	212.1434	NA	<0.05	53.0	53.0	9.7	<0.04	<0.04	0.10	0.11	11.0	11.0	1.40	0.06	6.7	6.9	15.0	15.0	20.0	260	<0.03	<0.03
UMA105	01/15/91	0.009	NA	237.7469	<0.03	NA	45.0	NA	9.1	1.10	NA	0.30	NA	14.0	NA	<0.02	0.44	7.6	NA	20.0	NA	11.0	260	<0.03	NA
UMA105	01/15/91	0.009	NA	240.1853	<0.03	NA	45.0	NA	9.2	1.10	NA	0.30	NA	14.0	NA	<0.02	0.45	7.8	NA	20.0	NA	11.0	260	<0.03	NA
UMA106	01/15/91	0.010	NA	308.4614	0.04	NA	39.0	NA	14.0	<0.04	NA	<0.01	NA	22.0	NA	1.50	0.05	4.7	NA	58.0	NA	29.0	340	<0.03	NA
UMA106	09/30/91	0.011	NA	309.6806	0.05	NA	37.0	37.0	13.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	0.80	0.05	4.2	4.4	53.0	51.0	14.0	320	<0.03	NA
UMA106	11/21/91	0.010	0.010	315.7766	0.06	NA	41.0	39.0	13.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	1.10	0.05	4.9	4.6	57.0	56.0	13.0	330	<0.03	<0.03
UMA106	03/10/92	0.010	NA	327.9688	0.04	NA	37.0	37.0	13.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	0.47	0.06	4.9	5.0	53.0	54.0	17.0	320	<0.03	<0.03
UMA106	05/19/92	0.013	0.013	248.7198	0.04	NA	27.0	28.0	12.0	<0.04	<0.04	<0.01	<0.01	15.0	15.0	0.63	0.06	4.1	4.2	45.0	46.0	14.0	280	0.04	0.03
UMA106	05/19/92	0.013	0.013	249.9390	0.04	NA	28.0	28.0	12.0	<0.04	<0.04	<0.01	<0.01	16.0	15.0	0.06	0.05	4.1	4.3	46.0	46.0	14.0	280	0.04	0.03
UMA106	06/23/92	0.011	NA	291.3923	NA	0.09	35.0	36.0	13.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	0.70	0.05	4.5	4.8	50.0	51.0	15.0	300	0.03	<0.03
UMA106	07/16/92	0.009	NA	284.0771	0.04	NA	34.0	32.0	14.0	<0.04	<0.04	<0.01	<0.01	19.0	17.0	0.75	0.05	4.1	3.9	50.0	48.0	14.0	310	<0.03	NA
UMA106	09/21/92	0.010	NA	292.6116	0.05	NA	36.0	36.0	14.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	0.74	0.06	4.9	5.1	50.0	50.0	11.0	310	<0.03	<0.03
UMA106	11/16/92	0.010	0.011	326.7496	0.07	NA	39.0	39.0	14.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	1.10	0.06	4.6	4.8	53.0	53.0	14.0	330	<0.03	<0.03
UMA106	01/14/93	0.011	0.011	323.0919	0.04	NA	0.1	0.2	14.0	<0.04	<0.04	<0.01	<0.01	<0.5	<0.5	0.78	0.05	0.7	1.0	140.0	140.0	19.4	390	<0.03	<0.03
UMA106	03/22/93	0.011	0.011	293.8308	0.05	NA	37.0	36.0	15.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	0.80	0.06	4.9	4.7	53.0	52.0	26.0	350	<0.03	<0.03
UMA107	01/15/91	0.012	NA	210.9242	<0.03	NA	47.0	NA	12.0	<0.04	NA	<0.01	NA	14.0	NA	1.90	0.05	4.7	NA	20.0	NA	21.0	260	0.04	NA
UMA108	01/15/91	<0.005	NA	285.2963	<0.03	NA	76.0	NA	26.0	<0.04	NA	<0.01	NA	20.0	NA	7.90	0.09	6.8	NA	40.0	NA	40.0	400	<0.03	NA
UMA109	01/15/91	0.008	NA	221.8971	<0.03	NA	54.0	NA	12.0	<0.04	NA	<0.01	NA	14.0	NA	2.80	0.09	6.2	NA	19.0	NA	17.0	260	<0.03	NA
UMA109	11/18/91	0.008	0.008	225.5547	0.05	NA	57.0	54.0	13.0	<0.04	<0.04	<0.01	<0.01	15.0	14.0	2.50	0.11	6.0	6.2	21.0	21.0	19.0	280	<0.03	<0.03
UMA109	01/13/92	0.007	0.007	219.4587	0.05	NA	50.0	50.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.40	0.09	5.7	5.4	19.0	19.0	18.0	260	<0.03	<0.03
UMA109	03/10/92	0.007	NA	224.3355	<0.03	NA	51.0	51.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.70	0.09	5.6	5.4	18.0	18.0	17.0	270	<0.03	<0.03
UMA109	06/23/92	0.008	NA	235.3085	NA	0.07	52.0	53.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	14.0	2.30	0.09	5.6	5.6	18.0	19.0	17.0	280	<0.03	<0.03
UMA109	06/23/92	0.008	NA	232.8700	NA	0.07	53.0	54.0	12.0	<0.04	<0.04	<0.01	<0.01	14.0	14.0	2.30	0.09	5.3	5.7	19.0	19.0	16.0	280	<0.03	<0.03
UMA109	07/13/92	0.008	NA	207.2665	0.05	NA	49.0	46.0	11.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.90	0.10	5.2	5.4	18.0	17.0	16.0	270	<0.03	NA
UMA109	09/21/92	0.009	NA	207.2665	0.03	NA	48.0	47.0	11.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.60	0.10	5.9	6.2	18.0	18.0	14.0	250	<0.03	<0.03
UMA109	11/16/92	0.008	0.009	219.4587	0.05	NA	51.0	50.0	13.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.10	0.10	5.4	5.2	19.0	18.0	17.0	270	<0.03	<0.03
UMA109	01/11/93	0.009	0.008	197.5128	0.05	NA	50.0	50.0	13.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.40	0.09	5.4	5.2	19.0	18.0	17.0	280	<0.03	<0.03
UMA109	03/22/93	0.007	0.008	224.3355	0.04	NA	51.0	50.0	13.0	<0.04	<0.04	<0.01	<0.01	14.0	13.0	2.60	0.10	5.5	5.2	18.0	17.0	12.0	280	<0.03	<0.03
UMA110	01/15/91	0.006	NA	370.6413	<0.03	NA	65.0	NA	13.0	<0.04	NA	<0.01	NA	40.0	NA	4.50	0.02	4.5	NA	23.0	NA	18.0	370	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA110	09/30/91	0.006	NA	399.9025	0.06	NA	72.0	66.0	17.0	<0.04	<0.04	<0.01	<0.01	44.0	41.0	6.80	0.02	4.4	3.7	21.0	19.0	22.0	440	0.03	NA
UMA110	11/21/91	0.006	0.007	391.3680	0.05	NA	73.0	72.0	14.0	<0.04	<0.04	<0.01	<0.01	44.0	42.0	5.00	0.02	4.5	4.2	22.0	22.0	21.0	430	<0.03	<0.03
UMA110	03/10/92	0.006	NA	373.0797	0.06	NA	63.0	64.0	11.0	<0.04	<0.04	<0.01	<0.01	38.0	39.0	3.70	0.02	4.2	4.5	20.0	20.0	16.0	390	<0.03	<0.03
UMA110	05/19/92	0.006	0.007	392.5872	0.04	NA	68.0	65.0	14.0	<0.04	<0.04	<0.01	<0.01	40.0	40.0	4.70	0.02	4.4	4.6	21.0	20.0	19.0	410	0.04	0.04
UMA110	06/23/92	0.006	NA	391.3680	NA	<0.05	66.0	67.0	14.0	<0.04	<0.04	<0.01	<0.01	40.0	40.0	5.40	0.01	4.1	4.4	21.0	22.0	18.0	420	0.04	0.03
UMA110	07/16/92	0.006	NA	377.9566	0.04	NA	71.0	69.0	18.0	<0.04	<0.04	<0.01	<0.01	42.0	41.0	5.90	0.02	4.4	4.4	22.0	21.0	19.0	450	0.04	NA
UMA110	09/24/92	0.006	NA	407.2178	0.05	NA	74.0	75.0	19.0	<0.04	<0.04	<0.01	<0.01	44.0	44.0	7.00	0.02	4.1	4.5	20.0	20.0	21.0	470	0.03	<0.03
UMA110	11/19/92	0.006	0.006	377.9566	0.03	NA	70.0	67.0	17.0	<0.04	<0.04	<0.01	<0.01	41.0	40.0	5.70	0.03	4.6	4.7	20.0	19.0	16.0	420	0.03	0.03
UMA110	01/14/93	0.007	0.007	374.2990	0.04	NA	66.0	66.0	14.0	<0.04	<0.04	<0.01	<0.01	39.0	39.0	4.90	0.02	4.6	4.6	20.0	20.0	15.0	410	0.03	0.03
UMA110	03/25/93	0.006	0.006	365.7644	0.04	NA	58.0	57.0	11.0	<0.04	<0.04	<0.01	<0.01	34.0	34.0	3.30	0.02	3.8	3.6	19.0	20.0	13.0	380	0.04	0.04
UMA111	01/15/91	<0.005	NA	153.6211	<0.03	NA	21.0	NA	14.0	5.10	NA	0.05	NA	7.7	NA	1.90	0.04	4.7	NA	45.0	NA	18.0	230	0.06	NA
UMA111	06/23/92	<0.005	NA	59.7415	NA	<0.05	10.0	9.9	5.4	0.30	<0.04	<0.01	<0.01	4.1	4.2	<0.02	0.05	2.4	2.4	11.0	11.0	7.9	100	<0.03	<0.03
UMA111	06/25/92	<0.005	NA	152.4019	NA	0.05	18.0	18.0	7.4	2.00	<0.04	<0.01	<0.01	6.1	6.1	0.88	0.01	4.3	4.1	38.0	39.0	12.0	220	0.06	0.06
UMA112	01/15/91	<0.005	NA	356.0107	0.04	NA	70.0	NA	8.2	<0.04	NA	<0.01	NA	25.0	NA	5.50	0.02	4.7	NA	37.0	NA	18.0	380	<0.03	NA
UMA112	10/02/91	<0.005	NA	352.3531	0.04	NA	67.0	67.0	8.0	<0.04	<0.04	<0.01	<0.01	24.0	23.0	5.00	0.02	4.6	4.6	35.0	33.0	17.0	380	<0.03	NA
UMA112	11/20/91	<0.005	<0.005	334.0649	0.03	NA	62.0	64.0	8.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	5.00	0.02	4.0	4.2	31.0	33.0	17.0	380	<0.03	0.04
UMA112	01/16/92	<0.005	<0.005	374.2990	0.08	NA	76.0	77.0	8.4	<0.04	<0.04	<0.01	<0.01	26.0	26.0	5.80	0.03	5.2	4.8	37.0	37.0	18.0	430	<0.03	<0.03
UMA112	03/11/92	<0.005	NA	357.2299	0.06	NA	69.0	66.0	7.4	<0.04	<0.04	<0.01	<0.01	24.0	23.0	5.00	0.03	4.8	4.5	34.0	34.0	17.0	400	<0.03	<0.03
UMA112	05/20/92	<0.005	<0.005	370.6413	0.06	NA	70.0	65.0	8.6	<0.04	<0.04	<0.01	<0.01	24.0	23.0	5.30	0.03	3.8	4.2	35.0	34.0	18.0	400	<0.03	<0.03
UMA112	06/24/92	<0.005	NA	348.6954	NA	0.07	69.0	64.0	8.1	<0.04	<0.04	<0.01	<0.01	24.0	22.0	5.10	0.02	4.5	4.2	34.0	32.0	17.0	390	<0.03	<0.03
UMA112	07/15/92	<0.005	NA	356.0107	0.07	NA	70.0	70.0	7.5	<0.04	<0.04	<0.01	<0.01	23.0	23.0	4.60	0.02	4.2	4.4	34.0	36.0	16.0	390	<0.03	NA
UMA112	09/23/92	<0.005	NA	366.9837	0.08	NA	72.0	69.0	8.9	<0.04	<0.04	<0.01	<0.01	24.0	23.0	5.50	0.02	4.7	4.4	34.0	34.0	17.0	410	<0.03	<0.03
UMA112	11/18/92	<0.005	<0.005	329.1880	0.05	NA	65.0	63.0	8.4	<0.04	<0.04	<0.01	<0.01	22.0	22.0	4.50	0.02	4.1	4.2	32.0	31.0	17.0	360	<0.03	<0.03
UMA112	01/13/93	<0.005	<0.005	336.5033	0.05	NA	64.0	65.0	8.0	<0.04	<0.04	<0.01	<0.01	21.0	22.0	4.40	0.02	4.2	4.4	31.0	31.0	17.0	370	<0.03	<0.03
UMA112	03/24/93	<0.005	<0.005	312.1190	0.06	NA	69.0	66.0	7.8	0.06	<0.04	<0.01	<0.01	23.0	22.0	4.40	0.02	4.2	4.5	35.0	32.0	18.0	380	<0.03	<0.03
UMA113	01/16/91	0.005	NA	286.5155	<0.03	NA	50.0	NA	12.0	0.07	NA	<0.01	NA	20.0	NA	1.90	0.03	7.8	NA	38.0	NA	25.0	320	<0.03	NA
UMA114	01/16/91	0.005	NA	298.7076	<0.03	NA	45.0	NA	11.0	0.08	NA	<0.01	NA	18.0	NA	1.40	0.02	9.3	NA	46.0	NA	26.0	330	<0.03	NA
UMA115	01/16/91	<0.005	NA	217.0202	<0.03	NA	<0.1	NA	9.4	0.09	NA	<0.01	NA	<0.5	NA	<0.02	0.24	0.6	NA	100.0	NA	17.0	260	<0.03	NA
UMA116	01/16/91	0.009	NA	315.7766	0.04	NA	67.0	NA	16.0	<0.04	NA	<0.01	NA	22.0	NA	3.10	0.06	6.8	NA	31.0	NA	23.0	350	<0.03	NA
UMA116	10/03/91	0.009	NA	314.5574	<0.03	NA	67.0	67.0	14.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	3.10	0.05	6.7	6.7	29.0	29.0	21.0	350	0.03	NA
UMA116	11/18/91	0.009	0.009	302.3653	0.06	NA	70.0	66.0	16.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	3.60	0.06	6.7	6.7	30.0	28.0	23.0	350	0.03	0.03
UMA116	01/13/92	0.008	0.008	313.3382	0.06	NA	64.0	64.0	16.0	<0.04	<0.04	<0.01	<0.01	20.0	21.0	3.70	0.06	5.9	6.1	28.0	28.0	25.0	360	0.04	0.03
UMA116	01/13/92	0.008	0.009	308.4614	0.07	NA	67.0	64.0	16.0	<0.04	<0.04	<0.01	<0.01	22.0	20.0	3.70	0.06	6.3	5.8	29.0	28.0	25.0	370	0.03	0.03
UMA116	03/10/92	0.009	NA	335.2841	0.05	NA	69.0	69.0	17.0	<0.04	<0.04	<0.01	<0.01	22.0	23.0	3.70	0.07	6.5	6.6	30.0	29.0	25.0	390	0.03	<0.03
UMA116	05/19/92	0.010	0.010	335.2841	0.06	NA	68.0	69.0	16.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	3.50	0.06	6.3	6.0	29.0	29.0	25.0	400	0.04	0.03
UMA116	06/23/92	0.009	NA	325.5304	NA	0.10	68.0	65.0	16.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	3.30	0.05	6.2	6.2	29.0	27.0	23.0	380	0.04	<0.03
UMA116	07/13/92	0.009	NA	316.9959	0.07	NA	66.0	65.0	16.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	3.00	0.06	6.2	6.2	27.0	27.0	21.0	360	0.04	NA
UMA116	09/21/92	0.009	NA	316.9959	0.04	NA	67.0	65.0	16.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	2.30	0.07	7.1	6.5	28.0	27.0	20.0	360	0.04	0.03
UMA116	11/16/92	0.010	0.010	329.1880	0.06	NA	68.0	69.0	17.0	<0.04	<0.04	<0.01	<0.01	21.0	22.0	3.20	0.06	5.9	6.0	29.0	30.0	23.0	380	0.04	<0.03
UMA116	11/16/92	0.009	0.010	325.5304	0.05	NA	68.0	67.0	17.0	<0.04	<0.04	<0.01	<0.01	21.0	21.0	3.30	0.06	6.2	5.9	29.0	29.0	23.0	380	0.04	<0.03
UMA116	01/11/93	0.011	0.010	307.2421	0.07	NA	69.0	70.0	17.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	3.20	0.07	6.5	6.5	31.0	30.0	23.0	390	0.04	0.04
UMA116	03/22/93	0.010	0.011	348.6954	0.06	NA	71.0	70.0	17.0	<0.04	<0.04	<0.01	<0.01	24.0	23.0	3.20	0.07	6.5	6.3	31.0	31.0	25.0	410	<0.03	<0.03
UMA117	01/16/91	0.009	NA	238.9661	<0.03	NA	55.0	NA	13.0	<0.04	NA	<0.01	NA	15.0	NA	2.40	0.10	5.5	NA	21.0	NA	18.0	270	<0.03	NA
UMA117	01/16/91	0.009	NA	236.5277	<0.03	NA	55.0	NA	13.0	<0.04	NA	<0.01	NA	15.0	NA	2.30	0.10	5.6	NA	22.0	NA	19.0	280	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA117	09/30/91	0.009	NA	240.1853	0.05	NA	58.0	54.0	12.0	<0.04	<0.04	<0.01	<0.01	15.0	14.0	3.00	0.10	5.3	5.2	22.0	21.0	20.0	310	<0.03	NA
UMA117	09/30/91	0.009	NA	238.9661	0.05	NA	56.0	52.0	13.0	<0.04	<0.04	<0.01	<0.01	14.0	14.0	3.30	0.10	5.3	5.2	21.0	20.0	20.0	290	<0.03	NA
UMA117	05/19/92	0.009	0.010	236.5277	0.04	NA	53.0	52.0	12.0	<0.04	<0.04	<0.01	<0.01	14.0	14.0	2.50	0.10	5.3	5.6	19.0	19.0	17.0	290	<0.03	<0.03
UMA117	06/22/92	0.007	NA	240.1853	NA	0.08	53.0	52.0	11.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.20	0.10	5.7	5.9	19.0	19.0	16.0	300	<0.03	<0.03
UMA118	01/17/91	<0.005	NA	97.5372	0.03	NA	12.0	NA	5.2	0.18	NA	<0.01	NA	1.1	NA	<0.02	0.14	5.4	NA	15.0	NA	7.3	80	<0.03	NA
UMA118	06/22/92	<0.005	NA	204.8281	NA	<0.05	37.0	35.0	6.6	0.12	0.13	0.14	0.13	14.0	14.0	0.03	0.06	6.0	5.6	17.0	17.0	13.0	240	<0.03	<0.03
UMA119	01/17/91	<0.005	NA	562.0580	0.04	NA	150.0	NA	33.0	<0.04	NA	<0.01	NA	43.0	NA	14.00	0.11	8.1	NA	32.0	NA	26.0	660	<0.03	NA
UMA119	10/03/91	<0.005	NA	398.6832	<0.03	NA	100.0	93.0	20.0	<0.04	<0.04	<0.01	<0.01	28.0	26.0	6.60	0.12	7.0	6.2	27.0	26.0	22.0	450	<0.03	NA
UMA119	11/20/91	<0.005	<0.005	490.1244	0.03	NA	130.0	130.0	31.0	<0.04	<0.04	<0.01	<0.01	36.0	35.0	12.00	0.11	7.5	7.1	29.0	29.0	29.0	590	<0.03	<0.03
UMA119	11/20/91	<0.005	<0.005	490.1244	0.03	NA	120.0	130.0	32.0	<0.04	<0.04	<0.01	<0.01	34.0	34.0	12.00	0.11	7.0	7.5	27.0	29.0	29.0	590	<0.03	<0.03
UMA119	01/15/92	<0.005	<0.005	513.2894	0.06	NA	150.0	150.0	38.0	<0.04	<0.04	<0.01	<0.01	41.0	40.0	16.00	0.11	8.5	8.2	32.0	31.0	30.0	650	<0.03	<0.03
UMA119	03/09/92	<0.005	<0.005	510.8510	0.05	NA	150.0	150.0	42.0	<0.04	<0.04	<0.01	<0.01	40.0	40.0	19.00	0.11	8.4	8.1	29.0	29.0	25.0	650	<0.03	<0.03
UMA119	05/18/92	<0.005	<0.005	431.6020	0.06	NA	120.0	110.0	33.0	<0.04	<0.04	<0.01	<0.01	33.0	33.0	14.00	0.11	6.2	6.8	28.0	26.0	28.0	550	<0.03	<0.03
UMA119	06/22/92	<0.005	NA	391.3680	NA	0.10	98.0	100.0	27.0	<0.04	<0.04	<0.01	<0.01	27.0	28.0	9.20	0.11	6.4	6.8	25.0	26.0	23.0	510	<0.03	<0.03
UMA119	07/15/92	<0.005	NA	365.7644	0.05	NA	91.0	94.0	24.0	<0.04	<0.04	<0.01	<0.01	25.0	26.0	6.70	0.11	6.4	6.5	25.0	25.0	21.0	440	<0.03	NA
UMA119	07/15/92	<0.005	NA	359.6684	0.05	NA	89.0	91.0	23.0	<0.04	<0.04	<0.01	<0.01	25.0	25.0	6.90	0.11	6.0	6.2	25.0	24.0	21.0	440	<0.03	NA
UMA119	09/23/92	0.009	NA	390.1487	0.06	NA	91.0	87.0	21.0	<0.04	<0.04	<0.01	<0.01	25.0	24.0	6.00	0.11	6.7	6.1	24.0	24.0	20.0	430	<0.03	<0.03
UMA119	11/18/92	<0.005	<0.005	436.4789	0.04	NA	110.0	110.0	29.0	<0.04	<0.04	<0.01	<0.01	31.0	31.0	12.00	0.11	7.0	7.1	28.0	27.0	25.0	530	<0.03	<0.03
UMA119	01/13/93	0.005	<0.005	459.6440	0.05	NA	130.0	130.0	37.0	<0.04	<0.04	<0.01	<0.01	34.0	35.0	16.00	0.11	7.6	7.6	28.0	28.0	31.0	600	<0.03	<0.03
UMA119	03/24/93	<0.005	<0.005	501.0973	0.05	NA	140.0	140.0	42.0	<0.04	<0.04	<0.01	<0.01	39.0	37.0	17.00	0.12	7.1	7.3	29.0	28.0	34.0	640	<0.03	<0.03
UMA120	01/17/91	<0.005	NA	152.4019	<0.03	NA	28.0	NA	4.4	<0.04	NA	<0.01	NA	9.1	NA	0.20	0.02	3.5	NA	14.0	NA	5.8	180	<0.03	NA
UMA120	06/24/92	<0.005	NA	146.3058	NA	<0.05	28.0	29.0	3.7	<0.04	<0.04	<0.01	<0.01	8.5	9.1	0.20	0.02	3.2	3.7	14.0	14.0	5.6	180	<0.03	0.03
UMA120	06/24/92	<0.005	NA	147.5250	NA	<0.05	29.0	29.0	3.7	<0.04	<0.04	<0.01	<0.01	9.1	8.8	0.20	0.02	3.6	3.7	14.0	14.0	5.2	180	<0.03	<0.03
UMA121	01/17/91	0.005	NA	349.9147	0.04	NA	<0.1	NA	12.0	<0.04	NA	<0.01	NA	<0.5	NA	2.00	0.07	<0.5	NA	150.0	NA	21.0	570	<0.03	NA
UMA121	06/22/92	0.008	NA	353.5723	NA	0.05	0.1	0.2	10.0	<0.04	<0.04	<0.01	<0.01	<0.5	<0.5	2.70	0.10	<0.5	1.8	150.0	150.0	20.0	410	<0.03	<0.03
UMA122	01/17/91	<0.005	NA	220.6779	<0.03	NA	67.0	NA	32.0	<0.04	NA	<0.01	NA	20.0	NA	7.90	0.11	4.5	NA	20.0	NA	30.0	350	<0.03	NA
UMA122	01/17/91	<0.005	NA	218.2395	<0.03	NA	66.0	NA	32.0	<0.04	NA	<0.01	NA	20.0	NA	7.90	0.12	4.3	NA	20.0	NA	31.0	340	<0.03	NA
UMA122	05/16/91	<0.005	NA	234.0892	<0.03	NA	100.0	NA	86.0	0.05	NA	<0.01	NA	31.0	NA	15.00	0.10	5.8	NA	27.0	NA	76.0	490	<0.03	NA
UMA122	08/07/91	<0.005	NA	219.4587	<0.03	NA	77.0	NA	44.0	<0.04	NA	<0.01	NA	22.0	NA	9.20	0.13	5.1	NA	21.0	NA	44.0	390	<0.03	NA
UMA122	08/07/91	<0.005	NA	219.4587	<0.03	NA	77.0	NA	45.0	0.04	NA	<0.01	NA	22.0	NA	9.10	0.12	5.0	NA	21.0	NA	40.0	400	<0.03	NA
UMA122	10/02/91	<0.005	NA	215.8010	<0.03	NA	63.0	61.0	26.0	<0.04	<0.04	<0.01	<0.01	18.0	18.0	8.20	0.13	5.0	4.6	21.0	21.0	32.0	330	<0.03	NA
UMA122	10/02/91	<0.005	NA	214.5818	<0.03	NA	65.0	62.0	27.0	<0.04	<0.04	<0.01	<0.01	18.0	18.0	8.00	0.14	4.8	5.0	21.0	20.0	32.0	330	<0.03	NA
UMA122	11/20/91	<0.005	<0.005	209.7050	<0.03	NA	59.0	58.0	23.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	6.90	0.12	4.2	4.4	20.0	20.0	38.0	330	<0.03	<0.03
UMA122	03/09/92	<0.005	<0.005	221.8971	<0.03	NA	87.0	84.0	53.0	<0.04	<0.04	<0.01	<0.01	24.0	24.0	13.00	0.12	5.8	5.2	22.0	22.0	55.0	450	<0.03	<0.03
UMA122	05/18/92	<0.005	<0.005	235.3085	<0.03	NA	99.0	95.0	70.0	<0.04	<0.04	<0.01	<0.01	29.0	28.0	NA	NA	5.2	5.2	26.0	25.0	68.0	520	<0.03	<0.03
UMA122	06/22/92	<0.005	NA	245.0622	NA	0.41	94.0	92.0	59.0	0.04	<0.04	<0.01	<0.01	27.0	26.0	12.00	0.11	5.9	5.9	25.0	26.0	57.0	510	<0.03	<0.03
UMA122	07/15/92	<0.005	NA	237.7469	0.03	NA	78.0	78.0	44.0	0.04	<0.04	<0.01	<0.01	23.0	22.0	9.70	0.11	4.8	4.5	24.0	24.0	48.0	420	<0.03	NA
UMA122	09/23/92	<0.005	NA	227.9932	0.04	NA	67.0	64.0	28.0	<0.04	<0.04	<0.01	<0.01	19.0	18.0	7.20	0.13	4.9	4.3	20.0	20.0	32.0	350	<0.03	<0.03
UMA122	11/20/92	<0.005	<0.005	223.1163	<0.03	NA	74.0	76.0	37.0	0.11	<0.04	<0.01	<0.01	22.0	22.0	10.00	0.12	5.0	5.0	22.0	21.0	40.0	390	<0.03	<0.03
UMA122	11/20/92	<0.005	<0.005	219.4587	<0.03	NA	76.0	74.0	39.0	0.11	<0.04	0.01	<0.01	22.0	21.0	10.00	0.12	4.7	5.1	22.0	21.0	43.0	390	<0.03	<0.03
UMA122	01/13/93	<0.005	<0.005	219.4587	<0.03	NA	88.0	89.0	58.0	0.07	<0.04	0.01	0.01	25.0	25.0	14.00	0.09	5.8	5.4	22.0	22.0	54.0	470	<0.03	<0.03
UMA122	03/24/93	<0.005	<0.005	217.0202	<0.03	NA	110.0	120.0	100.0	0.09	<0.04	<0.01	<0.01	31.0	33.0	20.00	0.10	5.9	5.9	24.0	25.0	80.0	630	<0.03	<0.03
UMA122	03/24/93	<0.005	<0.005	220.6779	<0.03	NA	120.0	110.0	100.0	0.08	<0.04	<0.01	<0.01	32.0	33.0	20.00	0.10	5.8	6.2	24.0	25.0	80.0	650	<0.03	<0.03
UMA123	01/17/91	<0.005	NA	190.1975	<0.03	NA	65.0	NA	45.0	0.08	NA	<0.01	NA	21.0	NA	6.40	0.08	4.3	NA	23.0	NA	47.0	350	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA123	06/22/92	<0.005	NA	206.0473	NA	0.42	75.0	75.0	55.0	<0.04	<0.04	<0.01	<0.01	23.0	23.0	10.00	0.08	5.1	5.3	24.0	24.0	54.0	440	<0.03	<0.03
UMA124	01/17/91	<0.005	NA	267.0080	<0.03	NA	60.0	NA	29.0	0.04	NA	<0.01	NA	27.0	NA	11.00	0.01	4.6	NA	45.0	NA	47.0	420	0.04	NA
UMA124	06/22/92	<0.005	NA	258.4735	NA	0.17	52.0	52.0	22.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	10.00	0.02	5.3	5.5	47.0	46.0	37.0	400	0.05	0.05
UMA125	01/17/91	0.005	NA	315.7766	<0.03	NA	66.0	NA	20.0	<0.04	NA	<0.01	NA	42.0	NA	19.00	0.02	4.0	NA	30.0	NA	38.0	400	0.03	NA
UMA125	10/03/91	0.005	NA	319.4343	<0.03	NA	82.0	80.0	24.0	<0.04	<0.04	<0.01	<0.01	53.0	53.0	29.00	0.02	5.5	5.3	30.0	30.0	54.0	560	0.04	NA
UMA125	11/21/91	<0.005	0.005	316.9959	0.04	NA	77.0	74.0	23.0	<0.04	<0.04	<0.01	<0.01	49.0	46.0	26.00	0.02	5.1	4.8	32.0	31.0	49.0	530	0.03	0.03
UMA125	03/10/92	0.005	NA	314.5574	0.04	NA	68.0	68.0	19.0	<0.04	<0.04	<0.01	<0.01	44.0	44.0	21.00	0.02	4.1	4.5	27.0	27.0	42.0	480	<0.03	<0.03
UMA125	05/19/92	0.005	0.005	304.8037	0.03	NA	67.0	64.0	21.0	<0.04	<0.04	<0.01	<0.01	42.0	43.0	17.00	0.02	4.7	4.7	27.0	26.0	44.0	470	<0.03	<0.03
UMA125	06/23/92	0.005	NA	318.2151	NA	0.09	74.0	77.0	38.0	<0.04	<0.04	<0.01	<0.01	48.0	49.0	24.00	0.01	4.8	4.7	27.0	28.0	51.0	530	0.04	<0.03
UMA125	07/16/92	<0.005	NA	347.4762	0.04	NA	220.0	220.0	490.0	<0.04	<0.04	<0.01	<0.01	140.0	130.0	27.00	0.02	6.7	6.8	30.0	29.0	58.0	1600	<0.03	NA
UMA125	09/24/92	<0.005	NA	368.2029	0.05	NA	84.0	86.0	30.0	<0.04	<0.04	<0.01	<0.01	53.0	54.0	17.00	0.02	5.2	5.5	30.0	31.0	75.0	580	0.04	0.03
UMA125	09/24/92	<0.005	NA	376.7374	0.05	NA	84.0	84.0	32.0	<0.04	<0.04	<0.01	<0.01	52.0	53.0	17.00	0.02	4.9	4.9	30.0	30.0	77.0	560	0.03	0.03
UMA125	11/19/92	<0.005	<0.005	343.8186	<0.03	NA	81.0	80.0	21.0	<0.04	<0.04	<0.01	<0.01	51.0	50.0	19.00	0.02	5.5	5.7	30.0	30.0	74.0	550	0.04	0.03
UMA125	03/25/93	0.006	0.006	313.3382	0.03	NA	63.0	57.0	17.0	<0.04	<0.04	<0.01	<0.01	41.0	37.0	13.00	0.02	4.3	4.0	24.0	25.0	43.0	430	0.04	0.04
UMA126	01/17/91	<0.005	NA	202.3897	<0.03	NA	13.0	NA	12.0	0.04	NA	0.03	NA	3.5	NA	0.02	<0.01	12.0	NA	71.0	NA	31.0	290	<0.03	NA
UMA126	06/24/92	<0.005	NA	195.0744	NA	0.08	13.0	13.0	12.0	<0.04	<0.04	0.03	0.03	3.5	3.1	0.03	0.01	13.0	13.0	74.0	73.0	34.0	280	<0.03	<0.03
UMA127	01/28/91	<0.005	NA	176.7861	0.04	NA	17.0	NA	13.0	<0.04	NA	0.02	NA	5.8	NA	0.32	<0.01	9.0	NA	43.0	NA	2.9	230	<0.03	NA
UMA128	01/28/91	0.006	NA	175.5669	<0.03	NA	100.0	NA	45.0	0.29	NA	<0.01	NA	40.0	NA	18.00	0.03	5.0	NA	41.0	NA	50.0	570	0.05	NA
UMA129	01/28/91	0.006	NA	251.1583	<0.03	NA	48.0	NA	55.0	0.23	NA	<0.01	NA	28.0	NA	11.00	0.01	9.3	NA	69.0	NA	42.0	460	<0.03	NA
UMA129	06/23/92	0.007	NA	259.6928	NA	0.36	50.0	52.0	52.0	<0.04	<0.04	<0.01	<0.01	26.0	27.0	12.00	0.01	9.0	9.4	65.0	69.0	47.0	460	<0.03	<0.03
UMA130	01/28/91	0.008	NA	230.4316	<0.03	NA	35.0	NA	39.0	<0.04	NA	<0.01	NA	19.0	NA	3.60	0.01	7.8	NA	63.0	NA	40.0	360	0.04	NA
UMA131	01/28/91	0.009	NA	275.5426	<0.03	NA	32.0	NA	23.0	<0.04	NA	<0.01	NA	26.0	NA	7.50	0.01	5.2	NA	66.0	NA	33.0	380	0.04	NA
UMA132	01/29/91	<0.005	NA	264.5696	<0.03	NA	55.0	NA	9.2	<0.04	NA	<0.01	NA	18.0	NA	4.50	0.09	4.8	NA	21.0	NA	19.0	310	<0.03	NA
UMA133	01/29/91	0.005	NA	348.6954	<0.03	NA	100.0	NA	55.0	<0.04	NA	<0.01	NA	32.0	NA	20.00	0.03	6.2	NA	55.0	NA	59.0	610	<0.03	NA
UMA133	10/02/91	<0.005	NA	347.4762	<0.03	NA	100.0	100.0	60.0	<0.04	<0.04	<0.01	<0.01	32.0	32.0	21.00	0.03	6.0	6.4	53.0	54.0	61.0	620	<0.03	NA
UMA133	11/20/91	0.005	0.005	360.8876	<0.03	NA	110.0	110.0	59.0	<0.04	<0.04	<0.01	<0.01	30.0	29.0	21.00	0.04	6.1	6.2	54.0	55.0	65.0	630	<0.03	<0.03
UMA133	01/16/92	0.005	<0.005	356.0107	<0.03	NA	110.0	110.0	54.0	0.10	<0.04	<0.01	<0.01	32.0	32.0	20.00	0.04	6.4	6.3	59.0	59.0	64.0	630	<0.03	<0.03
UMA133	03/11/92	0.006	NA	352.3531	<0.03	NA	100.0	97.0	53.0	<0.04	<0.04	<0.01	<0.01	31.0	29.0	20.00	0.10	6.2	6.0	55.0	53.0	62.0	610	<0.03	0.03
UMA133	05/20/92	<0.005	<0.005	346.2570	<0.03	NA	97.0	99.0	49.0	<0.04	<0.04	<0.01	<0.01	29.0	30.0	17.00	0.02	4.4	5.2	52.0	54.0	57.0	590	0.03	0.03
UMA133	06/24/92	<0.005	NA	349.9147	NA	0.21	100.0	95.0	51.0	<0.04	<0.04	<0.01	<0.01	30.0	28.0	18.00	0.03	5.8	5.7	54.0	51.0	60.0	600	<0.03	<0.03
UMA133	07/15/92	<0.005	NA	341.3802	<0.03	NA	100.0	99.0	52.0	<0.04	<0.04	<0.01	<0.01	29.0	29.0	17.00	0.03	5.7	5.7	51.0	53.0	61.0	610	0.03	NA
UMA133	09/23/92	<0.005	NA	353.5723	<0.03	NA	100.0	100.0	56.0	<0.04	<0.04	<0.01	<0.01	30.0	30.0	18.00	0.04	6.1	6.1	52.0	52.0	64.0	610	<0.03	<0.03
UMA133	11/18/92	<0.005	0.006	363.3260	<0.03	NA	100.0	94.0	53.0	<0.04	<0.04	<0.01	<0.01	31.0	27.0	18.00	0.04	6.0	5.3	54.0	47.0	65.0	600	0.03	0.03
UMA133	01/13/93	0.006	0.005	360.8876	<0.03	NA	110.0	110.0	57.0	<0.04	<0.04	<0.01	<0.01	30.0	30.0	20.00	0.04	5.9	6.4	53.0	53.0	64.0	630	0.04	0.03
UMA133	03/24/93	0.005	0.005	353.5723	<0.03	NA	100.0	100.0	53.0	<0.04	<0.04	<0.01	<0.01	30.0	29.0	19.00	0.04	6.1	6.0	53.0	51.0	63.0	610	<0.03	<0.03
UMA134	01/29/91	<0.005	NA	535.2353	0.05	NA	160.0	NA	46.0	<0.04	NA	<0.01	NA	41.0	NA	25.00	0.04	8.1	NA	39.0	NA	38.0	720	<0.03	NA
UMA134	06/23/92	<0.005	NA	524.2624	NA	0.19	150.0	150.0	45.0	<0.04	<0.04	<0.01	<0.01	37.0	37.0	24.00	0.05	7.3	7.2	35.0	34.0	41.0	690	<0.03	<0.03
UMA134	06/23/92	<0.005	NA	527.9200	NA	0.20	150.0	150.0	45.0	<0.04	<0.04	<0.01	<0.01	37.0	38.0	24.00	0.06	7.4	7.3	35.0	35.0	38.0	690	<0.03	<0.03
UMA135	01/29/91	<0.005	NA	NA	0.05	NA	160.0	NA	50.0	<0.04	NA	<0.01	NA	43.0	NA	25.00	0.04	8.7	NA	38.0	NA	36.0	730	<0.03	NA
UMA135	01/29/91	<0.005	NA	546.2082	0.05	NA	160.0	NA	53.0	<0.04	NA	<0.01	NA	43.0	NA	25.00	0.04	8.2	NA	37.0	NA	38.0	740	<0.03	NA
UMA136	01/29/91	<0.005	NA	286.5155	<0.03	NA	75.0	NA	15.0	<0.04	NA	<0.01	NA	24.0	NA	5.60	0.08	5.6	NA	31.0	NA	23.0	400	<0.03	NA
UMA136	06/23/92	<0.005	NA	298.7076	NA	0.06	71.0	70.0	15.0	<0.04	<0.04	<0.01	<0.01	19.0	19.0	6.70	0.09	5.0	4.5	22.0	22.0	20.0	360	<0.03	<0.03
UMA137	01/29/91	<0.005	NA	152.4019	<0.03	NA	51.0	NA	32.0	<0.04	NA	<0.01	NA	17.0	NA	4.40	0.11	4.4	NA	24.0	NA	32.0	320	<0.03	NA
UMA138	01/29/91	<0.005	NA	204.8281	<0.03	NA	26.0	NA	15.0	0.10	NA	0.06	NA	13.0	NA	0.30	0.02	4.5	NA	50.0	NA	29.0	270	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA138	06/24/92	<0.005	NA	237.7469	NA	0.07	30.0	30.0	16.0	0.05	0.05	0.07	0.07	14.0	14.0	0.04	0.02	4.2	4.3	48.0	50.0	29.0	280	<0.03	<0.03
UMA139	01/29/91	0.006	NA	273.1041	<0.03	NA	41.0	NA	9.0	<0.04	NA	<0.01	NA	17.0	NA	1.90	0.04	5.2	NA	41.0	NA	19.0	310	0.05	NA
UMA140	01/29/91	<0.005	NA	365.7644	0.04	NA	98.0	NA	73.0	<0.04	NA	<0.01	NA	40.0	NA	16.00	<0.01	4.5	NA	43.0	NA	35.0	540	<0.03	NA
UMA141	01/29/91	0.009	NA	259.6928	<0.03	NA	47.0	NA	8.6	<0.04	NA	<0.01	NA	21.0	NA	4.60	0.07	5.4	NA	23.0	NA	21.0	310	0.04	NA
UMA142	01/29/91	0.010	NA	327.9688	0.04	NA	72.0	NA	10.0	<0.04	NA	<0.01	NA	22.0	NA	7.80	0.32	5.4	NA	28.0	NA	25.0	400	<0.03	NA
UMA142	01/29/91	0.010	NA	329.1880	0.04	NA	73.0	NA	7.8	0.06	NA	<0.01	NA	22.0	NA	7.80	0.32	5.4	NA	28.0	NA	24.0	390	<0.03	NA
UMA143	01/29/91	0.009	NA	325.5304	0.03	NA	73.0	NA	9.7	0.05	NA	<0.01	NA	21.0	NA	7.60	0.25	5.1	NA	26.0	NA	25.0	380	0.03	NA
UMA144	01/30/91	0.009	NA	343.8186	0.06	NA	92.0	NA	43.0	0.36	NA	<0.01	NA	24.0	NA	18.00	0.10	9.5	NA	79.0	NA	79.0	590	<0.03	NA
UMA144	08/06/91	0.008	NA	269.4465	0.04	NA	64.0	NA	22.0	0.04	NA	<0.01	NA	16.0	NA	8.10	0.18	8.0	NA	41.0	NA	43.0	400	<0.03	NA
UMA144	10/01/91	0.008	NA	206.0473	<0.03	NA	44.0	42.0	12.0	<0.04	<0.04	<0.01	<0.01	11.0	11.0	2.90	<0.01	7.1	6.8	31.0	29.0	21.0	270	<0.03	NA
UMA144	11/19/91	0.008	0.008	321.8727	<0.03	NA	88.0	80.0	40.0	0.42	<0.04	<0.01	<0.01	22.0	21.0	18.00	0.12	9.1	8.0	70.0	64.0	79.0	560	<0.03	<0.03
UMA144	01/15/92	0.007	0.007	325.5304	0.04	NA	100.0	96.0	46.0	0.06	<0.04	<0.01	<0.01	26.0	26.0	20.00	0.10	9.8	9.0	84.0	80.0	55.0	640	<0.03	<0.03
UMA144	03/12/92	0.009	NA	340.1609	<0.03	NA	96.0	92.0	50.0	0.10	<0.04	<0.01	<0.01	26.0	25.0	21.00	0.09	9.2	8.7	78.0	78.0	98.0	660	<0.03	<0.03
UMA144	05/21/92	0.006	0.005	238.9661	<0.03	NA	52.0	55.0	14.0	0.07	<0.04	<0.01	<0.01	13.0	14.0	4.10	0.15	7.2	6.9	26.0	27.0	22.0	290	<0.03	<0.03
UMA144	06/25/92	0.006	NA	227.9932	NA	0.05	46.0	44.0	12.0	0.09	<0.04	<0.01	<0.01	12.0	11.0	2.10	0.13	6.7	6.4	30.0	30.0	20.0	270	<0.03	<0.03
UMA144	07/14/92	0.006	NA	247.5006	0.03	NA	55.0	55.0	19.0	0.14	<0.04	<0.01	<0.01	14.0	14.0	4.90	0.14	7.5	7.7	37.0	38.0	31.0	340	<0.03	NA
UMA144	09/22/92	0.006	NA	254.8159	0.04	NA	60.0	57.0	19.0	0.05	<0.04	<0.01	<0.01	15.0	14.0	3.40	0.12	8.3	8.3	38.0	35.0	30.0	340	<0.03	<0.03
UMA144	11/17/92	0.008	0.009	323.0919	0.03	NA	92.0	93.0	44.0	0.21	<0.04	<0.01	<0.01	23.0	24.0	18.00	0.11	8.4	9.1	75.0	74.0	85.0	580	<0.03	<0.03
UMA144	01/12/93	0.009	0.009	347.4762	0.04	NA	98.0	100.0	54.0	0.07	<0.04	<0.01	<0.01	26.0	26.0	20.00	0.10	9.8	9.7	78.0	78.0	100.0	660	<0.03	<0.03
UMA144	03/23/93	0.009	0.009	343.8186	0.04	NA	97.0	96.0	58.0	<0.04	<0.04	<0.01	<0.01	27.0	26.0	22.00	0.10	9.5	9.2	88.0	85.0	110.0	720	<0.03	<0.03
UMA145	01/30/91	<0.005	NA	246.2814	0.08	NA	21.0	NA	23.0	<0.04	NA	<0.01	NA	8.6	NA	1.80	0.05	11.0	NA	74.0	NA	18.0	310	<0.03	NA
UMA146	01/30/91	<0.005	NA	197.5128	0.08	NA	5.5	NA	17.0	0.06	NA	0.03	NA	1.9	NA	<0.02	0.04	9.2	NA	80.0	NA	0.5	240	<0.03	NA
UMA147	01/30/91	<0.005	NA	252.3775	0.07	NA	12.0	NA	22.0	0.04	NA	0.04	NA	5.7	NA	0.02	0.03	10.0	NA	99.0	NA	23.0	320	<0.03	NA
UMA148	01/30/91	0.007	NA	263.3504	0.04	NA	88.0	NA	25.0	0.05	NA	<0.01	NA	26.0	NA	18.00	0.06	7.6	NA	37.0	NA	55.0	450	<0.03	NA
UMA149	01/31/91	0.013	NA	304.8037	0.05	NA	68.0	NA	17.0	0.09	NA	<0.01	NA	22.0	NA	4.50	0.05	7.7	NA	38.0	NA	25.0	370	0.04	NA
UMA150	01/31/91	0.007	NA	431.6020	0.06	NA	93.0	NA	11.0	<0.04	NA	<0.01	NA	25.0	NA	0.60	0.06	6.7	NA	36.0	NA	10.0	400	<0.03	NA
UMA151	01/31/91	<0.005	NA	269.4465	0.03	NA	50.0	NA	15.0	0.20	NA	0.04	NA	23.0	NA	4.30	0.03	5.7	NA	39.0	NA	30.0	340	<0.03	NA
UMA152	01/31/91	0.005	NA	267.0080	0.04	NA	64.0	NA	13.0	<0.04	NA	<0.01	NA	26.0	NA	12.00	0.05	4.5	NA	32.0	NA	34.0	380	<0.03	NA
UMA152	01/31/91	0.006	NA	268.2273	0.04	NA	65.0	NA	12.0	0.09	NA	<0.01	NA	27.0	NA	12.00	0.05	4.5	NA	32.0	NA	34.0	380	<0.03	NA
UMA153	01/31/91	0.006	NA	227.9932	<0.03	NA	68.0	NA	43.0	<0.04	NA	<0.01	NA	37.0	NA	31.00	0.02	11.0	NA	52.0	NA	54.0	530	0.03	NA
UMA154	01/31/91	0.009	NA	262.1312	0.06	NA	69.0	NA	22.0	<0.04	NA	<0.01	NA	18.0	NA	12.00	0.05	8.3	NA	32.0	NA	29.0	380	<0.03	NA
UMA155	01/31/91	<0.005	NA	325.5304	<0.03	NA	53.0	NA	6.7	<0.04	NA	<0.01	NA	28.0	NA	7.80	0.03	4.8	NA	38.0	NA	17.0	360	0.05	NA
UMA156	01/31/91	0.006	NA	356.0107	0.04	NA	97.0	NA	18.0	0.04	NA	<0.01	NA	30.0	NA	18.00	0.04	5.9	NA	36.0	NA	34.0	490	<0.03	NA
UMA156	10/03/91	0.006	NA	374.2990	<0.03	NA	92.0	93.0	15.0	<0.04	<0.04	<0.01	<0.01	28.0	28.0	13.00	0.04	5.6	6.2	33.0	35.0	30.0	470	<0.03	NA
UMA156	10/03/91	0.007	NA	371.8605	<0.03	NA	94.0	90.0	15.0	<0.04	<0.04	<0.01	<0.01	28.0	27.0	13.00	0.04	6.0	5.5	34.0	33.0	30.0	470	<0.03	NA
UMA156	11/20/91	0.005	0.006	338.9417	<0.03	NA	92.0	89.0	19.0	<0.04	<0.04	<0.01	<0.01	28.0	26.0	18.00	0.04	5.3	5.2	38.0	38.0	37.0	510	<0.03	<0.03
UMA156	03/11/92	0.006	NA	341.3802	<0.03	NA	89.0	85.0	23.0	0.05	<0.04	<0.01	<0.01	27.0	27.0	18.00	0.05	5.5	5.4	38.0	37.0	30.0	510	<0.03	<0.03
UMA156	05/21/92	0.006	0.006	358.4492	0.04	NA	87.0	93.0	11.0	<0.04	<0.04	<0.01	<0.01	26.0	28.0	14.00	0.04	4.9	5.6	31.0	33.0	43.0	500	<0.03	<0.03
UMA156	06/23/92	0.007	NA	363.3260	NA	<0.05	84.0	82.0	8.8	<0.04	<0.04	<0.01	<0.01	24.0	24.0	7.90	0.04	5.0	4.9	25.0	25.0	27.0	430	<0.03	<0.03
UMA156	07/16/92	0.006	NA	373.0797	0.04	NA	90.0	90.0	10.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	10.00	0.04	4.9	5.2	24.0	24.0	25.0	460	<0.03	NA
UMA156	09/24/92	0.006	NA	346.2570	0.05	NA	92.0	96.0	14.0	<0.04	<0.04	<0.01	<0.01	28.0	28.0	16.00	0.04	5.2	5.4	22.0	24.0	34.0	460	<0.03	<0.03
UMA156	11/19/92	0.006	0.005	347.4762	0.03	NA	100.0	97.0	20.0	0.08	<0.04	<0.01	<0.01	28.0	28.0	19.00	0.04	5.7	5.8	32.0	32.0	41.0	510	<0.03	<0.03
UMA156	01/14/93	0.006	0.006	357.2299	0.04	NA	95.0	96.0	20.0	0.11	<0.04	<0.01	<0.01	28.0	28.0	18.00	0.05	5.9	5.5	33.0	33.0	37.0	530	<0.03	<0.03
UMA156	03/25/93	0.006	0.006	352.3531	0.04	NA	92.0	93.0	23.0	0.04	<0.04	<0.01	<0.01	28.0	28.0	19.00	0.05	4.8	5.2	35.0	35.0	39.0	530	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA157	01/31/91	<0.005	NA	199.9512	<0.03	NA	38.0	NA	32.0	0.20	NA	<0.01	NA	16.0	NA	5.80	0.20	4.3	NA	48.0	NA	18.0	310	0.03	NA
UMA158	01/31/91	<0.005	NA	276.7618	0.05	NA	100.0	NA	29.0	<0.04	NA	<0.01	NA	20.0	NA	7.80	0.16	8.0	NA	35.0	NA	81.0	450	<0.03	NA
UMA159	05/13/91	0.009	NA	345.0378	0.10	NA	110.0	NA	46.0	<0.04	NA	<0.01	NA	34.0	NA	35.00	0.03	11.0	NA	52.0	NA	98.0	580	<0.03	NA
UMA159	06/22/92	0.008	NA	269.4465	NA	0.12	110.0	110.0	44.0	<0.04	<0.04	<0.01	<0.01	33.0	33.0	30.00	0.03	11.0	11.0	52.0	50.0	90.0	630	<0.03	<0.03
UMA160	05/13/91	<0.005	NA	274.3233	0.07	NA	7.8	NA	17.0	<0.04	NA	0.02	NA	3.6	NA	0.02	0.03	8.1	NA	80.0	NA	0.8	260	<0.03	NA
UMA160	11/19/91	<0.005	<0.005	210.9242	0.05	NA	7.5	7.0	17.0	<0.04	<0.04	0.02	<0.01	3.3	3.2	0.06	0.04	7.9	7.4	74.0	71.0	1.3	260	<0.03	<0.03
UMA160	01/14/92	<0.005	<0.005	202.3897	0.07	NA	7.4	7.4	17.0	<0.04	<0.04	0.02	0.02	3.6	3.4	<0.02	0.04	7.9	7.7	77.0	78.0	0.6	270	<0.03	<0.03
UMA160	03/12/92	<0.005	NA	215.8010	0.04	NA	7.1	7.3	16.0	<0.04	<0.04	0.02	0.02	3.3	3.4	<0.02	0.04	7.6	7.7	70.0	73.0	0.9	260	<0.03	<0.03
UMA160	03/12/92	<0.005	NA	217.0202	0.04	NA	7.0	6.9	16.0	<0.04	<0.04	0.02	0.02	3.3	3.1	0.04	0.04	7.5	7.7	68.0	68.0	0.9	260	<0.03	<0.03
UMA160	05/21/92	<0.005	<0.005	213.3626	0.06	NA	6.9	7.1	17.0	<0.04	<0.04	0.02	0.02	3.0	3.2	<0.02	0.04	7.4	7.6	72.0	73.0	0.8	260	<0.03	<0.03
UMA160	06/22/92	<0.005	NA	202.3897	NA	0.16	7.8	7.3	17.0	<0.04	<0.04	0.02	0.02	3.5	3.3	0.02	0.04	8.3	7.5	80.0	75.0	0.9	280	<0.03	<0.03
UMA160	07/13/92	<0.005	NA	214.5818	0.08	NA	7.0	7.1	18.0	<0.04	<0.04	0.02	0.02	3.2	3.1	0.02	0.04	7.8	7.7	72.0	72.0	0.8	270	<0.03	NA
UMA160	09/22/92	<0.005	NA	213.3626	0.08	NA	7.3	7.3	17.0	<0.04	<0.04	0.02	0.02	3.4	3.3	<0.02	0.04	7.9	7.7	80.0	77.0	<0.05	270	<0.03	<0.03
UMA160	11/17/92	<0.005	<0.005	213.3626	0.06	NA	7.3	7.4	17.0	<0.04	<0.04	0.02	0.02	3.1	3.2	0.02	0.04	7.1	7.0	78.0	76.0	0.6	250	<0.03	<0.03
UMA160	01/12/93	<0.005	<0.005	195.0744	0.08	NA	7.2	7.2	17.0	<0.04	<0.04	0.02	0.02	3.2	3.2	<0.02	0.04	7.8	8.0	72.0	71.0	<0.5	270	<0.03	<0.03
UMA160	03/23/93	<0.005	<0.005	214.5818	0.06	NA	6.9	6.9	18.0	<0.04	<0.04	0.02	0.02	3.3	3.2	0.04	0.04	7.2	7.6	72.0	70.0	0.7	270	<0.03	<0.03
UMA161	05/14/91	0.006	NA	304.8037	0.04	NA	190.0	NA	100.0	<0.04	NA	<0.01	NA	50.0	NA	76.00	0.02	11.0	NA	44.0	NA	160.0	990	<0.03	NA
UMA161	06/22/92	<0.005	NA	243.8430	NA	0.14	200.0	200.0	96.0	<0.04	<0.04	<0.01	<0.01	53.0	51.0	67.00	0.03	12.0	12.0	49.0	48.0	170.0	1100	<0.03	<0.03
UMA162	05/14/91	0.006	NA	498.6589	0.09	NA	110.0	NA	56.0	<0.04	NA	<0.01	NA	35.0	NA	12.00	0.06	9.3	NA	68.0	NA	130.0	660	<0.03	NA
UMA162	05/14/91	0.006	NA	502.3165	0.09	NA	120.0	NA	56.0	<0.04	NA	<0.01	NA	38.0	NA	12.00	0.06	9.9	NA	73.0	NA	140.0	670	<0.03	NA
UMA162	07/13/92	0.007	NA	409.6562	0.10	NA	120.0	120.0	69.0	<0.04	<0.04	<0.01	<0.01	39.0	40.0	10.00	0.07	9.7	9.9	72.0	73.0	150.0	800	<0.03	NA
UMA163	05/14/91	<0.005	NA	203.6089	<0.03	NA	41.0	NA	5.6	<0.04	NA	<0.01	NA	8.4	NA	1.70	0.02	4.0	NA	13.0	NA	20.0	190	<0.03	NA
UMA163	06/23/92	<0.005	NA	141.4289	NA	<0.05	37.0	38.0	5.7	<0.04	<0.04	<0.01	<0.01	7.5	7.7	1.00	0.01	4.0	3.8	10.0	11.0	18.0	180	<0.03	<0.03
UMA163	06/23/92	<0.005	NA	141.4289	NA	<0.05	37.0	37.0	5.2	<0.04	<0.04	<0.01	<0.01	7.4	7.4	1.00	0.01	3.7	3.6	10.0	10.0	18.0	180	<0.03	<0.03
UMA164	05/14/91	0.006	NA	308.4614	<0.03	NA	57.0	NA	7.7	0.13	NA	<0.01	NA	14.0	NA	2.60	0.05	6.3	NA	20.0	NA	20.0	270	<0.03	NA
UMA164	10/01/91	0.006	NA	237.7469	<0.03	NA	52.0	52.0	8.7	0.10	<0.04	<0.01	<0.01	13.0	13.0	2.80	0.06	5.9	5.8	18.0	18.0	22.0	270	<0.03	NA
UMA164	11/19/91	0.005	0.005	229.2124	<0.03	NA	55.0	51.0	8.2	0.20	<0.04	<0.01	<0.01	13.0	13.0	2.80	0.06	5.9	5.7	19.0	18.0	20.0	270	<0.03	<0.03
UMA164	01/14/92	0.005	<0.005	247.5006	<0.03	NA	58.0	56.0	7.9	0.15	<0.04	<0.01	<0.01	14.0	14.0	2.80	0.06	5.9	6.1	20.0	20.0	19.0	290	<0.03	<0.03
UMA164	03/12/92	0.005	NA	242.6238	<0.03	NA	54.0	52.0	7.8	0.38	<0.04	<0.01	<0.01	13.0	13.0	2.90	0.05	6.2	5.9	17.0	17.0	19.0	280	<0.03	<0.03
UMA164	05/21/92	<0.005	<0.005	232.8700	<0.03	NA	56.0	57.0	8.7	<0.04	<0.04	<0.01	<0.01	13.0	14.0	3.00	0.05	5.6	6.0	18.0	19.0	19.0	280	<0.03	<0.03
UMA164	06/25/92	<0.005	NA	235.3085	NA	<0.05	54.0	54.0	8.5	0.05	<0.04	<0.01	<0.01	13.0	13.0	3.00	0.06	5.6	6.1	18.0	19.0	20.0	280	<0.03	<0.03
UMA164	07/14/92	0.005	NA	231.6508	<0.03	NA	56.0	55.0	8.8	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.90	0.06	6.1	5.8	19.0	19.0	20.0	280	<0.03	NA
UMA164	09/22/92	0.005	NA	237.7469	0.03	NA	58.0	57.0	8.2	0.06	<0.04	<0.01	<0.01	14.0	13.0	2.90	0.06	6.2	5.8	20.0	20.0	20.0	290	<0.03	<0.03
UMA164	11/17/92	0.005	0.006	230.4316	<0.03	NA	57.0	55.0	8.4	0.23	<0.04	<0.01	<0.01	13.0	13.0	2.80	0.06	5.1	5.4	20.0	19.0	21.0	270	<0.03	<0.03
UMA164	01/12/93	0.005	<0.005	234.0892	<0.03	NA	57.0	56.0	8.0	0.17	<0.04	<0.01	<0.01	13.0	13.0	2.10	0.05	6.2	6.5	18.0	18.0	24.0	290	<0.03	<0.03
UMA164	03/23/93	<0.005	<0.005	236.5277	<0.03	NA	54.0	54.0	8.4	<0.04	<0.04	<0.01	<0.01	13.0	13.0	1.70	0.05	6.1	6.2	19.0	19.0	28.0	300	<0.03	<0.03
UMA165	05/15/91	<0.005	NA	193.8552	<0.03	NA	29.0	NA	4.2	<0.04	NA	<0.01	NA	8.5	NA	0.62	0.01	3.5	NA	17.0	NA	6.5	190	<0.03	NA
UMA165	06/24/92	<0.005	NA	148.7442	NA	<0.05	28.0	29.0	4.1	<0.04	<0.04	<0.01	<0.01	8.3	8.6	0.58	0.01	3.3	3.4	16.0	16.0	6.3	190	<0.03	<0.03
UMA166	05/15/91	<0.005	NA	198.7320	<0.03	NA	46.0	NA	17.0	0.08	NA	<0.01	NA	17.0	NA	0.96	0.01	11.0	NA	70.0	NA	140.0	430	0.06	NA
UMA166	06/22/92	<0.005	NA	179.2246	NA	<0.05	42.0	42.0	16.0	0.92	<0.04	0.02	0.01	16.0	15.0	0.83	0.01	11.0	11.0	66.0	64.0	130.0	440	0.05	0.05
UMA167	05/16/91	<0.005	NA	385.2719	<0.03	NA	74.0	NA	24.0	<0.04	NA	<0.01	NA	22.0	NA	1.30	0.02	4.7	NA	50.0	NA	39.0	470	<0.03	NA
UMA167	06/24/92	<0.005	NA	374.2990	NA	0.13	71.0	74.0	25.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	1.10	0.04	4.4	4.4	49.0	51.0	24.0	440	<0.03	<0.03
UMA168	05/16/91	0.006	NA	231.6508	<0.03	NA	52.0	NA	14.0	<0.04	NA	<0.01	NA	17.0	NA	5.80	0.04	4.1	NA	23.0	NA	21.0	290	<0.03	NA
UMA168	05/16/91	0.007	NA	225.5547	<0.03	NA	53.0	NA	15.0	<0.04	NA	<0.01	NA	18.0	NA	5.70	0.04	4.3	NA	24.0	NA	22.0	290	<0.03	NA

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA168	10/02/91	0.006	NA	225.5547	<0.03	NA	48.0	46.0	13.0	0.04	<0.04	<0.01	<0.01	16.0	16.0	4.70	0.04	4.5	4.2	22.0	22.0	19.0	280	<0.03	NA
UMA168	11/20/91	0.005	0.005	235.3085	<0.03	NA	53.0	50.0	12.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	5.20	0.04	4.1	3.9	25.0	23.0	19.0	310	0.03	<0.03
UMA168	01/15/92	<0.005	<0.005	226.7740	<0.03	NA	51.0	50.0	12.0	0.05	<0.04	<0.01	<0.01	17.0	17.0	4.90	0.05	4.2	4.1	24.0	24.0	18.0	310	0.03	0.03
UMA168	03/11/92	0.006	NA	212.1434	<0.03	NA	45.0	44.0	9.7	0.04	<0.04	<0.01	<0.01	15.0	15.0	3.80	0.04	4.2	4.2	22.0	21.0	16.0	270	0.03	0.03
UMA168	05/20/92	0.005	0.005	223.1163	<0.03	NA	46.0	47.0	11.0	0.04	<0.04	<0.01	<0.01	15.0	15.0	3.90	0.04	3.1	3.5	22.0	23.0	17.0	280	<0.03	<0.03
UMA168	06/24/92	0.005	NA	220.6779	NA	0.06	45.0	45.0	10.0	0.08	<0.04	<0.01	<0.01	15.0	15.0	3.80	0.05	3.9	3.9	22.0	22.0	16.0	270	<0.03	<0.03
UMA168	07/15/92	0.005	NA	215.8010	<0.03	NA	45.0	45.0	11.0	0.06	<0.04	<0.01	<0.01	15.0	15.0	3.60	0.04	3.9	3.6	21.0	22.0	16.0	280	0.03	NA
UMA168	09/23/92	0.005	NA	213.3626	<0.03	NA	45.0	45.0	12.0	0.07	<0.04	<0.01	<0.01	15.0	15.0	4.30	0.05	4.0	4.0	20.0	21.0	18.0	280	<0.03	<0.03
UMA168	11/18/92	0.006	0.006	223.1163	<0.03	NA	50.0	49.0	15.0	<0.04	<0.04	<0.01	<0.01	17.0	16.0	5.30	0.05	4.0	4.1	22.0	22.0	22.0	300	0.03	0.03
UMA168	01/13/93	0.007	0.005	217.0202	<0.03	NA	50.0	51.0	16.0	0.07	<0.04	<0.01	<0.01	16.0	16.0	5.70	0.05	4.4	4.2	21.0	21.0	22.0	300	0.04	0.03
UMA168	03/24/93	0.005	0.005	221.8971	<0.03	NA	49.0	52.0	16.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	5.80	0.04	4.0	4.0	22.0	22.0	22.0	310	<0.03	<0.03
UMA169	08/05/91	0.008	NA	243.8430	0.05	NA	13.0	NA	56.0	0.12	NA	0.02	NA	8.9	NA	0.04	0.02	18.0	NA	110.0	NA	35.0	380	<0.03	NA
UMA170	08/05/91	0.006	NA	191.4167	<0.03	NA	36.0	NA	23.0	<0.04	NA	<0.01	NA	17.0	NA	9.30	0.02	5.0	NA	53.0	NA	36.0	360	0.04	NA
UMA170	06/22/92	0.006	NA	181.6630	NA	0.23	36.0	36.0	23.0	0.08	<0.04	<0.01	<0.01	17.0	17.0	9.00	0.02	4.4	4.6	52.0	52.0	35.0	360	0.04	0.04
UMA170	06/22/92	0.006	NA	181.6630	NA	0.20	37.0	37.0	24.0	<0.04	<0.04	<0.01	<0.01	17.0	18.0	9.60	0.02	4.5	4.5	52.0	52.0	35.0	360	0.04	0.04
UMA171	08/05/91	<0.005	NA	225.5547	0.07	NA	8.0	NA	38.0	0.26	NA	0.01	NA	2.4	NA	<0.02	0.01	15.0	NA	89.0	NA	0.7	320	<0.03	NA
UMA172	08/05/91	<0.005	NA	143.8673	<0.03	NA	42.0	NA	24.0	0.10	NA	<0.01	NA	12.0	NA	0.86	0.03	5.4	NA	27.0	NA	53.0	290	0.03	NA
UMA172	08/05/91	<0.005	NA	146.3058	<0.03	NA	42.0	NA	24.0	0.09	NA	<0.01	NA	12.0	NA	0.88	0.03	5.2	NA	26.0	NA	53.0	290	0.03	NA
UMA172	06/26/92	<0.005	NA	152.4019	NA	0.24	42.0	42.0	24.0	0.11	<0.04	<0.01	<0.01	12.0	12.0	0.71	0.03	4.9	5.0	25.0	25.0	52.0	300	<0.03	<0.03
UMA173	08/06/91	0.007	NA	246.2814	0.06	NA	150.0	NA	62.0	<0.04	NA	<0.01	NA	42.0	NA	50.00	0.04	10.0	NA	43.0	NA	130.0	850	<0.03	NA
UMA173	06/22/92	0.006	NA	259.6928	NA	0.13	160.0	160.0	72.0	<0.04	<0.04	<0.01	<0.01	46.0	44.0	49.00	0.04	11.0	10.0	46.0	45.0	140.0	890	<0.03	<0.03
UMA174	08/06/91	0.007	NA	227.9932	0.05	NA	110.0	NA	37.0	<0.04	NA	<0.01	NA	30.0	NA	34.00	0.03	10.0	NA	37.0	NA	91.0	610	<0.03	NA
UMA174	06/22/92	0.007	NA	226.7740	NA	0.10	120.0	110.0	40.0	<0.04	<0.04	<0.01	<0.01	32.0	31.0	33.00	0.03	11.0	10.0	38.0	37.0	90.0	630	<0.03	<0.03
UMA175	08/06/91	0.006	NA	221.8971	0.07	NA	140.0	NA	61.0	<0.04	NA	<0.01	NA	35.0	NA	51.00	0.03	11.0	NA	52.0	NA	140.0	880	<0.03	NA
UMA175	08/06/91	0.006	NA	223.1163	0.07	NA	140.0	NA	63.0	<0.04	NA	<0.01	NA	36.0	NA	51.00	0.03	11.0	NA	54.0	NA	140.0	880	<0.03	NA
UMA175	06/22/92	<0.005	NA	69.4952	NA	<0.05	19.0	19.0	1.9	0.18	<0.04	0.02	<0.01	4.5	4.6	0.38	0.03	0.8	0.7	3.4	3.4	9.5	77	<0.03	<0.03
UMA176	08/06/91	0.006	NA	351.1339	0.06	NA	110.0	NA	38.0	0.04	NA	<0.01	NA	34.0	NA	29.00	0.17	9.7	NA	41.0	NA	60.0	610	<0.03	NA
UMA176	06/22/92	0.005	NA	349.9147	NA	0.13	120.0	120.0	40.0	<0.04	<0.04	<0.01	<0.01	34.0	33.0	29.00	0.04	10.0	9.7	40.0	40.0	57.0	630	<0.03	<0.03
UMA177	08/06/91	0.007	NA	223.1163	0.03	NA	54.0	NA	17.0	<0.04	NA	<0.01	NA	16.0	NA	4.70	0.07	6.4	NA	28.0	NA	46.0	340	<0.03	NA
UMA177	10/01/91	0.007	NA	247.5006	<0.03	NA	66.0	66.0	24.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	7.90	0.08	6.7	6.3	31.0	30.0	51.0	390	<0.03	NA
UMA177	05/20/92	<0.005	<0.005	275.5426	<0.03	NA	73.0	75.0	27.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	8.20	0.08	6.0	6.0	33.0	33.0	66.0	450	<0.03	<0.03
UMA177	06/22/92	0.006	NA	263.3504	NA	0.15	75.0	73.0	26.0	<0.04	<0.04	<0.01	<0.01	22.0	21.0	7.30	0.07	7.1	7.0	32.0	32.0	60.0	420	<0.03	<0.03
UMA178	08/06/91	0.006	NA	299.9268	0.05	NA	91.0	NA	40.0	<0.04	NA	<0.01	NA	28.0	NA	18.00	0.04	8.8	NA	44.0	NA	59.0	520	<0.03	NA
UMA178	06/22/92	0.006	NA	299.9268	NA	0.22	89.0	93.0	40.0	<0.04	<0.04	<0.01	<0.01	26.0	27.0	19.00	0.04	8.7	8.7	42.0	43.0	57.0	530	<0.03	<0.03
UMA179	08/06/91	0.010	NA	398.6832	0.04	NA	58.0	NA	7.6	<0.04	NA	<0.01	NA	33.0	NA	1.30	0.02	3.4	NA	44.0	NA	20.0	400	0.03	NA
UMA179	06/23/92	0.010	NA	408.4370	NA	<0.05	65.0	63.0	9.9	<0.04	<0.04	<0.01	<0.01	35.0	34.0	0.89	0.02	3.7	3.5	38.0	37.0	23.0	410	<0.03	<0.03
UMA180	08/06/91	0.011	NA	520.6047	0.07	NA	84.0	NA	99.0	<0.04	NA	<0.01	NA	45.0	NA	0.62	0.04	7.1	NA	78.0	NA	71.0	630	0.04	NA
UMA180	10/01/91	0.011	NA	547.4275	0.06	NA	90.0	87.0	64.0	0.10	0.10	0.02	0.02	48.0	46.0	0.14	0.04	7.1	6.3	83.0	78.0	64.0	650	0.03	NA
UMA180	05/21/92	0.010	0.008	536.4545	0.07	NA	90.0	94.0	63.0	0.16	0.04	0.02	0.02	47.0	48.0	0.18	0.04	6.9	6.9	82.0	88.0	69.0	660	0.04	0.04
UMA180	06/25/92	0.011	NA	529.1392	NA	0.25	93.0	94.0	63.0	<0.04	<0.04	0.02	0.02	47.0	48.0	0.70	0.04	7.1	7.1	80.0	82.0	78.0	670	0.04	0.04
UMA180	09/22/92	0.011	NA	538.8930	0.08	NA	97.0	96.0	65.0	0.08	<0.04	0.02	0.02	51.0	48.0	0.09	0.05	7.6	7.5	92.0	89.0	84.0	680	0.04	0.04
UMA180	11/17/92	0.011	0.021	505.9742	0.06	NA	90.0	91.0	63.0	0.08	0.07	0.02	0.02	47.0	46.0	0.02	0.05	6.1	6.4	93.0	94.0	88.0	660	0.05	0.05
UMA181	08/07/91	0.008	NA	159.7171	<0.03	NA	32.0	NA	4.2	<0.04	NA	<0.01	NA	12.0	NA	2.00	0.03	3.1	NA	16.0	NA	9.2	210	0.05	NA
UMA181	06/24/92	0.008	NA	170.6901	NA	<0.05	35.0	36.0	5.9	<0.04	<0.04	<0.01	<0.01	13.0	13.0	2.30	0.03	2.9	3.3	16.0	17.0	9.4	220	0.05	0.05

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA182	08/07/91	<0.005	NA	395.0256	0.04	NA	100.0	NA	31.0	<0.04	NA	<0.01	NA	32.0	NA	18.00	0.04	6.6	NA	46.0	NA	31.0	550	<0.03	NA
UMA182	06/22/92	<0.005	NA	371.8605	NA	0.10	89.0	91.0	24.0	<0.04	<0.04	<0.01	<0.01	27.0	28.0	13.00	0.05	6.2	6.6	42.0	43.0	26.0	500	<0.03	<0.03
UMA183	08/07/91	0.012	NA	453.5479	0.04	NA	120.0	NA	42.0	<0.04	NA	<0.01	NA	56.0	NA	41.00	0.11	5.1	NA	49.0	NA	39.0	720	<0.03	NA
UMA183	06/22/92	0.013	NA	454.7671	NA	0.16	120.0	120.0	42.0	<0.04	<0.04	<0.01	<0.01	51.0	51.0	29.00	0.14	5.4	5.9	46.0	46.0	43.0	720	<0.03	<0.03
UMA184	08/07/91	0.007	NA	145.0866	<0.03	NA	43.0	NA	11.0	<0.04	NA	<0.01	NA	13.0	NA	9.70	0.03	4.0	NA	21.0	NA	23.0	270	0.05	NA
UMA184	06/22/92	0.007	NA	146.3058	NA	0.11	43.0	43.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	10.00	0.04	3.9	4.0	21.0	21.0	24.0	290	0.04	0.05
UMA184	06/22/92	0.007	NA	142.6481	NA	0.12	43.0	42.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	10.00	0.03	3.7	3.8	21.0	20.0	25.0	290	0.04	0.04
UMA185	08/07/91	<0.005	NA	146.3058	<0.03	NA	27.0	NA	3.8	<0.04	NA	<0.01	NA	9.5	NA	0.14	0.03	3.4	NA	14.0	NA	6.2	180	0.04	NA
UMA185	10/02/91	<0.005	NA	143.8673	<0.03	NA	25.0	25.0	3.9	<0.04	<0.04	<0.01	<0.01	8.9	9.1	0.13	0.03	3.9	3.8	14.0	14.0	6.2	170	0.03	NA
UMA185	11/20/91	<0.005	<0.005	141.4289	<0.03	NA	25.0	25.0	3.9	<0.04	<0.04	<0.01	<0.01	8.7	8.4	0.13	0.03	3.1	3.4	13.0	14.0	6.3	180	0.03	<0.03
UMA185	01/16/92	<0.005	<0.005	143.8673	<0.03	NA	26.0	26.0	3.8	<0.04	<0.04	<0.01	<0.01	9.2	9.2	0.10	0.04	3.8	3.5	14.0	15.0	6.0	190	0.04	0.04
UMA185	03/11/92	<0.005	NA	142.6481	<0.03	NA	26.0	24.0	3.8	<0.04	<0.04	<0.01	<0.01	9.0	8.4	0.15	0.04	3.4	3.4	14.0	13.0	5.8	180	0.04	0.04
UMA185	05/20/92	<0.005	<0.005	149.9634	<0.03	NA	25.0	25.0	3.7	<0.04	<0.04	<0.01	<0.01	8.5	8.7	0.14	0.04	2.9	3.1	13.0	15.0	6.0	180	0.04	0.04
UMA185	05/20/92	<0.005	<0.005	151.1826	<0.03	NA	25.0	24.0	3.9	<0.04	<0.04	<0.01	<0.01	8.6	8.6	0.13	0.04	2.0	3.3	14.0	14.0	5.7	180	0.04	0.04
UMA185	06/24/92	<0.005	NA	143.8673	NA	<0.05	25.0	26.0	3.9	<0.04	<0.04	<0.01	<0.01	8.6	8.8	0.13	0.05	3.5	3.4	14.0	14.0	5.7	170	0.04	0.04
UMA185	07/15/92	<0.005	NA	140.2097	<0.03	NA	26.0	25.0	3.9	0.08	<0.04	<0.01	<0.01	8.9	8.6	0.11	0.03	3.4	3.4	14.0	14.0	5.8	170	0.04	NA
UMA185	09/23/92	<0.005	NA	149.9634	<0.03	NA	25.0	25.0	3.8	<0.04	<0.04	<0.01	<0.01	8.7	8.7	0.13	0.04	3.6	3.4	13.0	13.0	5.7	180	0.03	0.03
UMA185	11/18/92	<0.005	<0.005	143.8673	<0.03	NA	26.0	25.0	3.8	<0.04	<0.04	<0.01	<0.01	8.4	8.7	0.13	0.03	3.6	3.6	18.0	13.0	5.6	180	0.04	0.04
UMA185	01/13/93	<0.005	<0.005	140.2097	<0.03	NA	25.0	25.0	4.0	<0.04	<0.04	<0.01	<0.01	8.6	8.5	0.13	0.03	3.6	3.9	13.0	13.0	5.8	170	0.05	0.04
UMA185	03/24/93	<0.005	<0.005	142.6481	<0.03	NA	25.0	25.0	4.0	<0.04	<0.04	<0.01	<0.01	8.3	8.7	0.14	0.03	3.2	3.5	14.0	13.0	5.8	170	0.04	0.04
UMA186	08/07/91	<0.005	NA	171.9093	<0.03	NA	37.0	NA	13.0	<0.04	NA	<0.01	NA	12.0	NA	2.60	0.07	4.3	NA	22.0	NA	13.0	240	<0.03	NA
UMA186	06/22/92	<0.005	NA	167.0324	NA	0.16	38.0	37.0	13.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	2.80	0.08	4.7	4.5	23.0	23.0	13.0	250	<0.03	<0.03
UMA187	08/07/91	<0.005	NA	143.8673	<0.03	NA	22.0	NA	19.0	0.06	NA	0.06	NA	6.9	NA	0.02	0.02	2.8	NA	31.0	NA	<0.5	200	<0.03	NA
UMA187	10/02/91	<0.005	NA	146.3058	<0.03	NA	22.0	21.0	18.0	<0.04	<0.04	0.06	0.06	6.7	6.5	0.02	0.01	3.0	3.1	32.0	30.0	0.8	180	<0.03	NA
UMA187	11/20/91	<0.005	<0.005	141.4289	<0.03	NA	22.0	22.0	18.0	0.14	<0.04	0.06	0.06	6.6	6.4	0.02	0.01	2.7	3.0	31.0	31.0	1.0	200	<0.03	<0.03
UMA187	01/16/92	<0.005	<0.005	145.0866	<0.03	NA	22.0	22.0	18.0	<0.04	<0.04	0.06	<0.01	6.8	6.9	<0.02	0.02	2.8	3.0	31.0	31.0	0.6	210	<0.03	<0.03
UMA187	03/11/92	<0.005	NA	148.7442	<0.03	NA	22.0	21.0	18.0	0.10	<0.04	0.06	0.06	6.9	6.6	<0.02	0.02	3.3	2.6	31.0	30.0	0.9	200	<0.03	<0.03
UMA187	05/20/92	<0.005	<0.005	148.7442	<0.03	NA	22.0	21.0	18.0	<0.04	<0.04	0.06	0.06	6.3	6.5	<0.02	0.02	2.3	2.2	31.0	32.0	1.0	210	<0.03	<0.03
UMA187	06/24/92	<0.005	NA	148.7442	NA	0.16	22.0	20.0	18.0	0.04	<0.04	0.06	0.06	6.5	6.4	<0.02	0.01	2.8	2.6	31.0	29.0	<0.5	190	<0.03	<0.03
UMA187	07/15/92	<0.005	NA	140.2097	<0.03	NA	21.0	22.0	20.0	<0.04	<0.04	0.06	0.06	6.5	6.7	<0.02	0.01	2.7	2.7	29.0	31.0	0.7	200	<0.03	NA
UMA187	09/23/92	<0.005	NA	153.6211	<0.03	NA	21.0	21.0	18.0	<0.04	<0.04	0.06	0.06	6.4	6.5	<0.02	0.01	2.6	2.9	29.0	29.0	<0.5	200	<0.03	<0.03
UMA187	11/18/92	<0.005	<0.005	146.3058	<0.03	NA	21.0	23.0	19.0	0.06	<0.04	0.06	0.06	6.5	6.6	<0.02	0.02	2.9	3.1	29.0	31.0	0.6	200	<0.03	<0.03
UMA187	01/13/93	<0.005	<0.005	140.2097	<0.03	NA	21.0	22.0	18.0	<0.04	<0.04	0.06	0.06	6.2	6.5	<0.02	0.01	2.6	3.1	28.0	29.0	0.6	190	<0.03	<0.03
UMA187	01/13/93	<0.005	<0.005	141.4289	<0.03	NA	22.0	22.0	18.0	<0.04	<0.04	0.06	0.06	6.4	6.5	<0.02	0.02	2.8	2.9	29.0	29.0	0.6	200	<0.03	<0.03
UMA187	03/24/93	<0.005	<0.005	143.8673	<0.03	NA	21.0	21.0	18.0	<0.04	<0.04	0.06	0.06	6.1	6.5	<0.02	0.03	2.5	2.6	29.0	29.0	0.9	200	<0.03	<0.03
UMA188	08/07/91	<0.005	NA	175.5669	0.03	NA	32.0	NA	47.0	0.04	NA	0.03	NA	17.0	NA	2.00	0.01	12.0	NA	54.0	NA	59.0	350	<0.03	NA
UMA188	06/22/92	<0.005	NA	174.3477	NA	0.49	33.0	33.0	49.0	<0.04	<0.04	0.16	<0.01	18.0	18.0	2.00	0.01	13.0	12.0	60.0	59.0	57.0	380	<0.03	<0.03
UMA189	08/07/91	<0.005	NA	65.8376	<0.03	NA	14.0	NA	4.4	0.95	NA	0.02	NA	5.6	NA	2.20	0.10	2.9	NA	8.9	NA	8.1	140	<0.03	NA
UMA189	06/24/92	<0.005	NA	67.0568	NA	<0.05	12.0	12.0	3.9	0.12	0.08	<0.01	<0.01	4.8	4.8	0.55	0.07	2.8	2.9	8.3	7.8	5.5	100	<0.03	<0.03
UMA190	08/07/91	<0.005	NA	67.0568	<0.03	NA	15.0	NA	7.7	0.45	NA	0.01	NA	5.2	NA	1.00	0.10	3.5	NA	10.0	NA	9.1	130	<0.03	NA
UMA190	10/02/91	<0.005	NA	74.3721	<0.03	NA	15.0	15.0	7.8	0.16	0.12	<0.01	<0.01	5.5	5.3	0.89	0.09	3.5	3.6	10.0	9.9	8.6	120	<0.03	NA
UMA190	11/21/91	<0.005	<0.005	81.6874	0.06	NA	39.0	40.0	44.0	0.11	<0.04	<0.01	<0.01	14.0	15.0	4.20	0.05	4.8	4.8	17.0	17.0	52.0	260	<0.03	<0.03
UMA190	01/17/92	<0.005	<0.005	71.9337	<0.03	NA	20.0	20.0	14.0	0.10	0.05	<0.01	<0.01	7.4	7.3	1.70	0.08	3.8	3.4	14.0	14.0	12.0	160	<0.03	<0.03
UMA190	03/10/92	<0.005	NA	53.6455	<0.03	NA	10.0	10.0	5.4	0.51	0.41	<0.01	<0.01	3.6	3.6	0.72	0.08	2.0	2.4	8.5	8.6	7.1	98	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA190	05/19/92	<0.005	<0.005	65.8376	<0.03	NA	14.0	12.0	6.6	0.25	0.09	<0.01	<0.01	4.8	4.6	0.80	0.10	3.1	3.1	9.5	9.8	7.3	110	<0.03	<0.03
UMA190	06/23/92	<0.005	NA	60.9607	NA	<0.05	12.0	12.0	5.6	0.16	0.13	<0.01	<0.01	4.2	4.0	0.63	0.10	2.7	2.6	9.1	8.8	6.6	110	<0.03	<0.03
UMA190	07/16/92	<0.005	NA	65.8376	<0.03	NA	12.0	13.0	5.0	0.18	0.10	0.01	0.01	4.4	4.5	0.56	0.10	3.0	3.1	9.1	9.6	5.7	120	<0.03	NA
UMA190	07/16/92	<0.005	NA	70.7145	<0.03	NA	12.0	12.0	5.0	0.19	0.10	0.01	0.01	4.2	4.3	0.54	0.10	3.0	2.8	8.9	9.1	5.7	110	<0.03	NA
UMA190	09/24/92	<0.005	NA	80.4682	0.08	NA	16.0	15.0	8.0	0.24	<0.04	0.01	<0.01	5.4	5.3	0.53	0.09	3.3	3.0	11.0	10.0	7.6	120	<0.03	<0.03
UMA190	11/19/92	<0.005	<0.005	75.5913	0.09	NA	21.0	21.0	16.0	<0.04	<0.04	<0.01	<0.01	7.5	7.2	1.90	0.10	3.8	3.6	14.0	13.0	18.0	150	<0.03	<0.03
UMA190	01/14/93	<0.005	<0.005	75.5913	0.06	NA	22.0	22.0	18.0	0.07	<0.04	<0.01	<0.01	8.0	8.0	2.20	0.07	4.0	3.8	15.0	15.0	22.0	170	<0.03	<0.03
UMA190	03/25/93	<0.005	<0.005	54.8647	<0.03	NA	12.0	12.0	7.8	0.64	0.50	<0.01	<0.01	4.6	4.6	1.40	0.08	2.5	2.1	10.0	9.0	10.0	120	<0.03	<0.03
UMA191	08/08/91	<0.005	NA	246.2814	0.06	NA	33.0	NA	9.9	0.06	NA	<0.01	NA	11.0	NA	0.72	0.14	3.9	NA	48.0	NA	15.0	300	0.04	NA
UMA191	10/02/91	<0.005	NA	243.8430	0.04	NA	34.0	33.0	10.0	0.09	<0.04	<0.01	<0.01	11.0	11.0	0.37	0.08	4.1	4.3	52.0	49.0	26.0	270	<0.03	NA
UMA191	11/21/91	<0.005	<0.005	240.1853	0.08	NA	32.0	30.0	8.5	0.07	<0.04	<0.01	<0.01	11.0	10.0	0.66	0.12	4.2	3.7	50.0	48.0	12.0	280	0.03	0.03
UMA191	01/17/92	<0.005	<0.005	246.2814	0.05	NA	36.0	36.0	9.0	0.07	0.06	<0.01	<0.01	11.0	11.0	0.70	0.12	4.0	4.5	53.0	54.0	12.0	290	0.05	0.05
UMA191	03/10/92	<0.005	NA	242.6238	0.07	NA	32.0	31.0	8.8	<0.04	<0.04	<0.01	<0.01	10.0	10.0	0.69	0.11	3.5	4.0	48.0	48.0	14.0	280	<0.03	<0.03
UMA191	05/19/92	<0.005	<0.005	318.2151	0.12	NA	55.0	50.0	22.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	1.20	0.13	4.9	4.1	58.0	53.0	21.0	380	0.04	0.04
UMA191	06/23/92	<0.005	NA	275.5426	NA	0.06	38.0	37.0	13.0	<0.04	<0.04	<0.01	<0.01	12.0	12.0	1.10	0.13	4.2	3.8	50.0	53.0	14.0	300	0.04	0.03
UMA191	07/16/92	<0.005	NA	243.8430	0.10	NA	32.0	31.0	11.0	<0.04	<0.04	<0.01	<0.01	10.0	10.0	0.87	0.13	3.7	3.4	50.0	49.0	12.0	280	0.04	NA
UMA191	09/24/92	<0.005	NA	230.4316	0.09	NA	30.0	28.0	8.7	0.12	<0.04	<0.01	<0.01	9.4	9.2	0.54	0.13	3.7	3.6	50.0	49.0	11.0	270	0.05	0.04
UMA191	11/19/92	<0.005	<0.005	237.7469	0.06	NA	31.0	30.0	9.5	<0.04	<0.04	<0.01	<0.01	10.0	9.9	0.44	0.13	4.0	4.3	50.0	48.0	11.0	270	0.05	0.05
UMA191	01/14/93	<0.005	<0.005	238.9661	0.06	NA	32.0	31.0	9.0	<0.04	<0.04	<0.01	<0.01	10.0	10.0	0.47	0.13	4.1	3.6	47.0	46.0	11.0	280	0.05	0.04
UMA191	03/25/93	<0.005	<0.005	268.2273	0.05	NA	38.0	38.0	12.0	<0.04	<0.04	<0.01	<0.01	12.0	13.0	0.69	0.13	3.9	3.4	46.0	48.0	14.0	300	0.04	0.03
UMA191	03/25/93	<0.005	<0.005	265.7888	0.05	NA	36.0	36.0	12.0	<0.04	<0.04	<0.01	<0.01	13.0	12.0	0.72	0.13	3.7	3.8	47.0	43.0	14.0	300	0.04	0.04
UMA192	08/08/91	<0.005	NA	173.1285	0.06	NA	33.0	NA	9.7	<0.04	NA	<0.01	NA	15.0	NA	1.80	0.15	7.8	NA	15.0	NA	15.0	240	<0.03	NA
UMA192	08/08/91	<0.005	NA	173.1285	0.05	NA	32.0	NA	9.7	<0.04	NA	<0.01	NA	15.0	NA	1.90	0.15	7.3	NA	15.0	NA	15.0	240	<0.03	NA
UMA192	06/25/92	<0.005	NA	156.0595	NA	0.08	33.0	32.0	9.8	<0.04	<0.04	<0.01	<0.01	14.0	14.0	2.50	0.16	8.2	7.7	13.0	13.0	18.0	230	<0.03	<0.03
UMA193	08/08/91	0.008	NA	235.3085	<0.03	NA	66.0	NA	8.7	0.06	NA	<0.01	NA	18.0	NA	8.00	0.05	3.4	NA	11.0	NA	22.0	320	<0.03	NA
UMA193	06/24/92	0.008	NA	231.6508	NA	<0.05	65.0	60.0	7.9	<0.04	<0.04	<0.01	<0.01	17.0	16.0	8.60	0.06	3.7	3.3	11.0	10.0	14.0	300	0.03	<0.03
UMA193	06/24/92	0.008	NA	227.9932	NA	<0.05	66.0	61.0	7.9	<0.04	<0.04	<0.01	<0.01	18.0	16.0	8.50	0.05	3.9	3.6	11.0	10.0	14.0	310	0.03	<0.03
UMA194	08/08/91	<0.005	NA	151.1826	<0.03	NA	43.0	NA	18.0	<0.04	NA	<0.01	NA	15.0	NA	8.60	0.01	4.8	NA	27.0	NA	46.0	340	0.06	NA
UMA194	06/22/92	<0.005	NA	145.0866	NA	0.18	45.0	45.0	19.0	<0.04	0.09	<0.01	<0.01	15.0	15.0	9.30	0.02	5.1	5.7	27.0	27.0	43.0	340	0.05	0.50
UMA195	08/09/91	<0.005	NA	256.0351	<0.03	NA	50.0	NA	13.0	<0.04	NA	<0.01	NA	22.0	NA	7.40	0.02	4.9	NA	30.0	NA	25.0	350	0.05	NA
UMA195	06/23/92	0.006	NA	198.7320	NA	<0.05	42.0	42.0	7.4	<0.04	<0.04	<0.01	<0.01	20.0	19.0	7.60	0.02	3.5	3.5	15.0	15.0	16.0	300	0.03	0.04
UMA196	08/09/91	<0.005	NA	145.0866	<0.03	NA	26.0	NA	10.0	0.16	NA	<0.01	NA	11.0	NA	1.10	0.02	3.3	NA	41.0	NA	12.0	250	0.06	NA
UMA196	09/30/91	<0.005	?	145.0866	?	?	26.0	?	10.0	0.16	?	?	?	11.0	?	1.10	0.02	3.3	?	41.0	?	12.0	250	0.06	?
UMA196	06/24/92	<0.005	NA	181.6630	NA	0.16	24.0	22.0	11.0	<0.04	<0.04	<0.01	<0.01	10.0	9.3	1.20	0.02	3.3	3.1	42.0	37.0	12.0	240	0.07	0.06
UMA197	10/09/91	<0.005	<0.005	204.8281	<0.03	NA	11.0	11.0	36.0	0.37	0.08	0.03	0.03	3.4	3.5	<0.02	0.06	7.8	8.1	110.0	120.0	98.0	420	<0.03	<0.03
UMA198	10/10/91	0.007	<0.005	169.4709	<0.03	NA	38.0	34.0	37.0	6.50	0.22	0.33	0.03	18.0	16.0	5.80	0.05	3.7	3.1	31.0	29.0	15.0	280	0.05	<0.03
UMA198	11/21/91	<0.005	<0.005	208.4857	<0.03	NA	55.0	52.0	45.0	0.02	<0.04	0.01	0.01	26.0	25.0	16.00	0.01	3.8	3.6	46.0	44.0	23.0	390	<0.03	<0.03
UMA198	01/16/92	<0.005	<0.005	185.3207	<0.03	NA	41.0	43.0	39.0	0.67	0.06	0.01	<0.01	22.0	23.0	7.20	0.02	2.9	3.0	27.0	27.0	15.0	310	<0.03	<0.03
UMA198	01/16/92	<0.005	<0.005	182.8822	<0.03	NA	42.0	44.0	38.0	0.73	0.06	0.01	<0.01	23.0	23.0	7.10	0.02	3.2	3.0	27.0	27.0	15.0	310	0.03	<0.03
UMA198	03/11/92	<0.005	NA	196.2936	<0.03	NA	45.0	41.0	43.0	0.11	<0.04	<0.01	<0.01	23.0	22.0	10.00	0.01	3.5	3.2	33.0	32.0	18.0	340	0.03	0.03
UMA198	05/20/92	<0.005	<0.005	193.8552	<0.03	NA	44.0	44.0	44.0	<0.04	<0.04	<0.01	<0.01	24.0	23.0	9.40	0.01	2.4	2.7	29.0	30.0	16.0	340	0.03	0.03
UMA198	06/24/92	<0.005	NA	192.6359	NA	0.29	46.0	43.0	43.0	<0.04	<0.04	<0.01	<0.01	24.0	23.0	9.00	0.02	3.3	3.0	29.0	27.0	16.0	320	0.04	0.03
UMA198	07/15/92	<0.005	NA	192.6359	<0.03	NA	42.0	41.0	42.0	<0.04	<0.04	<0.01	<0.01	22.0	22.0	7.90	<0.01	2.9	3.0	28.0	28.0	15.0	330	0.03	NA
UMA198	09/23/92	<0.005	NA	196.2936	<0.03	NA	42.0	42.0	44.0	<0.04	<0.04	<0.01	<0.01	22.0	23.0	9.30	0.01	3.4	3.2	27.0	29.0	16.0	340	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA198	11/18/92	<0.005	<0.005	225.5547	<0.03	NA	37.0	38.0	36.0	2.80	0.06	<0.01	<0.01	18.0	18.0	8.60	0.01	3.6	3.7	39.0	40.0	19.0	320	0.04	0.04
UMA198	11/18/92	<0.005	<0.005	204.8281	<0.03	NA	37.0	38.0	35.0	0.43	0.06	<0.01	<0.01	18.0	18.0	8.70	0.02	3.5	3.7	40.0	41.0	19.0	320	0.04	0.04
UMA198	01/13/93	<0.005	<0.005	176.7861	<0.03	NA	39.0	39.0	38.0	<0.04	<0.04	<0.01	<0.01	20.0	20.0	7.40	0.01	3.3	3.3	28.0	27.0	14.0	300	0.04	0.03
UMA198	03/24/93	<0.005	<0.005	195.0744	<0.03	NA	46.0	44.0	45.0	<0.04	<0.04	<0.01	<0.01	25.0	23.0	9.70	<0.01	3.1	3.0	31.0	30.0	16.0	340	0.03	<0.03
UMA199	10/10/91	<0.005	<0.005	123.1407	<0.03	NA	41.0	18.0	2.7	0.06	<0.04	<0.01	0.13	11.0	8.3	0.28	0.06	3.2	3.1	11.0	10.0	3.5	200	<0.03	<0.03
UMA199	10/10/91	<0.005	<0.005	195.0744	<0.03	NA	40.0	40.0	2.7	0.10	0.09	<0.01	<0.01	11.0	11.0	0.28	0.06	3.2	3.0	11.0	11.0	3.6	200	<0.03	<0.03
UMA199	06/24/92	<0.005	NA	170.6901	NA	<0.05	37.0	37.0	3.3	1.30	<0.04	<0.01	<0.01	10.0	10.0	0.84	0.07	3.0	3.1	11.0	11.0	5.3	190	<0.03	<0.03
UMA200	10/10/91	<0.005	<0.005	267.0080	<0.03	NA	58.0	54.0	13.0	1.10	<0.04	0.08	0.05	21.0	19.0	2.40	0.09	4.2	3.4	24.0	22.0	24.0	300	<0.03	<0.03
UMA200	06/25/92	<0.005	NA	198.7320	NA	0.06	43.0	41.0	9.2	0.21	<0.04	0.03	0.02	15.0	15.0	1.90	0.04	3.5	3.2	22.0	22.0	16.0	240	<0.03	<0.03
UMA201	11/22/91	0.007	0.007	279.2002	0.04	NA	78.0	74.0	39.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	12.00	0.04	8.4	7.8	46.0	43.0	52.0	450	0.03	<0.03
UMA201	01/14/92	0.008	0.007	280.4194	0.05	NA	76.0	72.0	38.0	<0.04	<0.04	<0.01	<0.01	26.0	24.0	11.00	0.05	7.8	7.3	44.0	42.0	48.0	470	<0.03	<0.03
UMA201	01/14/92	0.007	0.007	268.2273	0.05	NA	75.0	72.0	39.0	<0.04	<0.04	<0.01	<0.01	25.0	25.0	11.00	0.06	7.6	7.3	44.0	42.0	49.0	480	<0.03	<0.03
UMA201	03/11/92	0.008	NA	282.8578	0.04	NA	74.0	72.0	38.0	<0.04	<0.04	<0.01	<0.01	26.0	24.0	12.00	0.05	8.0	8.0	43.0	42.0	50.0	460	<0.03	<0.03
UMA201	03/11/92	0.007	NA	281.6386	0.04	NA	72.0	74.0	38.0	<0.04	<0.04	<0.01	<0.01	25.0	25.0	12.00	0.05	7.8	7.9	42.0	42.0	49.0	470	<0.03	<0.03
UMA201	06/24/92	0.008	NA	296.2692	NA	0.29	79.0	76.0	42.0	<0.04	<0.04	<0.01	<0.01	26.0	25.0	12.00	0.05	7.9	7.7	45.0	43.0	43.0	480	<0.03	<0.03
UMA201	06/24/92	0.008	NA	295.0500	NA	0.26	78.0	77.0	42.0	<0.04	<0.04	<0.01	<0.01	26.0	26.0	12.00	0.06	7.9	7.5	44.0	45.0	43.0	480	<0.03	<0.03
UMA201	07/14/92	0.008	NA	297.4884	0.04	NA	78.0	75.0	44.0	<0.04	<0.04	<0.01	<0.01	25.0	24.0	11.00	0.05	7.9	7.5	40.0	40.0	56.0	480	<0.03	NA
UMA201	09/22/92	0.007	NA	298.7076	0.05	NA	82.0	79.0	44.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	12.00	0.05	8.8	7.9	46.0	45.0	48.0	500	<0.03	<0.03
UMA201	11/17/92	0.008	0.008	296.2692	0.04	NA	79.0	80.0	43.0	<0.04	<0.04	<0.01	<0.01	26.0	26.0	12.00	0.05	7.3	7.8	44.0	45.0	51.0	480	0.03	<0.03
UMA201	01/12/93	0.008	0.008	280.4194	0.05	NA	81.0	79.0	43.0	0.07	<0.04	<0.01	<0.01	26.0	26.0	12.00	0.04	8.2	8.3	41.0	43.0	49.0	490	<0.03	<0.03
UMA201	03/23/93	0.007	0.007	303.5845	0.04	NA	77.0	78.0	45.0	<0.04	<0.04	<0.01	<0.01	26.0	26.0	12.00	0.05	8.1	8.0	43.0	42.0	50.0	500	<0.03	<0.03
UMA202	07/10/92	0.041	NA	341.3802	NA	0.27	57.0	28.0	17.0	17.00	<0.04	0.68	0.09	35.0	28.0	0.12	0.84	6.5	5.1	80.0	78.0	72.0	400	0.04	<0.03
UMA203	07/10/92	0.027	NA	273.1041	NA	0.17	50.0	51.0	20.0	0.21	<0.04	<0.01	<0.01	22.0	22.0	0.37	0.13	7.4	7.9	53.0	54.0	72.0	380	0.03	0.03
UMA204	07/10/92	0.021	NA	267.0080	NA	0.26	70.0	70.0	46.0	4.00	<0.04	0.13	<0.01	32.0	32.0	18.00	0.24	11.0	10.0	78.0	80.0	100.0	560	<0.03	<0.03
UMA205	07/10/92	0.036	NA	323.0919	NA	0.16	44.0	36.0	15.0	3.80	<0.04	0.48	0.13	23.0	22.0	0.05	0.23	6.2	5.6	87.0	89.0	68.0	450	<0.03	<0.03
UMA206	07/10/92	0.020	NA	196.2936	NA	0.17	61.0	59.0	18.0	4.10	<0.04	0.09	<0.01	18.0	16.0	8.00	0.24	9.5	9.0	19.0	19.0	35.0	340	<0.03	<0.03
UMA207	07/12/92	<0.005	NA	265.7888	NA	0.19	69.0	68.0	18.0	0.15	<0.04	<0.01	<0.01	19.0	19.0	6.20	0.10	5.2	5.3	26.0	26.0	22.0	370	<0.03	<0.03
UMA208	07/12/92	<0.005	NA	173.1285	NA	0.42	45.0	43.0	30.0	1.70	<0.04	0.03	<0.01	32.0	31.0	16.00	0.10	2.6	2.3	45.0	45.0	70.0	440	0.05	0.05
UMA209	07/12/92	0.012	NA	168.2516	NA	0.70	46.0	43.0	19.0	1.50	<0.04	0.03	<0.01	20.0	19.0	7.40	0.18	4.2	4.2	25.0	26.0	36.0	330	0.05	0.05
UMA210	07/12/92	0.022	NA	157.2787	NA	0.19	50.0	37.0	20.0	16.00	<0.04	0.31	<0.01	22.0	17.0	6.70	0.58	4.3	3.3	28.0	27.0	31.0	290	0.07	0.04
UMA211	07/12/92	0.010	NA	230.4316	NA	0.09	74.0	61.0	19.0	28.00	<0.04	0.56	<0.01	24.0	18.0	8.00	0.96	7.3	5.3	28.0	27.0	28.0	360	0.08	<0.03
UMA212	07/12/92	0.006	NA	227.9932	NA	0.11	68.0	64.0	20.0	7.40	<0.04	0.14	<0.01	20.0	18.0	9.60	0.37	5.8	4.8	31.0	30.0	29.0	380	0.04	<0.03
UMA213	07/13/92	0.116	NA	290.1731	NA	0.63	45.0	45.0	18.0	1.10	<0.04	0.03	<0.01	35.0	36.0	6.40	0.17	5.0	5.4	86.0	88.0	130.0	540	<0.03	<0.03
UMA214	07/13/92	0.014	NA	143.8673	NA	0.19	81.0	82.0	50.0	0.09	<0.04	<0.01	<0.01	22.0	22.0	27.00	0.06	10.0	10.0	25.0	26.0	50.0	510	<0.03	<0.03
UMA215	07/13/92	0.020	NA	165.8132	NA	0.37	82.0	80.0	61.0	0.14	<0.04	<0.01	<0.01	21.0	21.0	8.70	0.07	9.5	9.0	27.0	26.0	71.0	460	<0.03	<0.03
UMA216	07/13/92	0.012	NA	145.0866	NA	0.22	36.0	35.0	31.0	4.80	<0.04	0.08	<0.01	35.0	34.0	18.00	0.12	2.3	1.7	23.0	22.0	35.0	370	0.11	0.09
UMA217	07/13/92	0.026	NA	253.5967	NA	2.20	49.0	28.0	15.0	32.00	<0.04	0.36	<0.01	41.0	28.0	6.20	1.00	9.1	5.4	44.0	42.0	71.0	350	0.29	0.13
UMA218	07/14/92	0.008	NA	141.4289	NA	0.22	36.0	31.0	22.0	7.20	<0.04	0.14	<0.01	28.0	24.0	7.80	0.16	3.2	2.3	23.0	23.0	43.0	300	0.15	0.08
UMA219	07/08/92	0.007	NA	142.6481	NA	0.52	57.0	47.0	54.0	48.00	<0.04	1.30	<0.01	36.0	27.0	16.00	1.10	5.0	2.8	22.0	20.0	18.0	390	0.15	0.05
UMA220	07/08/92	<0.005	NA	125.5791	NA	1.20	37.0	29.0	18.0	18.00	<0.04	0.42	<0.01	16.0	13.0	6.20	0.69	5.0	3.8	16.0	15.0	9.8	240	0.10	0.05
UMA221	07/09/92	0.014	NA	152.4019	NA	0.22	43.0	41.0	19.0	4.30	<0.04	0.08	<0.01	20.0	18.0	8.70	0.26	4.4	3.6	25.0	25.0	39.0	310	0.06	0.05
UMA222	07/09/92	0.058	NA	302.3653	NA	0.44	620.0	78.0	35.0	170.00	<0.04	2.90	<0.01	160.0	66.0	18.00	11.40	18.0	4.0	48.0	47.0	180.0	710	0.28	0.03
UMA223	07/09/92	0.009	NA	167.0324	NA	3.10	36.0	33.0	27.0	17.00	<0.04	0.23	<0.01	35.0	31.0	10.00	0.70	7.2	6.0	29.0	30.0	45.0	370	0.11	0.05
UMA224	07/10/92	0.007	NA	165.8132	NA	0.12	84.0	87.0	23.0	0.11	<0.04	0.03	<0.01	31.0	32.0	47.00	0.06	9.1	9.0	24.0	24.0	42.0	620	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA225	07/10/92	0.008	NA	176.7861	NA	0.17	98.0	98.0	18.0	0.11	<0.04	0.02	<0.01	25.0	26.0	52.00	0.05	18.0	18.0	22.0	23.0	38.0	660	<0.03	<0.03
UMA226	07/10/92	0.016	NA	163.3748	NA	0.17	57.0	50.0	17.0	12.00	<0.04	0.22	<0.01	18.0	13.0	13.00	0.80	7.0	5.6	26.0	25.0	28.0	330	0.06	0.03
UMA226	07/10/92	0.014	NA	158.4979	NA	0.16	50.0	49.0	17.0	1.90	<0.04	0.03	<0.01	14.0	14.0	13.00	0.38	6.5	5.6	26.0	25.0	28.0	330	0.04	<0.03
UMA227	07/10/92	0.011	NA	169.4709	NA	0.15	46.0	44.0	18.0	5.50	<0.04	0.09	<0.01	21.0	20.0	9.80	0.23	4.6	3.9	22.0	22.0	29.0	310	0.04	0.03
UMA228	07/09/92	0.007	NA	159.7171	NA	0.24	31.0	30.0	16.0	10.00	<0.04	0.19	<0.01	26.0	25.0	6.10	0.19	2.8	2.4	19.0	19.0	29.0	280	0.12	0.08
UMA229	07/09/92	0.008	NA	213.3626	NA	0.13	56.0	52.0	14.0	10.00	<0.04	0.17	<0.01	17.0	15.0	5.10	0.40	5.8	4.8	24.0	24.0	22.0	310	0.04	<0.03
UMA230	07/09/92	0.007	NA	267.0080	NA	0.13	82.0	66.0	22.0	25.00	<0.04	0.44	<0.01	25.0	19.0	11.00	0.80	6.6	4.8	34.0	34.0	23.0	410	0.07	<0.03
UMA231	06/23/92	0.007	NA	206.0473	NA	0.06	82.0	77.0	17.0	8.20	<0.04	0.18	<0.01	21.0	20.0	21.00	0.27	7.8	7.2	26.0	26.0	39.0	420	0.04	<0.03
UMA232	06/23/92	0.010	NA	225.5547	NA	0.10	77.0	73.0	18.0	2.20	<0.04	0.06	<0.01	21.0	20.0	13.00	0.25	8.2	7.9	30.0	30.0	52.0	420	<0.03	<0.03
UMA232	06/23/92	0.009	NA	225.5547	NA	0.11	75.0	NA	18.0	1.90	NA	0.06	NA	20.0	NA	13.00	0.25	8.1	NA	30.0	NA	50.0	410	<0.03	NA
UMA233	06/23/92	0.008	NA	190.1975	NA	0.24	74.0	NA	28.0	0.98	NA	0.02	NA	40.0	NA	31.00	0.06	6.5	NA	40.0	NA	63.0	560	0.04	NA
UMA234	06/25/92	<0.005	NA	404.7793	NA	0.14	100.0	99.0	42.0	0.06	<0.04	<0.01	<0.01	67.0	68.0	22.00	0.05	3.9	3.8	24.0	24.0	36.0	500	0.06	0.07
UMA235	06/25/92	<0.005	NA	170.6901	NA	0.18	31.0	30.0	31.0	0.05	<0.04	<0.01	<0.01	15.0	15.0	5.50	0.04	3.4	3.7	40.0	40.0	9.4	260	0.08	0.07
UMA236	06/25/92	0.008	NA	159.7171	NA	0.05	14.0	13.0	6.9	<0.04	<0.04	<0.01	<0.01	6.7	6.3	0.18	0.06	4.0	3.6	52.0	48.0	12.0	210	0.32	0.32
UMA237	06/25/92	<0.005	NA	510.8510	NA	0.25	160.0	140.0	110.0	4.40	<0.04	0.17	<0.01	85.0	78.0	36.00	0.56	6.1	5.5	57.0	52.0	55.0	880	0.04	0.04
UMA238	06/25/92	<0.005	NA	474.2746	NA	0.13	130.0	120.0	53.0	0.07	<0.04	<0.01	<0.01	89.0	83.0	21.00	0.05	4.2	4.0	26.0	24.0	37.0	770	0.04	0.04
UMA239	06/24/92	<0.005	NA	160.9364	NA	0.08	140.0	35.0	14.0	71.00	<0.04	1.90	<0.01	32.0	17.0	1.10	0.56	7.9	3.0	17.0	15.0	27.0	250	0.17	<0.03
UMA240	06/24/92	<0.005	NA	169.4709	NA	1.00	66.0	68.0	92.0	5.20	<0.04	0.15	<0.01	15.0	15.0	2.90	0.18	2.3	1.9	72.0	69.0	87.0	490	<0.03	<0.03
UMA240	06/24/92	<0.005	NA	170.6901	NA	0.97	74.0	67.0	90.0	4.50	<0.04	0.14	<0.01	17.0	15.0	3.00	0.12	2.4	1.9	74.0	72.0	80.0	500	0.03	<0.03
UMA241	06/24/92	<0.005	NA	146.3058	NA	3.90	33.0	30.0	8.7	5.90	<0.04	0.34	0.20	9.1	7.6	2.10	1.30	9.8	11.0	24.0	22.0	16.0	230	<0.03	<0.03
UMA242	06/24/92	<0.005	NA	318.2151	NA	0.48	89.0	79.0	51.0	22.00	<0.04	0.76	<0.01	31.0	26.0	11.00	0.66	7.4	5.5	87.0	81.0	94.0	590	0.07	<0.03
UMA243	06/22/92	0.120	NA	431.6020	NA	0.08	670.0	63.0	28.0	1200.00	0.07	20.00	0.01	300.0	16.0	2.70	50.80	93.0	8.4	79.0	58.0	24.0	510	2.00	<0.03
UMA244	06/22/92	<0.005	NA	90.2219	NA	<0.05	21.0	16.0	4.5	23.00	<0.04	0.40	<0.01	8.7	6.7	0.60	0.76	5.0	3.7	14.0	12.0	6.2	170	0.06	<0.03
UMA245	06/25/92	<0.005	NA	151.1826	NA	0.05	29.0	30.0	5.3	<0.04	<0.04	<0.01	<0.01	10.0	11.0	0.72	0.07	3.4	3.6	16.0	17.0	9.9	190	<0.03	0.03
UMA246	06/25/92	<0.005	NA	347.4762	NA	0.32	91.0	89.0	37.0	<0.04	<0.04	<0.01	<0.01	36.0	36.0	18.00	0.15	6.4	6.5	47.0	47.0	35.0	550	<0.03	<0.03
UMA247	06/25/92	<0.005	NA	174.3477	NA	0.08	37.0	37.0	9.0	<0.04	<0.04	<0.01	<0.01	13.0	13.0	1.70	0.06	4.5	4.5	19.0	20.0	14.0	230	0.03	0.04
UMA248	06/23/92	<0.005	NA	260.9120	NA	0.09	50.0	52.0	31.0	10.00	7.50	1.70	1.70	20.0	21.0	0.03	0.39	7.3	7.4	32.0	33.0	27.0	330	<0.03	<0.03
UMA248	06/23/92	<0.005	NA	257.2543	NA	0.10	49.0	50.0	30.0	10.00	7.10	1.60	1.70	20.0	20.0	<0.02	0.39	7.2	7.2	31.0	31.0	28.0	330	<0.03	<0.03
UMA249	06/23/92	<0.005	NA	217.0202	NA	0.11	47.0	49.0	16.0	<0.04	<0.04	<0.01	<0.01	16.0	17.0	6.50	0.17	5.6	6.1	32.0	32.0	18.0	330	<0.03	<0.03
UMA250	06/24/92	<0.005	NA	557.1812	NA	0.30	110.0	110.0	90.0	0.08	<0.04	0.04	<0.01	40.0	40.0	21.00	0.07	9.6	9.9	130.0	120.0	35.0	810	<0.03	<0.03
UMA251	06/24/92	<0.005	NA	249.9390	NA	1.30	160.0	160.0	160.0	0.19	<0.04	<0.01	<0.01	46.0	46.0	21.00	0.07	7.3	7.1	41.0	41.0	150.0	880	<0.03	<0.03
UMA252	06/24/92	<0.005	NA	176.7861	NA	1.20	140.0	140.0	150.0	<0.04	<0.04	<0.01	<0.01	41.0	42.0	26.00	0.05	6.9	6.8	46.0	47.0	130.0	860	<0.03	<0.03
UMA253	06/24/92	0.012	NA	162.1556	NA	0.48	60.0	58.0	46.0	1.10	<0.04	0.03	<0.01	17.0	17.0	13.00	0.13	6.1	5.7	42.0	40.0	73.0	420	<0.03	<0.03
UMA254	06/24/92	<0.005	NA	288.9539	NA	0.14	50.0	50.0	12.0	<0.04	<0.04	<0.01	<0.01	17.0	17.0	4.00	0.10	5.3	5.3	45.0	45.0	24.0	350	<0.03	0.03
UMA255	06/24/92	<0.005	NA	152.4019	NA	0.12	42.0	43.0	10.0	0.32	<0.04	<0.01	<0.01	14.0	15.0	2.80	0.16	4.1	4.5	50.0	52.0	23.0	340	<0.03	<0.03
UMA256	06/24/92	<0.005	NA	287.7347	NA	0.16	48.0	48.0	14.0	<0.04	<0.04	<0.01	<0.01	15.0	16.0	4.50	0.13	4.0	3.9	54.0	56.0	30.0	370	<0.03	<0.03
UMA257	06/24/92	<0.005	NA	277.9810	NA	0.13	48.0	47.0	11.0	0.12	<0.04	<0.01	<0.01	16.0	16.0	5.10	0.14	5.1	5.0	50.0	50.0	23.0	350	<0.03	0.03
UMA258	06/23/92	<0.005	NA	553.5235	NA	4.30	90.0	91.0	88.0	1.60	<0.04	0.79	0.61	38.0	38.0	14.00	0.22	8.3	8.5	140.0	150.0	47.0	800	<0.03	<0.03
UMA259	06/22/92	<0.005	NA	93.8795	NA	<0.05	18.0	17.0	4.9	1.30	<0.04	0.02	<0.01	7.1	6.9	0.70	0.09	3.9	3.6	13.0	12.0	6.4	160	<0.03	<0.03
UMA260	06/22/92	0.074	NA	370.6413	NA	0.11	160.0	55.0	29.0	250.00	<0.04	6.20	<0.01	79.0	14.0	4.50	25.00	25.0	4.7	97.0	91.0	37.0	540	0.45	0.05
UMA260	06/22/92	0.072	NA	279.2002	NA	0.11	150.0	57.0	30.0	210.00	<0.04	7.60	<0.01	67.0	14.0	4.50	18.00	21.0	4.9	100.0	94.0	35.0	520	0.36	0.05
UMA261	06/25/92	<0.005	NA	191.4167	NA	0.16	52.0	53.0	23.0	1.00	<0.04	0.03	<0.01	17.0	18.0	11.00	0.16	5.0	5.0	30.0	30.0	27.0	340	<0.03	<0.03
UMA262	06/22/92	<0.005	NA	264.5696	NA	0.07	59.0	59.0	13.0	0.73	<0.04	0.02	<0.01	20.0	20.0	2.10	0.12	6.2	6.8	18.0	18.0	23.0	350	<0.03	<0.03
UMA263	06/23/92	0.012	NA	152.4019	NA	1.20	77.0	77.0	110.0	0.61	<0.04	<0.01	<0.01	40.0	41.0	12.00	0.04	3.7	3.5	38.0	39.0	76.0	570	0.04	0.04

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
UMA263	06/23/92	0.012	NA	152.4019	NA	1.40	75.0	80.0	110.0	0.45	<0.04	<0.01	<0.01	39.0	42.0	12.00	0.04	3.5	3.8	37.0	40.0	76.0	550	0.04	0.04
UMA264	06/23/92	0.021	NA	176.7861	NA	0.34	19.0	19.0	26.0	1.50	<0.04	0.03	<0.01	8.3	8.6	NA	NA	3.8	3.7	85.0	88.0	NA	370	0.06	0.05
UMA265	06/23/92	0.009	NA	182.8822	NA	0.20	26.0	27.0	16.0	0.49	<0.04	<0.01	<0.01	11.0	11.0	4.90	0.04	3.9	4.0	56.0	60.0	31.0	330	0.06	0.06
UMA266	06/24/92	0.007	NA	245.0622	NA	0.10	120.0	120.0	40.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	41.00	0.03	9.7	9.7	36.0	35.0	74.0	710	<0.03	<0.03
UMA267	06/24/92	0.034	NA	487.6859	NA	0.10	120.0	120.0	71.0	<0.04	<0.04	<0.01	<0.01	35.0	35.0	20.00	1.30	9.7	9.5	86.0	86.0	32.0	730	<0.03	<0.03
UMA268	06/24/92	0.010	NA	314.5574	NA	0.09	99.0	99.0	35.0	<0.04	<0.04	<0.01	<0.01	27.0	27.0	20.00	0.07	6.9	6.6	41.0	40.0	56.0	550	<0.03	<0.03
UMA268	06/24/92	0.010	NA	315.7766	NA	0.10	96.0	96.0	35.0	<0.04	<0.04	<0.01	<0.01	27.0	26.0	19.00	0.08	6.4	6.6	40.0	40.0	54.0	540	<0.03	<0.03
UMA269	06/24/92	<0.005	NA	182.8822	NA	0.15	3.4	3.4	18.0	<0.04	<0.04	<0.01	<0.01	0.8	0.8	0.05	0.04	9.2	9.1	73.0	73.0	0.8	260	<0.03	<0.03
UMA270	06/25/92	0.010	NA	164.5940	NA	0.18	53.0	54.0	19.0	0.24	<0.04	0.03	0.02	17.0	17.0	12.00	0.06	6.8	6.7	25.0	25.0	41.0	330	<0.03	<0.03
UMA271	06/23/92	0.006	NA	298.7076	NA	1.90	160.0	150.0	240.0	0.79	<0.04	0.03	<0.01	84.0	82.0	26.00	0.05	5.5	5.1	61.0	57.0	160.0	1200	0.03	<0.03
UMA272	06/23/92	0.008	NA	223.1163	NA	0.28	20.0	20.0	35.0	0.12	0.10	0.03	0.03	9.4	10.0	<0.02	0.02	11.0	11.0	77.0	77.0	35.0	360	<0.03	<0.03
UMA273	06/23/92	<0.005	NA	182.8822	NA	0.20	40.0	39.0	27.0	0.54	<0.04	0.13	<0.01	22.0	21.0	0.10	0.13	7.2	7.1	110.0	110.0	220.0	570	<0.03	<0.03
UMA273	06/23/92	<0.005	NA	185.3207	NA	0.19	41.0	38.0	27.0	0.32	<0.04	0.12	<0.01	22.0	21.0	0.07	0.12	7.3	6.9	110.0	110.0	210.0	570	<0.03	<0.03
UMA274	06/23/92	<0.005	NA	811.9971	NA	1.00	46.0	45.0	130.0	3.50	<0.04	0.23	<0.01	65.0	63.0	<0.02	2.00	17.0	17.0	300.0	300.0	210.0	1200	<0.03	<0.03
UMA275	06/23/92	0.040	NA	217.0202	NA	1.30	110.0	100.0	190.0	1.50	<0.04	<0.01	<0.01	56.0	53.0	32.00	0.16	20.0	19.0	160.0	150.0	240.0	1100	0.03	<0.03
UMA276	07/13/92	0.020	NA	217.0202	NA	0.17	55.0	57.0	18.0	1.50	<0.04	0.05	<0.01	18.0	18.0	2.00	0.09	8.2	8.0	24.0	23.0	35.0	330	0.05	<0.03
UMA277	06/24/92	<0.005	NA	316.9959	NA	0.13	70.0	71.0	28.0	<0.04	<0.04	<0.01	<0.01	23.0	23.0	8.90	0.02	4.7	4.5	52.0	52.0	48.0	470	<0.03	0.03
UMA278	06/24/92	<0.005	NA	249.9390	NA	0.16	48.0	47.0	17.0	0.07	<0.04	<0.01	<0.01	19.0	19.0	6.10	0.04	6.0	6.1	37.0	36.0	35.0	330	0.04	0.04
404168	06/22/92	<0.005	NA	279.2002	NA	0.08	64.0	65.0	17.0	0.09	<0.04	0.02	0.01	19.0	20.0	5.00	0.10	5.8	5.7	27.0	28.0	22.0	360	<0.03	<0.03
404474	06/24/92	0.006	NA	260.9120	NA	0.07	60.0	60.0	14.0	<0.04	<0.04	<0.01	<0.01	16.0	16.0	3.40	0.10	6.7	6.7	27.0	26.0	26.0	330	<0.03	<0.03
404475	06/24/92	0.005	NA	313.3382	NA	0.14	62.0	62.0	55.0	0.11	0.07	<0.01	0.01	18.0	18.0	6.30	2.80	14.0	14.0	79.0	80.0	36.0	510	<0.03	<0.03
404476	06/24/92	<0.005	NA	273.1041	NA	0.08	59.0	58.0	15.0	<0.04	<0.04	0.01	0.03	18.0	18.0	3.70	0.21	6.2	5.7	28.0	29.0	22.0	330	<0.03	<0.03
404476	06/24/92	<0.005	NA	274.3233	NA	0.08	59.0	58.0	15.0	0.05	<0.04	0.01	0.01	18.0	18.0	3.70	0.22	6.3	6.0	29.0	28.0	22.0	330	<0.03	<0.03
404477	06/24/92	<0.005	NA	165.8132	NA	0.05	25.0	25.0	10.0	0.04	<0.04	0.03	0.03	11.0	12.0	0.05	0.24	5.4	5.0	25.0	25.0	13.0	210	<0.03	<0.03
404478	06/24/92	<0.005	NA	621.7996	NA	0.09	32.0	27.0	37.0	0.92	0.08	0.05	0.01	13.0	12.0	0.02	13.70	90.0	87.0	180.0	190.0	14.0	870	<0.03	<0.03
404479	06/24/92	<0.005	NA	62.1800	NA	<0.05	11.0	11.0	3.1	0.84	0.23	0.02	<0.01	4.1	4.0	0.11	0.10	2.5	2.5	7.5	7.5	4.0	100	<0.03	<0.03
404480	06/24/92	<0.005	NA	63.3992	NA	<0.05	11.0	12.0	3.1	0.54	0.49	0.02	<0.01	4.2	4.3	0.03	0.08	2.2	2.9	7.5	8.3	3.8	92	<0.03	<0.03
404481	06/24/92	<0.005	NA	65.8376	NA	<0.05	12.0	11.0	3.6	1.40	0.28	0.02	<0.01	4.6	4.1	<0.02	0.09	2.8	2.4	8.1	7.9	4.0	100	<0.03	<0.03
404482	06/23/92	<0.005	NA	159.7171	NA	0.08	30.0	30.0	400.0	7.70	1.80	0.31	0.23	12.0	10.0	<0.02	9.80	59.0	56.0	320.0	310.0	3.8	1300	<0.03	<0.03
404483	06/23/92	<0.005	NA	75.5913	NA	<0.05	12.0	12.0	6.8	0.14	<0.04	0.01	<0.01	4.7	4.7	0.03	0.06	5.6	5.8	11.0	12.0	3.4	100	<0.03	<0.03
404484	06/23/92	<0.005	NA	60.9607	NA	<0.05	10.0	9.8	5.6	0.38	0.37	<0.01	<0.01	4.3	3.9	0.26	0.08	2.9	2.8	12.0	12.0	9.9	110	<0.03	<0.03
404485	06/23/92	<0.005	NA	82.9066	NA	0.06	14.0	14.0	9.0	0.07	0.06	<0.01	<0.01	5.8	5.5	<0.02	0.04	2.7	3.1	16.0	16.0	12.0	130	<0.03	<0.03
404486	06/22/92	<0.005	NA	664.4721	NA	0.08	34.0	32.0	46.0	5.40	0.09	0.18	0.18	29.0	28.0	0.76	18.80	130.0	130.0	66.0	66.0	21.0	690	<0.03	<0.03
404487	06/22/92	<0.005	NA	932.6993	NA	<0.05	30.0	27.0	66.0	0.56	0.11	0.19	0.16	37.0	37.0	0.10	34.50	200.0	200.0	96.0	93.0	22.0	970	<0.03	<0.03
404488	06/22/92	<0.005	NA	214.5818	NA	<0.05	40.0	39.0	9.7	0.32	0.04	0.05	0.06	14.0	14.0	1.20	0.13	5.2	5.4	24.0	24.0	16.0	260	<0.03	<0.03
404489	06/25/92	<0.005	NA	67.0568	NA	<0.05	17.0	17.0	1.6	0.71	0.04	0.06	<0.01	4.5	4.3	<0.02	0.05	0.8	0.7	2.9	3.2	8.9	77	<0.03	<0.03
404490	06/25/92	<0.005	NA	147.5250	NA	0.06	26.0	25.0	16.0	0.06	<0.04	0.01	<0.01	16.0	15.0	<0.02	0.02	4.0	3.8	30.0	29.0	39.0	210	<0.03	<0.03
404490	06/25/92	<0.005	NA	147.5250	NA	0.06	25.0	24.0	16.0	0.04	<0.04	0.01	<0.01	16.0	15.0	<0.02	0.02	4.1	4.0	30.0	29.0	38.0	210	<0.03	<0.03
404491	06/25/92	<0.005	NA	312.1190	NA	<0.05	33.0	30.0	76.0	0.36	<0.04	0.06	<0.01	10.0	8.4	0.04	2.50	25.0	24.0	120.0	130.0	53.0	540	<0.03	<0.03
404492	06/25/92	<0.005	NA	67.0568	NA	<0.05	17.0	18.0	1.6	0.14	<0.04	0.02	<0.01	4.1	4.2	0.04	0.02	0.7	0.6	2.8	2.9	9.0	73	<0.03	<0.03
404493	06/25/92	<0.005	NA	2450.6218	NA	<0.05	120.0	97.0	240.0	2.50	0.66	0.45	0.10	74.0	68.0	0.11	71.00	560.0	550.0	180.0	160.0	39.0	2200	<0.03	<0.03
404494	06/25/92	<0.005	NA	158.4979	NA	<0.05	38.0	38.0	8.1	0.63	<0.04	0.05	<0.01	11.0	11.0	2.10	0.16	3.5	3.3	16.0	15.0	18.0	200	<0.03	<0.03
404495	06/25/92	<0.005	NA	64.6184	NA	<0.05	17.0	17.0	1.4	0.53	<0.04	0.02	<0.01	4.2	4.2	0.02	0.06	0.9	0.5	3.0	3.0	9.3	73	<0.03	<0.03
404498	06/23/92	<0.005	NA	57.3031	NA	<0.05	10.0	10.0	2.8	0.70	0.34	0.02	0.01	3.9	3.9	0.05	0.08	2.5	2.4	6.8	7.0	3.6	110	<0.03	<0.03

Site-ID	date	Arsenic	Arsenic	Bicarbonate	Boron	Bromide	Calcium	Calcium	Cloride	Iron	Iron	Manganese	Manganese	Magnesium	Magnesium	Nitrate	Phosphate	Potassium	Potassium	Sodium	Sodium	Sulfate	TDS	Vanadium	Vanadium
		Total As	Diss. As	HCO3	Diss. B	Br	Total Ca	Diss. Ca	Cl	Total Fe	Diss. Fe	Total Mn	Diss. Mn	Total Mg	Diss. Mg	NO3+NO2-N	Tot.PO4-P	Total K	Diss. K	Total Na	Diss. Na	SO4		Total V	Diss. V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
404499	06/23/92	<0.005	NA	107.2909	NA	0.06	26.0	25.0	11.0	0.58	0.07	0.03	0.02	12.0	12.0	<0.02	0.04	2.6	2.4	20.0	21.0	46.0	220	<0.03	<0.03
404500	06/23/92	<0.005	NA	128.0176	NA	<0.05	10.0	10.0	2.9	1.10	0.39	0.03	<0.01	4.0	3.9	0.11	0.11	2.4	2.4	6.6	6.7	3.6	110	<0.03	<0.03
DRAIN	07/13/92	0.015	NA	229.2124	0.05	NA	62.0	62.0	22.0	<0.04	<0.04	<0.01	<0.01	18.0	18.0	17.00	0.07	7.5	7.0	36.0	35.0	46.0	390	0.03	NA

Appendix 4G

Project Groundwater Sampling Data

Detected Pesticides
and
Volatile Organic Compounds

(July 1990 - December 1994)

LOWER UMATILLA BASIN GROUNDWATER MANAGEMENT AREA

Volatile Organic Compound and Pesticide Detections
Detections from July 1990 through December 1994

VOC = Volatile Organic Compound
PEST = Pesticide
PLC = Probable Laboratory Contamination
Y = Yes
N = No
? = Uncertain

Site-ID	date	Dectected?	ETHYLENE DIBROMIDE 77651 (VOC) mg/L		1,1,2,2 TETRACHLOROETHYLENE 34475 (VOC) mg/L		CHLOROFORM 32106 (VOC) mg/L		TOLUENE 34010 (VOC) mg/L		ATRAZINE 39033 (PESTICIDE) ug/L	DACTHAL ACID (PESTICIDE) ppb
	yr-mo-dy											
MCL			0.00005		0.0050		0.1000		1.0000		3.00	
UMA003	910514	Y									0.20	
UMA044	900117	Y	0.0019	A								
UMA044	900117	Y	0.0021	B								
UMA044	901010	Y	0.0019	B								
UMA044	901010	Y	0.0026	B								
UMA044	901010	Y	0.0022	A								
UMA044	901010	Y	0.0016	A								
UMA044	920922	Y									1.30	
UMA044	920922	Y	0.0015	B								
UMA044	920922	Y	0.0015	A								
UMA062	900910	?			NA	B						
UMA062	900910	?			0.0009	A						
UMA067	901009	Y									2.30	
UMA068	900910	Y									0.60	
UMA094	911120	Y					0.0006	A				
UMA094	911120	Y					0.0007	B				
UMA101	910114	Y					0.0006	B				
UMA101	910114	Y					0.0028	A				
UMA116	940314	Y			0.0011							
UMA119	940713	Y										0.1
UMA125	931104	Y										0.6
UMA125	940127	Y										6.2
UMA125	940317	Y										20.0
UMA125	940711	Y										3.2
UMA133	940713	Y										0.4
UMA144	910130	Y							0.0013	B		
UMA144	910130	Y							0.0010	A		
UMA156	931104	Y										1.8
UMA156	940127	Y										6.1
UMA156	940317	Y										11.0
UMA156	940713	Y										0.1
UMA162	910514	Y									0.40	
UMA162	910514	Y									0.40	

Appendix 4H

Constituent vs Constituent Graphical Analysis

This project conducted constituent versus constituent graphical analysis to chemically identify sources contributing nitrate to Lower Umatilla Basin groundwater. Data presumably representing areas influenced by a single land use activity appeared as distinct groupings (fields) on chloride versus potassium, bromide versus potassium, and chloride/bromide versus chloride graphs. Not all potential sources are represented. Omitting these other sources should not be interpreted as vindicating their role as a nitrate contributor to the basin's groundwater.

Lower Umatilla Basin groundwater sampling data related to other areas were similarly graphed. Project analysis compared and noted where the other area data plotted relative to data fields presumably representing single land use activity influences.

The comparisons help indicate land uses possibly influencing local groundwater. The results alone are not conclusive. For example, some data related to areas with apparently no food processing activity graphed within the presumably food processing field. This and similar situations indicates a need to consider the comparison results with other analyses and information to properly identify local land use influences upon groundwater.

The results of the comparisons are presented in the tables that follow. Each table groups sampling sites within a common geographic area.

Table 4H.1 Constituent versus constituent analyses to identify human activity influencing Threemile Canyon and Sixmile Canyon area groundwater.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 271	Basalt (Elephant Mtn)	C	none above FP	FP & I
UMA 272	Basalt (multiple)	I	none near I	FP
UMA 273	Basalt (Elephant Mtn)	C	none near I & C	FP & I
UMA 274	Alluvial	none beyond I	none beyond I	FP
UMA 275	Alluvial	none beyond I	none beyond I	none beyond FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for Bromide

Note: This investigation identified no food processing wastewater land application occurring in this area. The FP is interpreted as representing irrigation related activity.

Table 4H.2 Constituent versus constituent analyses to identify human activity influencing Boardman area groundwater.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 002	Alluvial	FP	FP	FP
UMA 003	Basalt (basal Elephant Mtn)	none left of FP	FP	FP
UMA 028	Basalt (basal Elephant Mtn)	S	none near S	FP & I
UMA 029	Basalt (basal Elephant Mtn)	FP	FP	FP
UMA 030	Basalt (basal Elephant Mtn)	C	C	FP & I
UMA 031	Alluvial	I	none near I	C & FP
UMA 085	Alluvial	C	none between FP & C	FP
UMA 086	Alluvial	none near C & S	S	C & I
UMA 129	Basalt (basal Elephant Mtn/ Rattlesnake Ridge)	I	none near I	FP
UMA 170	Basalt (sub-Selah)	FP	FP	FP & I
UMA 179	Basalt (basal Elephant Mtn/ Rattlesnake Ridge)	FP	none left of S	ND
UMA 233	Alluvial-basal Elephant Mtn	--	--	FP next to I

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.3 Constituent versus constituent analyses to identify human activity influencing Port of Morrow area groundwater east of Boardman.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 176	Alluvial	I	I	I & C & FP
UMA 177	Alluvial	C	C	FP & I
UMA 178	Alluvial	I	none between C & I	FP next to C
UMA 201	Alluvial	C	none between C & I	FP
UMA 231	Alluvial	S next to I	S	S
UMA 232	Alluvial	I & S	I	S & I & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Table 4H.4 Constituent versus constituent analyses to identify human activity influencing groundwater in a crop irrigation area east of Boardman.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 159	Alluvial	I	I	I
UMA 160	Alluvial	--	I	I & S & FP
UMA 161	Alluvial	none beyond I	none near I	none beyond I
UMA 163	Alluvial	FP	none near S	ND
UMA 173	Alluvial	I	I	I
UMA 174	Alluvial	I	I	I
UMA 176	Alluvial	I	I	I & C & FP
UMA 231	Alluvial	S next to I	S	S
UMA 232	Alluvial	I & S	I	S & I & FP
UMA 270	Alluvial	S	C	S & I & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.5 Constituent versus constituent analyses to identify human activity influencing groundwater in the Irrigon area.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 026	Alluvial	S & I	S	S next to C
UMA 032	Alluvial	S	none near S	S
UMA 033	Alluvial	S	S	ND
UMA 034	Alluvial	S	S	ND
UMA 036	Alluvial	S	S	S
UMA 053	Alluvial	I	S	I & C
UMA 059	Alluvial	S	I near S	I & S & FP
UMA 099	Alluvial	S	S	ND
UMA 100	Alluvial	S	S	S & FP
UMA 102	Alluvial	S	S	S & FP
UMA 103	Alluvial	none between FP & C & S	none between C & FP	S & FP
UMA 144	Alluvial	S	S	S
UMA 180	Alluvial	FP & C	C	FP beyond C
UMA 266	Alluvial	I	I next to S	S
UMA 267	Alluvial	none next to I	S	none beyond I
UMA 268	Alluvial	C	C next to S	S
UMA 269	Basalt (basal Pomona)	S near I	I	I & S & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.6 Constituent versus constituent analyses to identify human activity influencing groundwater in the Irrigon to Umatilla area.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 037	Alluvial	C	C	I & FP
UMA 038	Alluvial	C & S	C	C & I & FP
UMA 054	Basalt	I	I	I & FP
UMA 095	Basalt (2 zones)	none right of S	I	I & FP
UMA 096	Alluvial	none next to C	none next to C & S	I & C
UMA 097	Alluvial	none next to S	none near C	I & FP next to S
UMA 103	Alluvial	none between FP & C & S	none between C & FP	S & FP
UMA 164	Basalt (basal Elephant Mtn/ Rattlesnake Ridge)	S	S	ND
UMA 269	Basalt (basal Pomona)	S near I	I	I & S & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.7 Constituent versus constituent analyses to identify human activity influencing groundwater in the U.S. Army Umatilla Depot Activity Ammunition Demolition Area (western Depot area).

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 202	Alluvial	S	FP	S & I & FP
UMA 203	Alluvial	S & I	I	S & I
UMA 204	Alluvial	I	none near I	FP
UMA 205	Alluvial	S	none between C & FP	I & S & FP
UMA 206	Alluvial	S next to I	I	I & S & FP
UMA 213	Alluvial	S	FP	S
UMA 214	Alluvial	I	I	C
UMA 215	Alluvial	none next to I	none above I	FP
UMA 276	Alluvial	S & I	I	I & S & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Constituent versus constituent fields representative of Depot activities were not established.

Table 4H.8 Constituent versus constituent analyses to identify human activity influencing groundwater in the U.S. Army Umatilla Depot Activity Active Landfill Area (northeast Depot area).

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 208	Alluvial	none left of FP	none left of FP	FP
UMA 219	Alluvial	none left of FP	none left of FP	FP
UMA 220	Alluvial	FP	none left of FP	S
UMA 222	Alluvial	FP	none left of FP	FP
UMA 223	Alluvial	none near FP & C & S	none left of FP	none below FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Constituent versus constituent fields representative of Depot activities were not established.

Table 4H.9 Constituent versus constituent analyses to identify human activity influencing groundwater in the U.S. Army Umatilla Depot Activity Explosive Washout Lagoon Area (central Depot area).

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 209	Alluvial	FP	none left of FP	S
UMA 210	Alluvial	FP	none next to FP	I & FP
UMA 221	Alluvial	FP	none next to FP	I & S & FP
UMA 224	Alluvial	I	I	I & FP
UMA 225	Alluvial	none right of S	none right of I	I & S & FP
UMA 226	Alluvial	S	next to FP	I & S & FP
UMA 227	Alluvial	FP	FP	I & S & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Constituent versus constituent fields representative of Depot activities were not established.

Table 4H.10 Constituent versus constituent analyses to identify human activity influencing groundwater in the U.S. Army Umatilla Depot Activity General and Inactive Landfill Areas (southern Depot area).

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 207	Alluvial	S	FP	S & I & FP
UMA 211	Alluvial	S	none next to S	S next to FP & I & C
UMA 212	Alluvial	S & FP	none between S & FP	S & I & FP
UMA 216	Alluvial	none left of FP	none left of FP	FP near I
UMA 218	Alluvial	FP	none left of FP	I & FP
UMA 228	Alluvial	FP	none left of FP	I & FP & S
UMA 229	Alluvial	S	none next to FP	S & I & FP
UMA 230	Alluvial	FP	none next to FP	I & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Constituent versus constituent fields representative of Depot activities were not established.

Table 4H.11 Constituent versus constituent analyses to identify human activity influencing groundwater in the agricultural area south of the U.S. Army Umatilla Depot Activity.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 079	Basalt?	FP	none near S	ND
UMA 112	Alluvial	none between FP & S	none next to S	S
UMA 133	Alluvial	FP	none between C & FP	C & FP
UMA 165	Basalt	FP	none near S	ND
UMA 166	Alluvial	none right of S	none right of S	ND
UMA 167	Alluvial	FP	FP	I & FP
UMA 168	Alluvial	FP	none between S & FP	S & FP
UMA 172	Basalt (upper Pomona?)	FP	FP	I & FP
UMA 181	Alluvial	FP	none left of S	ND
UMA 182	Alluvial	C	C	C & I
UMA 183	Alluvial	FP	FP	C & FP
UMA 184	Alluvial	FP	FP	S & I & FP
UMA 194	Basalt (basal Pomona?)	S	none near FP	S & I & FP
UMA 239	Alluvial	FP	FP	S & FP
UMA 240	Alluvial	none left of FP	none left of FP	FP
UMA 241	Alluvial	none right of S	none right of FP	S

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.12 Constituent versus constituent analyses to identify human activity influencing groundwater in the Butter Creek Area south of Interstate 84.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 080	Alluvial	FP & S	none next to S	S & I & FP
UMA 120	Alluvial	FP	none next to S	ND
UMA 122	Alluvial	FP	FP	FP
UMA 185	Alluvial	FP	none next to S	ND
UMA 186	Alluvial	S	FP	S & I & FP
UMA 187	Alluvial	FP	none left of FP	S & I & FP
UMA 242	Alluvial (shallow unconfined)	FP	FP	FP
UMA 249	Alluvial (shallow unconfined)	S	none near C & S	S & I & FP
UMA 251	Alluvial	FP	FP	FP
UMA 252	Alluvial	FP	FP	FP
UMA 253	Alluvial	FP	FP	FP
UMA 254	Alluvial (shallow unconfined)	S near FP	none between FP & S & C	S & I & FP
UMA 255	Alluvial (shallow unconfined)	S near FP	none next to FP	S & I & FP
UMA 256	Alluvial (shallow unconfined)	FP	FP	S & I & FP
UMA 257	Alluvial (shallow unconfined)	S	none between FP & S & C	S & I & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.13 Constituent versus constituent analyses to identify human activity influencing groundwater in the Butter Creek-Umatilla River confluence area.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 058	Alluvial	none between FP & I	none above I	FP
UMA 080	Alluvial	FP	none between FP & S	FP & S
UMA 081	Alluvial	C	C next to I	C
UMA 122	Alluvial	FP	FP	FP
UMA 245	Alluvial	FP	none between FP & S	S outside of FP & I
UMA 246	Alluvial (shallow unconfined)	C	C	FP
UMA 247	Alluvial	S	S	S & FP
UMA 248	Alluvial (shallow unconfined)	C	I	I & C
UMA 249	Alluvial (shallow unconfined)	S	none between FP & S & C	FP & I & S
UMA 250	Alluvial (shallow unconfined)	none between FP & I	none above I	FP
UMA 258	Alluvial (shallow unconfined)	FP	FP	FP
UMA 261	Alluvial (shallow unconfined)	FP	FP	FP & I

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.14 Constituent versus constituent analyses to identify human activity influencing groundwater in the Butter Creek Highway (Hwy 207) area north of Interstate 84 and east of the Umatilla River.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 069	Alluvial	C	C	C & I & FP
UMA 070	Alluvial	S	S	ND
UMA 072	Alluvial	S & I	I next to S	S & I & FP
UMA 073	Alluvial	S next to FP	FP	S & I & FP
UMA 077	Alluvial	FP	none between S & FP	S
UMA 081	Alluvial	C	C	C & FP
UMA 084	Alluvial	C	C	C & FP
UMA 088	Alluvial	none next to S & FP	S	C next to S
UMA 089	Alluvial	C	C	I & FP
UMA 119	Alluvial	C	C next to S	C & I
UMA 121	Alluvial	none next to FP	none next to FP	S & FP
UMA 134	Alluvial	C	C	C & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.15 Constituent versus constituent analyses to identify human activity influencing groundwater in the Butter Creek Highway (Hwy 207) area north of Interstate 84 and west of the Umatilla River.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 063	Alluvial	FP	FP	S & FP
UMA 078	Alluvial	S	S	S
UMA 088	Alluvial	none next to S & FP	S	C next to S
UMA 092	Alluvial	S	S	S
UMA 094	Alluvial	S next to FP	S	C
UMA 136	Alluvial	S & FP	S	S
UMA 138	Alluvial and Basalt	S	none next to S	S
UMA 181	Alluvial	FP	none left of S	ND
UMA 198	Alluvial	FP	none left of FP	FP
UMA 207	Alluvial	S	FP	S & FP & I
UMA 234	Alluvial	FP	FP	FP & C
UMA 235	Alluvial	FP	FP	FP next to I
UMA 236	Alluvial	FP	none between FP & S	S next to FP
UMA 237	Alluvial (shallow unconfined)	FP	FP	FP
UMA 238	Alluvial (shallow unconfined)	FP	FP	FP & I
UMA 243	Alluvial	I	S next to I	none next to I

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.16 Constituent versus constituent analyses to identify human activity influencing groundwater in the City of Umatilla and Hat Rock areas.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 037	Alluvial	C	C	I & FP
UMA 038	Alluvial	C & S	C	C & I & FP
UMA 065	Alluvial	none beyond I	none beyond I	FP
UMA 066	Alluvial	C & S	C	C & I & S & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.17 Constituent versus constituent analyses to identify human activity influencing groundwater in the terrace north of Hermiston.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 039	Alluvial	S	S	S
UMA 040	Alluvial	S	none right of S	ND
UMA 055	Alluvial	S	S	S
UMA 057	Alluvial	S	S	S
UMA 090	Uncertain	S	NA	NA
UMA 104	Alluvial	S	S	ND
UMA 106	Basalt (basal Pomona)	S	S	S & FP next to I
UMA 108	Uncertain	C	NA	NA
UMA 109	Alluvial	S	S	S & FP
UMA 113	Uncertain	S next to I	NA	NA
UMA 114	Alluvial and Basalt	S	NA	NA
UMA 116	Alluvial	S	none next to S & C	S & I & FP
UMA 117	Alluvial	S	S	S & FP
UMA 149	Uncertain	S & I	NA	NA
UMA 153	Uncertain	I	NA	NA
UMA 154	Uncertain	I	NA	NA
UMA 158	Uncertain	I	NA	NA

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.18 Constituent versus constituent analyses to identify human activity influencing groundwater in the Hermiston basin/trough.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 041	Alluvial	S	S	S
UMA 060	Alluvial	S	S	S
UMA 064	Alluvial	S	S & I	S & I & FP
UMA 068	Alluvial	none beyond S	none beyond I	S & FP
UMA 070	Alluvial	S	S	ND
UMA 072	Alluvial	S & I	I	S & I & FP
UMA 074	Alluvial	S	S	S
UMA 075	Uncertain	S & I	NA	NA
UMA 076	Alluvial	S	S & I	S
UMA 077	Alluvial	FP	none between FP & S	S
UMA 107	Alluvial and Basalt	S	NA	NA
UMA 115	Uncertain	none left of FP	NA	NA
UMA 126	Basalt (3 zones)	none right of S	none right of I	S & FP next to I
UMA 150	Uncertain	S	NA	NA
UMA 278	Alluvial	S	none between FP & C	S & I & FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.19 Constituent versus constituent analyses to identify human activity influencing groundwater in the terrace south of Hermiston.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 042	Alluvial	S	S	S & FP
UMA 043	Alluvial	S	none between C & S & FP	S & FP & I
UMA 044	Alluvial	FP & S	FP and between C & S	I & FP
UMA 045	Alluvial	S	none left of S	ND
UMA 046	Alluvial	FP	none left of S	ND
UMA 052	Alluvial	FP	FP	S & FP & I
UMA 056	Alluvial	FP	FP	FP
UMA 082	Alluvial	C	C	I & FP
UMA 087	Alluvial and Basalt	S	NA	NA
UMA 101	Alluvial	FP	FP	FP
UMA 110	Alluvial	S	none left of S	ND
UMA 111	Alluvial	none next to FP	none near S	ND
UMA 124	Alluvial	none next to S, near FP	none between FP & C	FP & I
UMA 125	Basalt (basal Pomona?)	FP	S	I
UMA 151	Alluvial and Basalt	S	NA	NA
UMA 152	Uncertain	S	NA	NA
UMA 155	Uncertain	S	NA	NA
UMA 156	Alluvial	S	none left of S	ND
UMA 195	Alluvial	FP	none left of S	ND
UMA 200	Alluvial	FP	none near FP	S
UMA 263	Alluvial	none left of FP	none left of FP	FP

UMA 264	Alluvial	FP	none left of FP	FP
UMA 265	Alluvial	FP	FP	S & I & FP
UMA 278	Alluvial	S	none between FP & C	S & I & FP

Note: C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.

Table 4H.20 Constituent versus constituent analyses to identify human activity influencing groundwater in the Echo Meadows and Umatilla Meadows area.

Well	Aquifer	Cl vs K Graphs	Br vs K Graphs	Cl/Br vs Cl Graphs
UMA 047	Basalt	FP	FP	FP & I & S
UMA 048	Alluvial	FP	none near FP	S & FP next to I
UMA 049	Alluvial	FP	none left of S	ND
UMA 051	Basalt (multiple)	none beyond S	none beyond I	FP & S & I
UMA 052	Alluvial	FP	FP	FP & S & I
UMA 118	Basalt?	S	S	ND
UMA 188	Basalt (multiple)	none beyond I	none beyond I	FP
UMA 189	Alluvial	FP	none left of S	ND
UMA 190	Alluvial	FP	none left of S	ND
UMA 191	Alluvial	FP	none between FP & S	S next to FP
UMA 192	Alluvial	I	S	S & FP next to I
UMA 193	Alluvial	FP	none left of S	ND
UMA 196	Basalt?	FP	FP	FP & I & S
UMA 244	Alluvial (shallow unconfined)	FP	none left of S	ND
UMA 259	Alluvial	FP	none left of S	ND
UMA 260	Alluvial (shallow unconfined)	FP	none between FP & S	C & I
UMA 262	Alluvial	S next to I	S	S next to FP

Note:
C = Confined Animal Operation
I = Irrigated Crop Agriculture
FP = Food Processing Wastewater
S = Septic System
ND = Bromide not detected by laboratory analysis
NA = No laboratory analysis for bromide

Note: Some FP in the table are interpreted as representing irrigation related activity based upon local land use activity identified.