

GROUNDWATER QUALITY REPORT FOR THE KLAMATH BASIN, OREGON

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State of Oregon
Department of
Environmental
Quality



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EXECUTIVE SUMMARY

Preventing groundwater contamination and conserving and restoring this resource are statewide goals in Oregon. Groundwater monitoring and assessment programs provide statewide groundwater quality information. The groundwater is an important natural resource in the Klamath Basin, providing drinking water to 134 public water systems, serving over 60,000 people, and over 9,000 private residential systems.

The Klamath Basin is located in south-central Oregon, and encompasses most of Klamath County, and portions of Jackson and Lake counties. The major land use in the Klamath Basin is Forest (75%). Agricultural land and Range land each comprise about ten percent of the basin's area. The remaining land use categories (water/wetland, urban, and mountainous terrain) make up about five percent of the basin's total area.

Klamath Basin geology consists predominantly of volcanic rocks. Minor amounts of sedimentary rocks and unconsolidated sediments also occur in the basin. Important groundwater sources include both shallow alluvial aquifers and deep basalt aquifers.

The Department of Environmental Quality (DEQ) and other state and local agencies have collected data and conducted several groundwater quality studies in the Klamath Basin. This report compiles and summarizes groundwater quality information from the following sources:

- The Oregon Department of Human Services (DHS) Domestic Well Testing for Real Estate Transactions program.
- The Oregon DHS Public Water Systems program.
- Four DEQ studies.

Over the course of these studies, the following constituents were analyzed:

- Nitrate
- Bacteria
- Volatile Organic Compounds
- Physical parameters
- Metals
- Pesticides

DEQ studies of private, domestic water wells in the basin show some constituents exceed federal Maximum Contaminant Levels (MCLs). These constituents include nitrate, arsenic, volatile organic compounds (VOCs), and bacteria. The VOCs were due to leaking underground gasoline storage tanks. The VOC-contaminated groundwater was a local problem, rather than a regional, aquifer-wide problem. The bacteria contamination may have been due to substandard well construction and poor well maintenance practices. This contamination was a local problem, and not a regional, aquifer-wide problem.

The Department of Human Services, Drinking Water Program database shows numerous constituents have exceeded MCLs in some Public Water Systems (PWS). These constituents include nitrate (1 PWS), bacteria (50 PWS), lead (3 PWS), cadmium (5 PWS), thallium (1 PWS), arsenic (1 PWS), beryllium (1 PWS), cyanide (1 PWS), pentachlorophenol (2 PWS), and methylene chloride (1 PWS).

Potential sources for Klamath Basin groundwater nitrate and bacteria contamination include the following:

- High on-site septic system densities in areas with permeable, sandy soils.
- Land application of nitrate-laden commercial and industrial wastewater.
- Substandard domestic well construction and poor maintenance practices, allowing for surface water contamination to penetrate the well casing.

Arsenic in groundwater can come from several sources, including the following:

- Naturally occurring arsenic-containing minerals, especially in volcanic rocks.
- Arsenic-containing pesticides and wood preservatives.

Further investigations and monitoring are warranted in local areas where contaminants have been found. Recommendations include the following:

- Establish a well monitoring network in the Klamath Falls area and conduct monitoring on a periodic basis to track groundwater quality changes over time.
- Establish a well network and implement a sampling event in the Klamath Falls – Merrill area, as directed in the Statewide Ambient Groundwater Monitoring Program’s Master Plan.
- Conduct public outreach to educate private well owners how to protect and maintain their wells.
- Provide owners of property with septic systems information on maintaining and improving system performance.
- Provide industrial and commercial businesses with best management practices for land application of process wastewater.
- Provide agricultural businesses with best management practices for fertilization processes.
- Provide livestock businesses with best management practices for waste handling.

INTRODUCTION

In 1989, the Oregon Legislative Assembly passed a comprehensive set of laws known as the Groundwater Protection Act. These laws established the state goal to prevent groundwater contamination:

"... it is the goal of the people of the State of Oregon to prevent contamination of Oregon's groundwater resource while striving to conserve and restore this resource and to maintain the high quality of Oregon's groundwater resource for present and future uses." (Oregon Revised Statutes [468B.155](#))

The Department of Environmental Quality (DEQ), the Water Resources Department, and Oregon State University are directed to:

"... conduct an ongoing statewide monitoring and assessment program of the quality of the groundwater resource of this state." (Oregon Revised Statutes [468B.190](#))

Other state agencies, including the Department of Human Services and local agencies, also conduct groundwater monitoring and assessment programs.

This report presents the following for the Klamath Basin:

- A compilation of groundwater quality data from the Oregon Department of Environmental Quality and other state and local agency studies.
- Summary information with references to other reports when available.
- Links to data repositories or on-line information and data sources.
- Status updates for local studies in the Klamath Basin.
- Background information on the Klamath Basin's environmental setting.
- General information about geology and hydrogeology.
- Groundwater use information.
- A discussion of potential pollutant sources in the basin.
- An evaluation of the Klamath Basin's overall groundwater quality status.
- Recommendations for potential actions that could be taken.

ENVIRONMENTAL SETTING

Geography

The Klamath Basin occupies about 5,700 square miles in southern Oregon (Figure 1). The Oregon Water Resources Department (OWRD) Map No. 14 defines the Klamath Basin for water management purposes. The Klamath Basin is one of the 18 major river drainage basins in the state.

Location of Klamath Basin



Figure 1. Location of the Klamath Basin in Oregon.

The Klamath Basin encompasses most of Klamath County, and portions of Jackson and Lake counties (see Figure 2, below). The basin's southern, political boundary, coincides with the Oregon – California state line. The basin's southern, physical boundary, however, continues into northern California.

The Klamath Basin shares its eastern and northeastern border with the Goose and Summer Lakes basin. Fault-block ridges and valleys (horsts and grabens) characterize this part of the state, also referred to, geomorphologically, as the Basin and Range physiographic province.

The Klamath Basin shares its northern border with the Deschutes Basin. This part of the state is known as the High Lava Plains, so named for the relatively flat lying lava flows and associated volcanic deposits, occupying elevations of around 4,000 feet above mean sea level.

The Klamath Basin shares its northwest and western borders with the Umpqua and Rogue basins, respectively. This portion of the state is in the High Cascades physiographic province, and includes such prominent landmarks as Crater Lake National Park, and Mt. McLoughlin (9,495 ft).

Figure 3 on the next page shows the Klamath Basin's major geographic features.



Figure 2. Klamath Basin and Oregon Counties.

Klamath Basin Geography

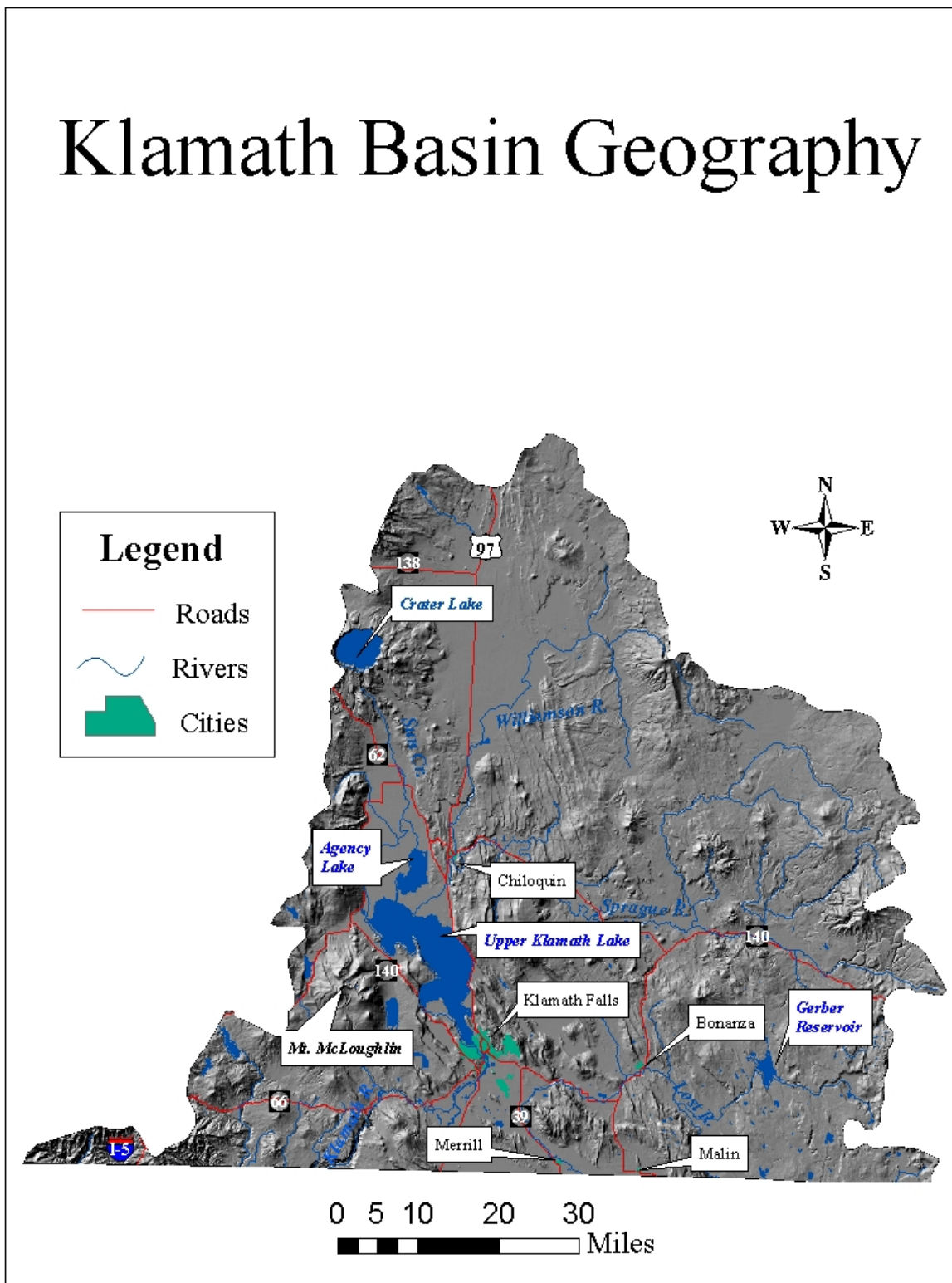


Figure 3. Map of Klamath Basin, showing major geographic features.

Land Use and Population

The predominant land use in the Klamath Basin is Forest (75%). Agricultural Land and Range Land each comprise about ten percent of the basin's area. The remaining land use categories make up about five percent of the basin's total area (Figure 4).

The resident population within the Klamath Basin is about 64,800 (U.S. Census Bureau, 2003 estimate). Major industries in the basin include wood products, ranching, agriculture, tourism, and recreation.

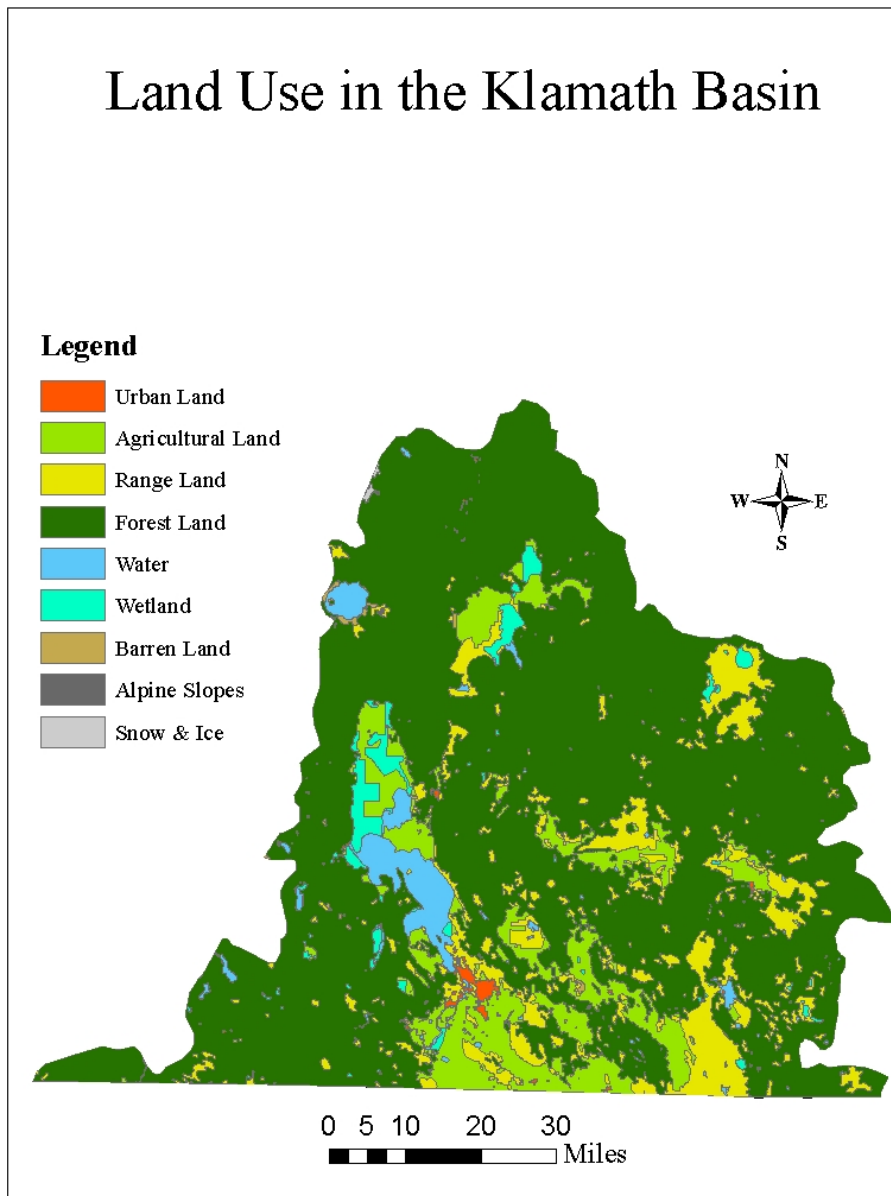


Figure 4. Land Use in the Klamath Basin, Oregon.

Climate and Precipitation

The climate in most of the Klamath Basin is semi-arid, with total average annual precipitation measuring 20-inches or less. The more mountainous portions of the basin receive more precipitation, up to about 70-inches on the basin's extreme western border, in the High Cascades. Figure 5 shows the average annual precipitation distribution in the Klamath Basin.

The wettest months in Klamath Falls are November through January, and the driest months are July through September. The average monthly precipitation in November, December, and January is about 2-inches. In July, August, and September, precipitation rarely exceeds 0.5-inches.

Temperatures vary greatly in the Klamath Basin, depending on location and time of year. In Klamath Falls, for example, the average high temperature occurs in July or August at about 83°F. The average low temperature occurs in December or January at about 21°F. By contrast, at Crater Lake the average high temperature occurs in August at a noticeably lower value of about 69°F, while the average low occurs in January or February at about 18°F. This information comes from the Oregon Climate Service, and includes data from 1961 to 2004 (<http://www.ocs.orst.edu/>).

Annual Precipitation Distribution in the Klamath Basin

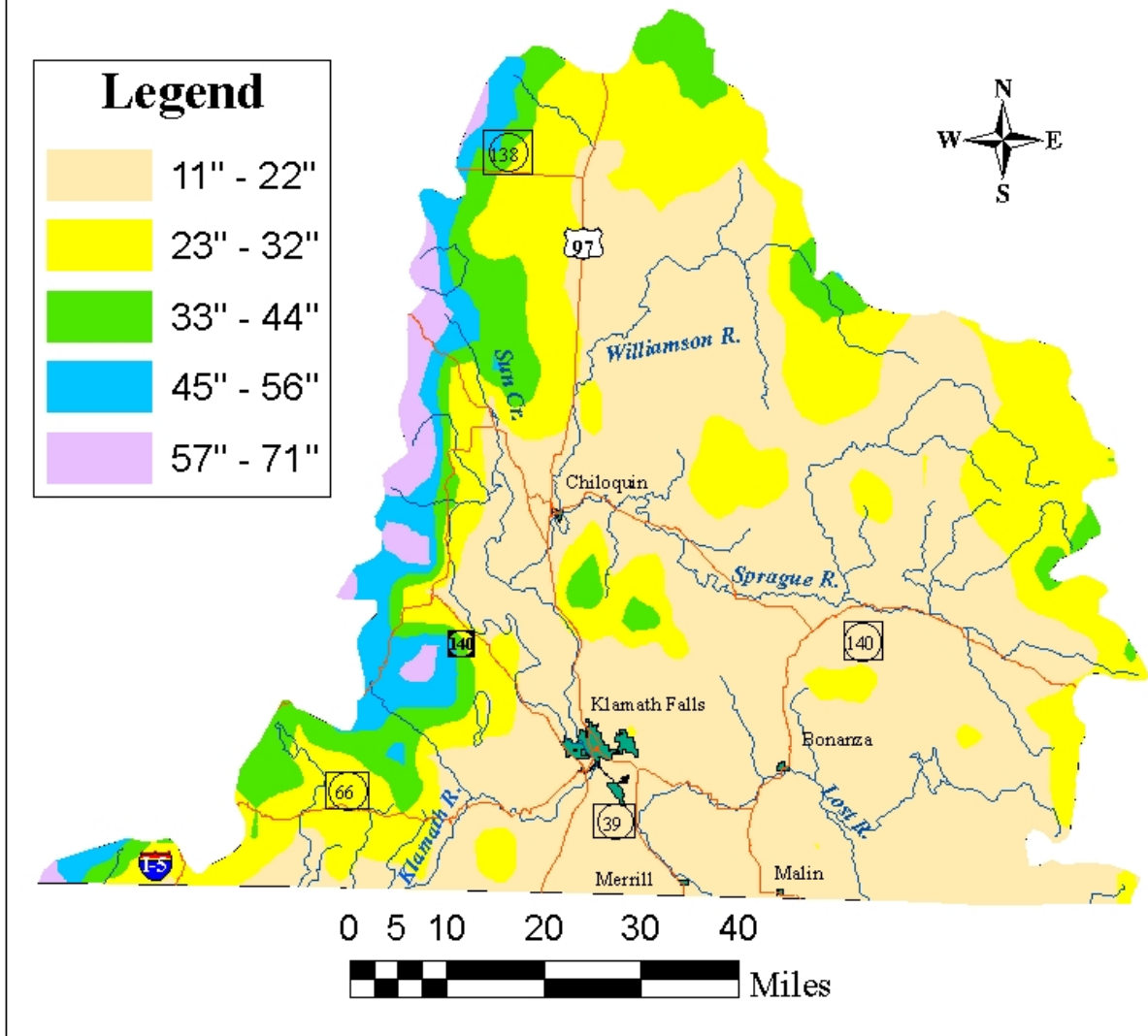


Figure 5. Map of annual precipitation distribution in the Klamath Basin.

Geology

Volcanic rocks dominate the Klamath Basin's geology. Initial volcanic activity began in the Miocene, and continued into the Pleistocene. This activity produced basalts, tuffs, and tuffaceous sediments. As the crust thinned and fissures appeared, magma erupted to cover the area. A broad shield volcano near Steens Mountain, east of the Klamath Basin, extruded basalts and ash. Later, numerous large calderas in the southeastern part of the state erupted thick ash deposits, and were the source of voluminous stream-deposited sediments in the basin. Geophysical evidence suggests the crust is so thin in this part of the Basin and Range province, that the Miocene aged rocks actually represent the basement, or oldest rocks, in the province.

The valley fill sediments and sedimentary rocks occur as lacustrine, fluvial, and volcanoclastic deposits. These deposits range in thickness from a few feet to hundreds of feet, and overlie volcanic rocks. Some basalt dikes, sills, and flows occur within the valley fill.

In Pleistocene time, beginning about 2 million years ago and continuing as late as 15,000 years ago, continental ice sheets advanced southward. Accompanying the ice was increased precipitation. Rainfall and mountain runoff filled the great depressions or valleys between the mountainous ridges. At the peak of the moist Pleistocene environment, vast freshwater lakes covered much of the state. The largest of these lakes was ancient Lake Modoc. The lake covered over 1,000 square miles, and was almost 75 miles long. Today, in the relatively warm and dry interglacial period, Lake Modoc has shrunk to occupy what is now Upper and Lower Klamath Lakes in Oregon, and Tule Lake in California. As Lake Modoc's size shrunk in response to a drying climate, the basins were no longer connected. Individual basin water levels fluctuated variously among the now separated and smaller lakes. Yonna and Langell valleys in the Klamath Basin's eastern portion, were once part of ancient Lake Modoc.

Much of the Klamath Basin is included in the Basin and Range Physiographic province. The predominant tectonic regime in the Basin and Range province is crustal extension, or stretching, and the movement of large tectonic blocks. This tectonic activity has produced a series of long, narrow, north-south trending fault-block mountain ranges, alternating with broad basins. The Klamath Basin's complex of faults and fissures give the basin its characteristic tilted, raised mountains, and down-dropped basin structure.

Numerous hot springs occur in the Klamath Basin. Due to extensive basin faulting, rainwater percolates downward and encounters hot rocks. The rainwater recirculates to the surface under pressure, and emerges as hot springs. For example, hot springs southwest of Lorella occur in the vicinity of intersecting faults, in the eastern Lost River sub-basin. The geothermal resources in the basin supply heat for greenhouse and aquaculture operations, as well as space heating.

The most striking geologic feature on the western edge of the Klamath Basin is Crater Lake. Some 6,900 years ago a volcano known as Mount Mazama, once stood about as high as northern California's Mount Shasta. Mt. Mazama erupted violently, like Mt. St. Helens did in 1980, only on a much larger scale. After ejecting tremendous volumes of pumice, ash, and volcanic dust, the mountain collapsed. Rainwater and snow melt eventually filled in the collapse structure, creating Crater Lake, Oregon's only National Park.

Generalized Geologic Map of the Klamath Basin

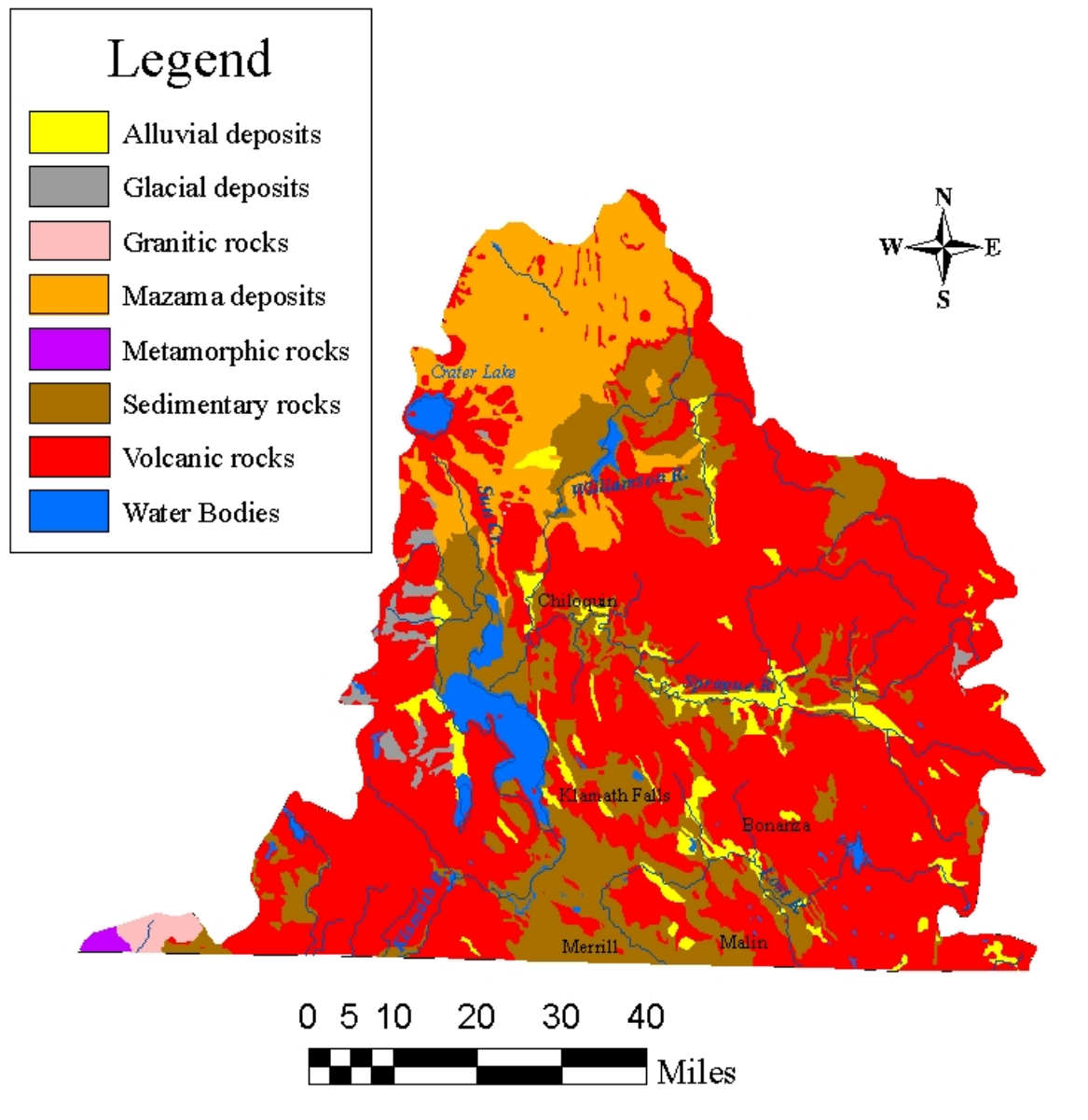


Figure 6. Generalized geologic map of the Klamath Basin.

Hydrogeology

Groundwater use in the Klamath Basin comes from wells completed in both shallow and deep aquifers. The vast majority of shallow wells in the basin are completed in valley fill sediments and sedimentary rocks. Wells completed in the basin fill sediments and sedimentary rocks are generally low yield, suitable for most domestic uses, but inadequate to satisfy irrigation needs, in the basin's intensely irrigated agricultural areas. The deeper and significantly more productive wells are completed in volcanic rocks, principally basalts. These wells supply irrigation water to the basin's agricultural fields, and supplement surface water allocations. Valley margin faults in the Klamath Basin provide abundant water for many high production wells.

Because land use in the basin includes large areas of intensely irrigated agriculture, water is a most precious commodity. In 1996 applications for 32 groundwater permits required the Oregon Water Resources Department (OWRD) to conduct scientific research in the matter. One of the questions OWRD had to answer was whether groundwater use under the permits would significantly diminish flows in the Lost River or Bonanza Big Springs. Another major issue OWRD had to determine was whether groundwater use has caused long-term water level declines.

An OWRD study was conducted to address these issues (Grondin, 2004). This study found most of the groundwater permits and associated wells are located in the Bonanza area, and that the wells are directly connected to the Lost River via Bonanza Big Springs. This is an important issue because Bonanza Big Springs is a drinking water source for the city of Bonanza. The study's data indicated that the potential negative impact to the Lost River is greatest in this part of the basin. The study used various calculations to assess potential negative impact from groundwater pumping to Lost River stage, under two scenarios: maximum permitted rate, and typical, historical use. Under the worst case scenario, after pumping at the maximum rate for 184 days, the predicted drawdown at Bonanza Big Springs is just over seven feet. Given the current management of the Lost River, the calculated total groundwater drawdown, under typical pumping rates, would be sufficient to stop the Bonanza Big Springs flow in most years.

Other areas in the Lost River sub-basin show less impact under typical and maximum groundwater pumping rates. Some areas show essentially no impact, due to lower aquifer transmissivities and boundary conditions. Water level monitoring shows groundwater levels decline and recover seasonally and over multiple years. Seasonal fluctuations correspond to the groundwater use and recharge. Fluctuations over multiple years correspond to changes in long-term precipitation trends. Despite increasing groundwater use over the decades, water level monitoring shows well use has not caused excessively declining groundwater levels, as defined in Oregon Administrative Rule ([OAR 690-08-001](#)). To summarize these rules, water well use has not caused excessive declines in groundwater levels, if the use has not caused the following conditions to occur:

- Preclude perpetual use of the aquifer.
- Induce pumping to exceed economic levels.
- Interfere with a senior surface water diversion, in-stream water right, or exceed minimum stream flows.

- Induce water level drawdown greater than 50 feet below the highest known water level.
- Induce groundwater pollution.

Groundwater is generally hydraulically interconnected between the basin fill aquifers, and the underlying basalt aquifers. While irrigation canals are used in the basin, leakage from the canals has essentially no effect on the groundwater in the basalt aquifers, except at certain, localized sites. The basin's deeper, higher yield aquifers are hydraulically connected to the rivers. Groundwater discharge is greatest at fault-controlled valley floor springs where the host rock is at or near land surface. The discharge is least where overlying basin fill deposits are the thickest. Groundwater flow in both the basin fill sediments, and the underlying basalt aquifers is predominantly horizontal.

Based on 1996 amendments to the Safe Drinking Water Act, the Oregon Department of Human Services (DHS) is certifying groundwater sources of drinking water. The DEQ is certifying surface water sources. Sweet and others (1980) produced a statewide map of aquifers sensitive to contamination. Figure 7 shows the locations of groundwater-based drinking water protection areas, in relation to the sensitive aquifers in the Klamath Basin.

The sensitive aquifers shown in the figure are based on saturated, near-surface alluvial sediments. Since the basin's geology includes fractured and faulted rocks, some of the basin's basalt aquifers should also be considered sensitive or vulnerable to contamination from human activities.

Groundwater-Based Drinking Water Protection Areas and Sensitive Aquifers

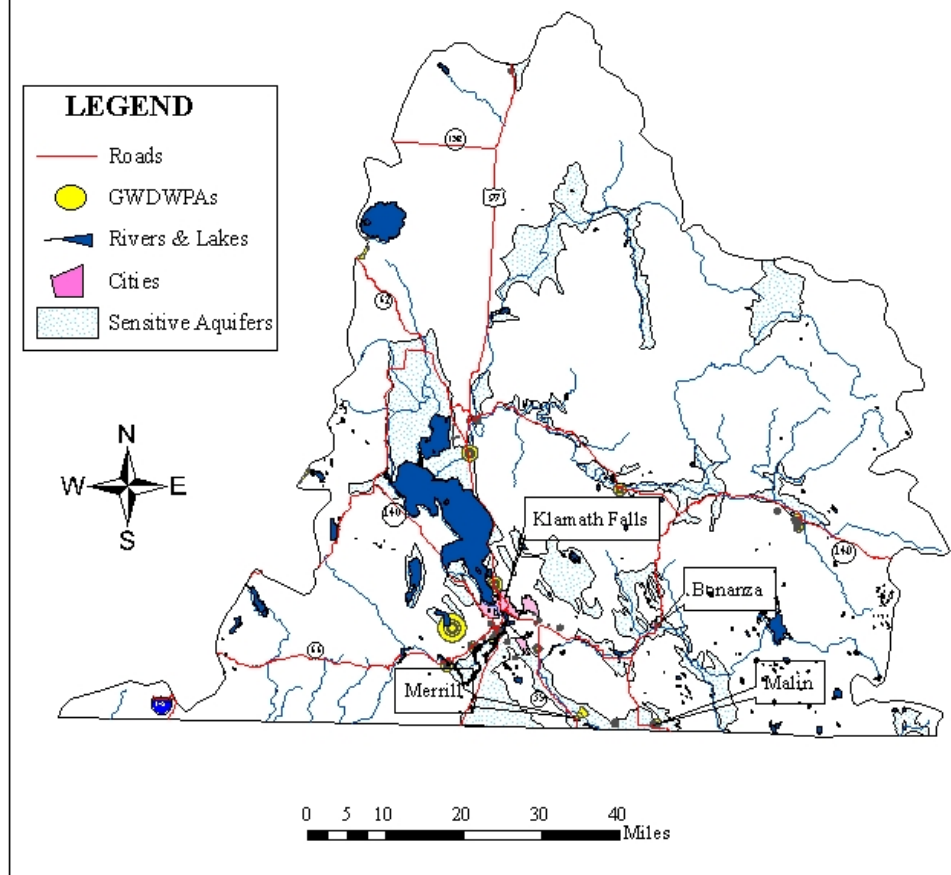


Figure 7. Groundwater-based drinking water protection areas and sensitive aquifers in the Klamath Basin.

GROUNDWATER USE

Overview

The Oregon Water Resources Department (OWRD) manages statewide groundwater use through water rights applications, permits, certificates, transfers, and leases. Groundwater in the Klamath Basin is available for such beneficial uses as the following ([OAR 690-500-0010\(5\)](#)):

- Domestic
- Livestock
- Municipal
- Irrigation
- Power development
- Industrial
- Mining
- Recreation
- Wildlife
- Fish life

Exempt uses do not require a permit. Exempt uses ([ORS 537.545](#)) include the following:

- Domestic use under 15,000 gallons a day.
- Stock watering.
- Small lawn or garden watering.
- School grounds watering.
- Down-hole heat exchange.
- Industrial or commercial use less than 5,000 gallons a day.
- Land application associated with permitted uses.

Klamath Basin groundwater use is discussed in more detail below. Specific water right information can be accessed through the OWRD website at: [OWRD Water Rights](#).

Groundwater Rights

OWRD information shows a total of 3,023 points of diversion (POD) in the Klamath Basin. Of these, 829 are groundwater-based. These PODs provide water for the following uses:

- Campground
- Domestic
- Fish
- Irrigation
- Manufacturing
- Municipal
- Stock
- Wildlife

Figure 8 illustrates the locations of these groundwater-based PODs.

Groundwater-Based Points of Diversion in the Klamath Basin

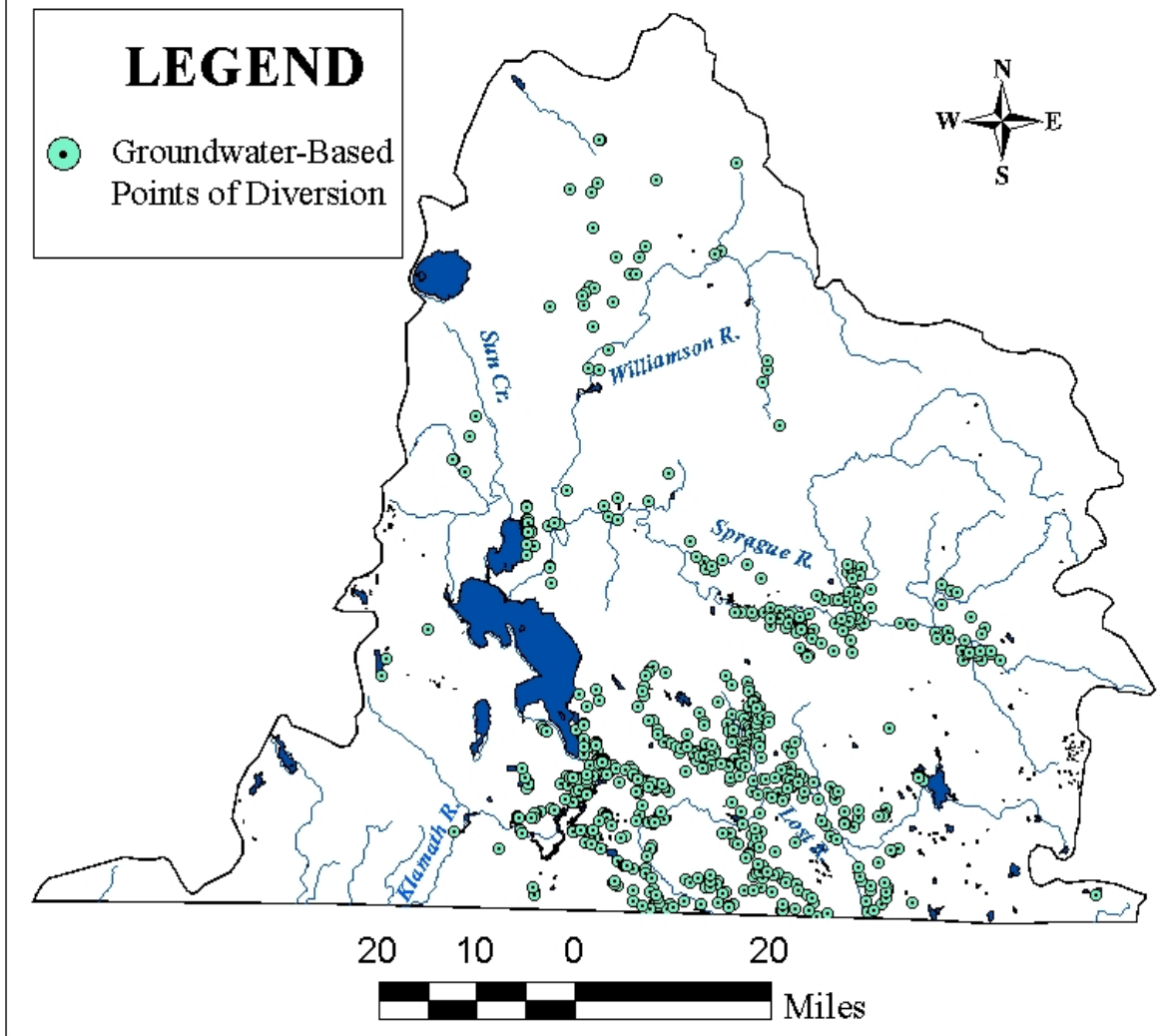


Figure 8. Locations of Groundwater-Based Points of Diversion in the Klamath Basin.

Domestic and Other Exempt Uses

No permit is required to use groundwater for domestic purposes. Current statutes ([ORS 537.765](#)) and administrative rules ([OAR 690-205-0210](#)) require well logs to be filed with OWRD upon well completion. The OWRD maintains a database of well logs, and can be found at the following web site: [OWRD Well Logs](#).

The number of private, domestic water wells constructed and reported to OWRD estimates how many potential domestic water users exist. The database contains 11,206 well logs on file for the Klamath Basin (B. Devyldere, personal communication, 7-27-05). Of these, 1,253 are geotechnical well logs, 861 are monitoring well logs, and 9,092 are water well logs. The number of water wells in the basin is probably higher since, prior to 1955, state law did not require water well owners to file well logs for wells drilled and completed on their property (T. Eichenlaub, OWRD, oral communication to David Cole, DEQ, 8/11/03).

Public Water Systems

The Klamath Basin has 134 groundwater-based Public Water Systems (PWS). These systems are designed to provide water for over 60,000 people. Figure 9 shows the system locations. Many of these PWS use more than one well to provide the drinking water. Many of these PWS also have backup wells in case of emergency.

Water quality information for individual systems is available through the Oregon Department of Human Services Drinking Water Program, and can be accessed on-line at: [DHS Public Water Supply Inventory](#).

Groundwater-Based Public Water Supply Locations in the Klamath Basin

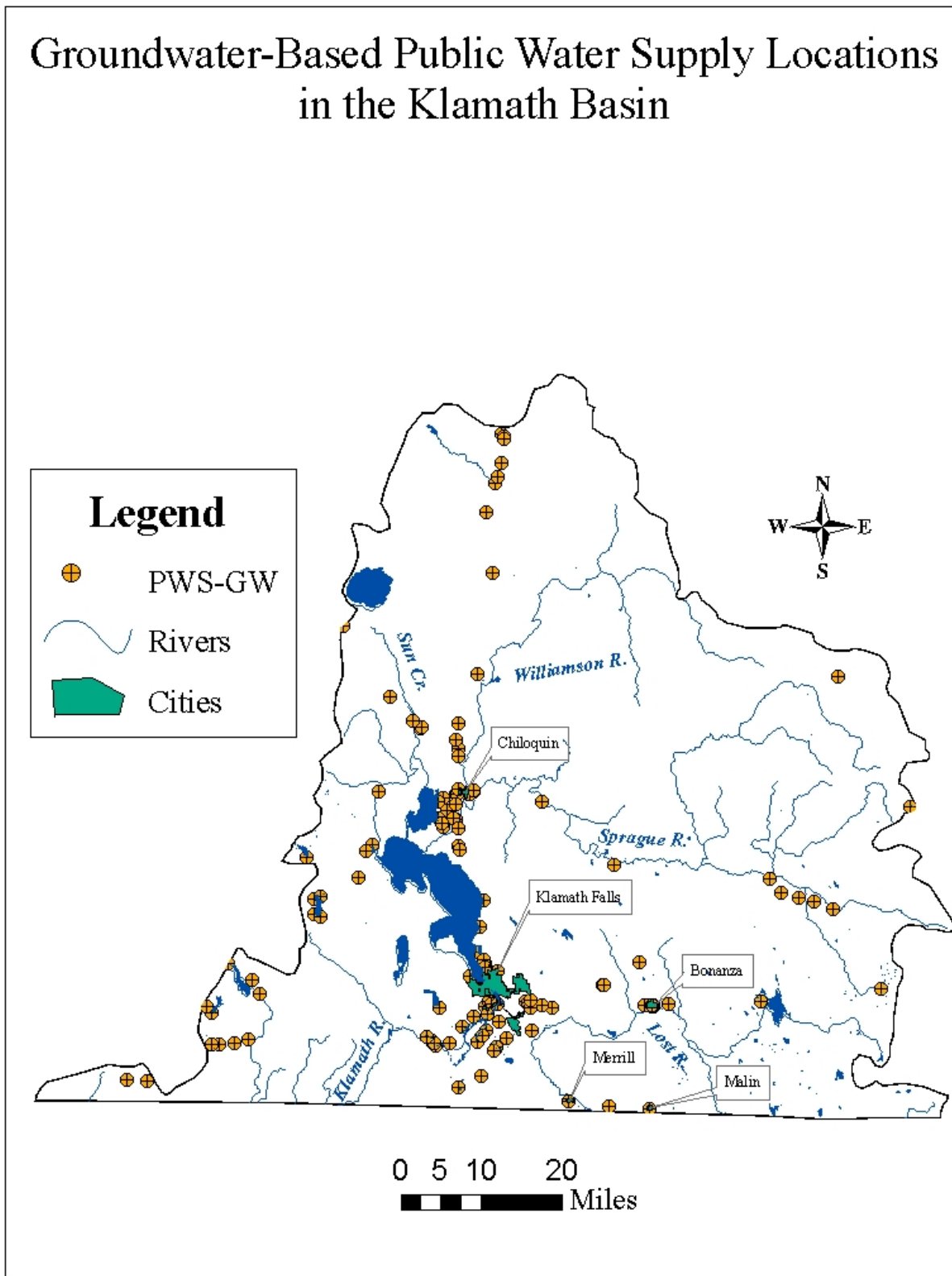


Figure 9. Locations of Groundwater-Based Public Water Systems in the Klamath Basin.

GROUNDWATER QUALITY CONCERNS

In April 1986, the DEQ submitted a grant application to the EPA, requesting funding to support a statewide assessment of the impact of agricultural activities on groundwater. An inter-agency committee collaborated to identify 12 areas in Oregon that were vulnerable to pesticide groundwater contamination. Klamath Falls was one of the areas identified and prioritized for investigation. A discussion of this study and its results is presented below.

In 1992 the DEQ began to develop the Statewide Ambient Groundwater Monitoring Program. A major component of this program was the Master Plan. This plan identified and prioritized 32 areas in the state that are vulnerable to groundwater contamination from anthropogenic activities. One of these areas is the Klamath Falls – Merrill area. Due to limited resources, this area has yet to receive groundwater quality sampling.

GROUNDWATER QUALITY STUDIES

Overview

The Groundwater Quality Protection Act mandates the DEQ and other state agencies to conduct on-going statewide groundwater quality monitoring and assessment (ORS [468B.190](#)). The DEQ and other state agencies have collected data and conducted several groundwater quality and quantity studies in the Klamath Basin. Statewide and regional assessments conducted in the early 1980s provided initial groundwater quality information.

In February 1987, as part of the DEQ's Assessment of Oregon's Groundwater for Agricultural Chemicals, the DEQ performed the initial sampling. In March 1987, the DEQ conducted confirmational resampling.

In November 1989, the DEQ returned to the Klamath Falls area and conducted another groundwater quality sampling event.

In 1995 and 2001, the DEQ conducted groundwater quality sampling in the Keno area. The DEQ conducted this study to address concerns that one or more leaky underground storage tanks (LUSTS) had contaminated the local groundwater resource.

In 1995, the DEQ conducted groundwater quality sampling in southern Klamath Falls. In this area a wastewater land application process had the potential to contaminate the local groundwater resource.

The DEQ has collected and analyzed groundwater samples at two permitted landfills in the Klamath Basin. These are the Klamath Falls and Collins Forest Products landfills, in the vicinity of Klamath Falls. The [Solid Waste Facilities](#) section of this report summarizes water quality monitoring results from sampling events conducted at these landfills.

This report summarizes information and studies in order of basinwide studies, and then area studies. Figure 10 shows the study area locations. The following section discusses the results.

Basinwide Studies

- [Domestic Well Testing](#) for Real Estate Transactions; Oregon Department of Human Services.
- [Public Water Systems](#); Oregon Department of Human Services.

Area Studies

- Klamath Falls Groundwater Quality Study (1987); Oregon Department of Environmental Quality (DEQ).
- Klamath Falls Groundwater Study (1989); Oregon Department of Environmental Quality.
- Keno Groundwater (1995, 2001); Oregon Department of Environmental Quality.
- Masami Foods Groundwater (1995); Oregon Department of Environmental Quality.

Klamath Falls Study Areas

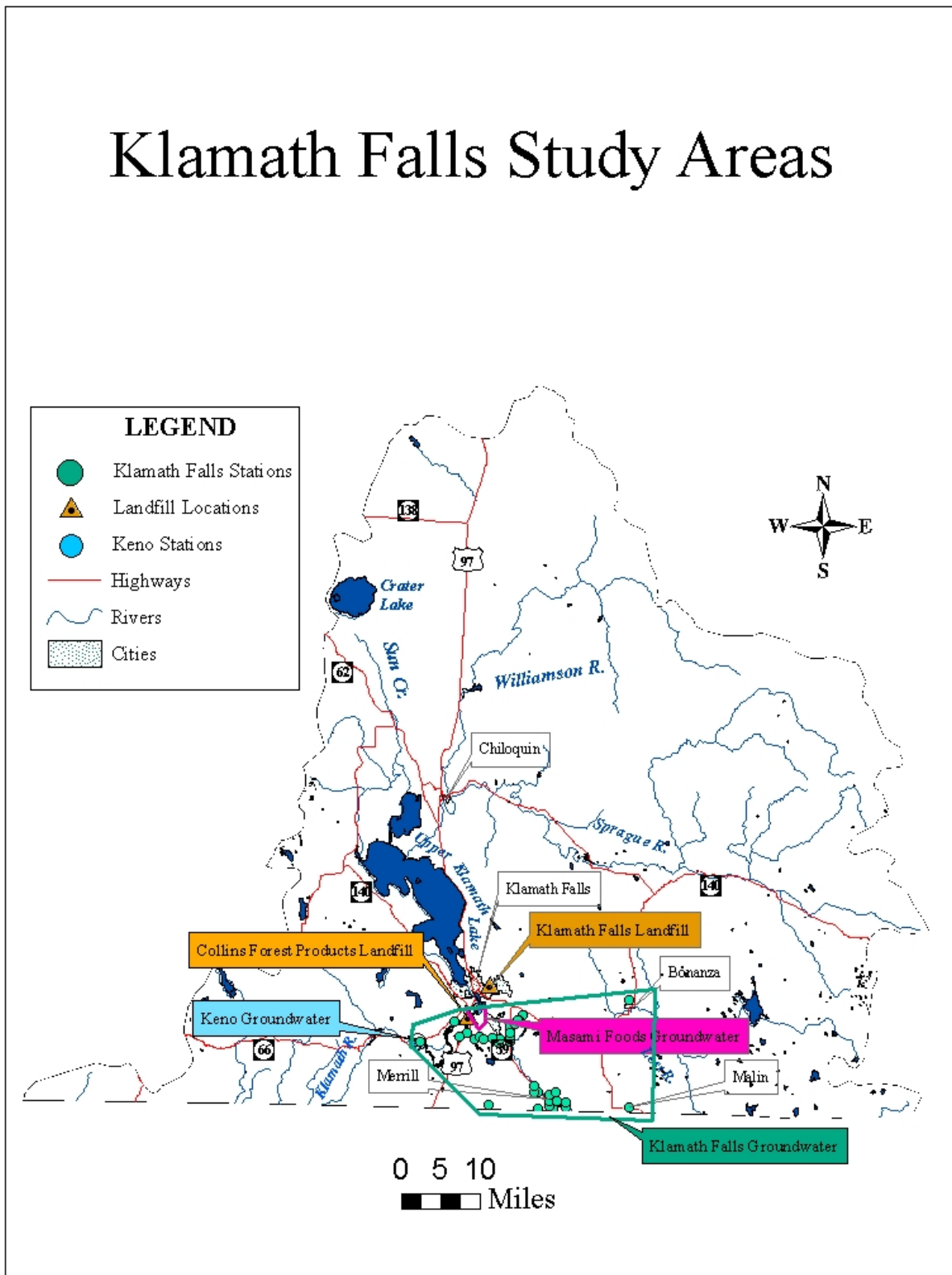


Figure 10. Locations of Groundwater Quality Study Areas in the Klamath Basin.

Basinwide Studies

Domestic Well Testing for Real Estate Transactions

Oregon Department of Human Services

Summary

In 1989, Oregon established a program to monitor the quality of groundwater used for domestic purposes (ORS 448.271). For any real estate transaction involving a domestic water supply well, the seller must test the well water for nitrate and total coliform bacteria. The seller must complete and submit a Water Systems Data Sheet, including the laboratory test results, to the Oregon Department of Human Services (DHS).

Results

The DHS database shows 894 tests have been performed for nitrate and bacteria in the Klamath Basin. The testing results includes data compiled between 1987 and 2003. The following summarizes the testing results:

- 393 of the tests analyzed for nitrate. Seven of these (2%) exceeded the drinking water standard of 10 mg/L.
- 85 of the nitrate tests (22%) had levels between 2 mg/L and 10 mg/L.
- 301 of the nitrate tests (76%) had levels less than 2 mg/L, the approximate cutoff point, above which indicates impacts arising from anthropogenic activities. Concentrations less than 2 mg/L may be natural background, may be due to land use activities, or a combination of the two (DHS, Drinking Water Program, [Nitrate Fact Sheet](#)).
- 501 of the tests analyzed for bacteria, 37 of which (4%) were positive.

Information about the Real Estate Transaction Domestic Well Testing Program is available online at [Domestic Well Testing](#). Data can be obtained from the DHS or the DEQ. Figure 11 shows the locations of the nitrate testing results. Figure 12 shows the locations of the wells which tested positive for bacteria.

Locations of Wells Tested for Nitrates, Department of Human Services, Real Estate Transaction Testing Program

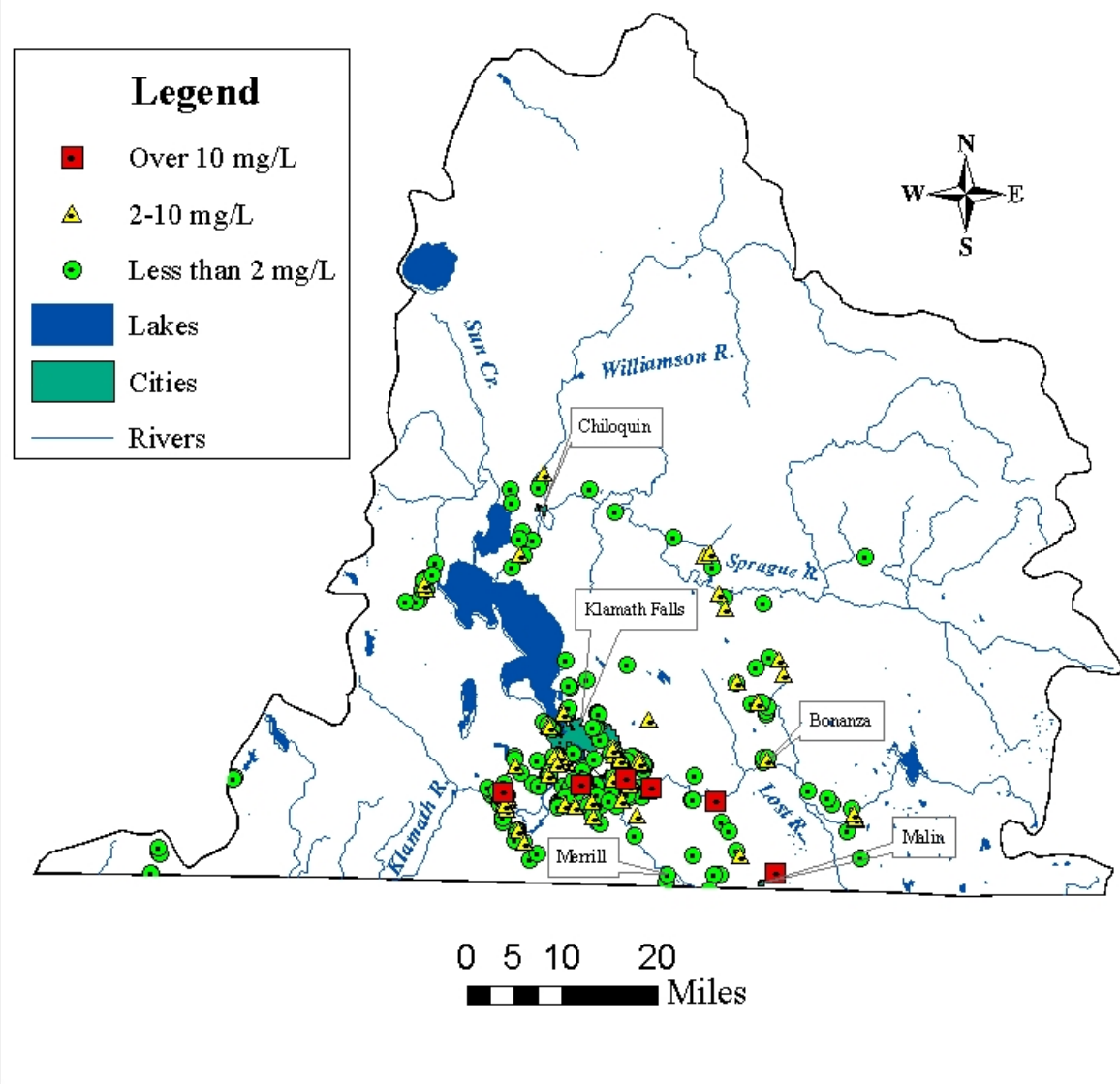


Figure 11. Well Locations for Department of Human Services, Drinking Water Program, Real Estate Transaction Program Testing for Nitrate.

Locations of Wells Tested Positive for Bacteria, Department of Human Services, Real Estate Transaction Testing Program

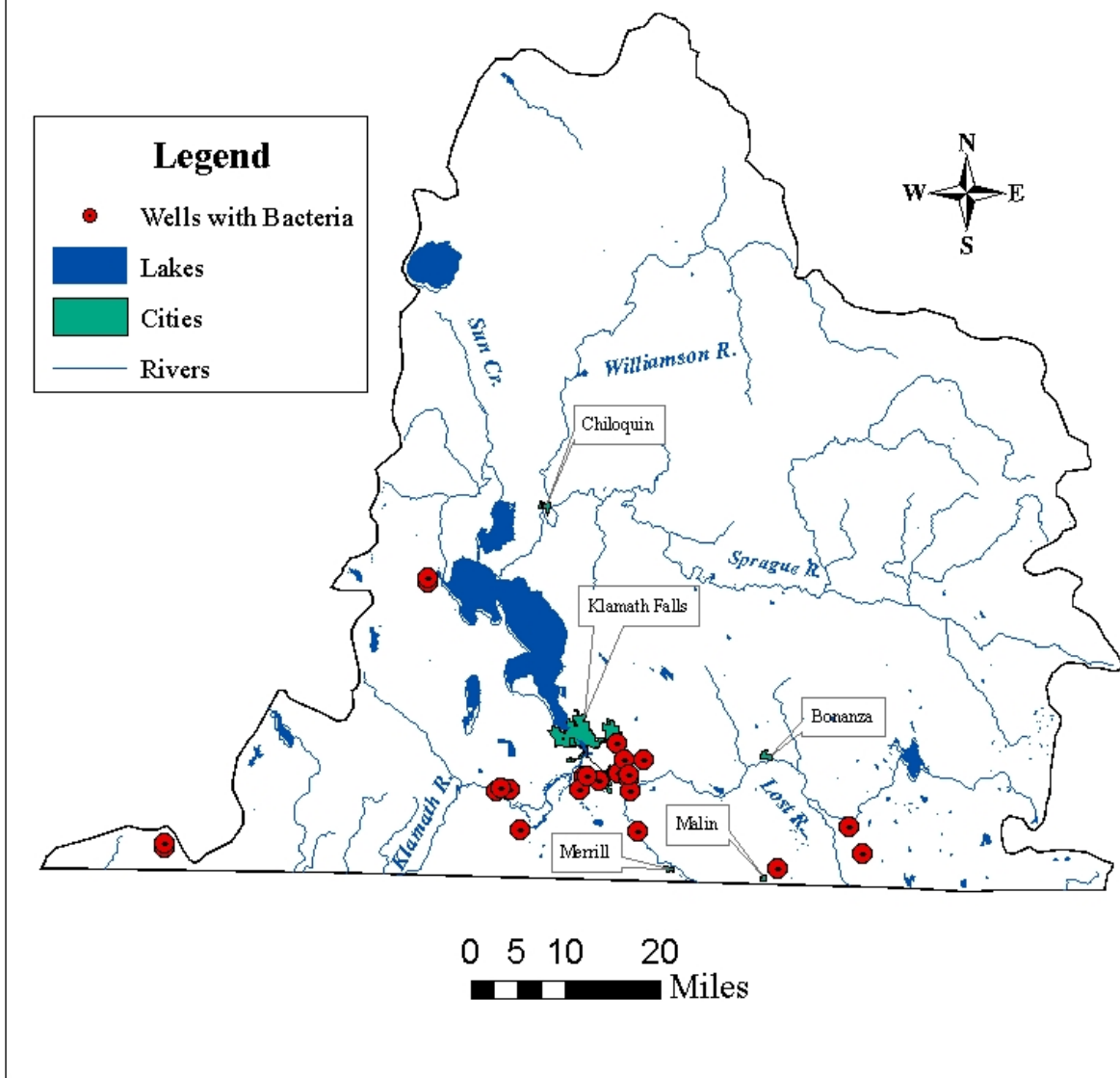


Figure 12. Locations of Wells Tested Positive for Bacteria, Department of Human Services, Drinking Water Program, Real Estate Transaction Program.

Public Water Systems

Oregon Department of Human Services

Summary

The Oregon Department of Human Services Drinking Water Program (DHSDWP) database shows 134 groundwater-based public water systems (PWS) provide drinking water to Klamath Basin residents. The DHSDWP Program maintains water quality information on these systems. Water quality information for individual systems is available through the Oregon Department of Human Services Drinking Water Program, and can be accessed on-line at [Public Water Supply Inventory](#).

Results

Table 1 below summarizes testing results for groundwater-based PWS. Not all PWS have the same period of record for testing results. Also, not all PWS tested for the same constituents during their period of record. The results include the following:

- Nitrate was detected in 120 PWS, and exceeded the 10 mg/L Maximum Contaminant Level (MCL) in one system. Twenty-three PWS had nitrate levels equal to or greater than 2 mg/L, indicative of anthropogenic influences.
- Bacteria was detected in 50 PWS.
- Lead was detected in three wells, at levels equal to or greater than the Action Level of 0.015 mg/L.
- Thallium was detected in one well at the MCL of 0.002 mg/L.
- Methylene chloride was detected in two wells, one of which exceeded the MCL of 0.005 mg/L.
- Cadmium was detected in eight wells, five of which were at or above the MCL of 0.005 mg/L.
- Cyanide was detected in one well above the MCL of 0.2 mg/L.
- Beryllium was detected in one well above the MCL of 0.004 mg/L.
- Arsenic was detected in one well, below the MCL.
- Mercury was detected in one well below the MCL.
- Nickel was detected in one well below the MCL.
- Pentachlorophenol was detected in two wells above the MCL of 0.001 mg/L.
- Chloroform was detected in one well. Chloroform has no established MCL.
- Tetrachloroethylene was detected in two wells, below the MCL.
- Diquat was detected in one well below the MCL.
- Phthalate was detected in one well below the MCL.
- Xylenes were detected in one well below the MCL.
- Toluene was detected in one well below the MCL.
- Dibromomethane was detected in one well. Dibromomethane has no established MCL.

Figure 13 shows the distribution of nitrate in Klamath Basin groundwater-based Public Water Supply Systems. The nitrate distribution uses 2 mg/L as an approximate indicator of

anthropogenic influence (Department of Human Services, Drinking Water Program, [Nitrate Fact Sheet](#)).

Figure 14 shows the locations of groundwater-based public water systems where total coliform bacteria has been detected, either once or multiple times. The period of record varies from one system to another. Some systems have data going back about 20 years. Other systems have only a few year’s worth of data. Some systems have no test data.

Figure 15 shows the locations of the PWS in the Klamath Basin with other exceedances (i.e., lead, cadmium, thallium, beryllium, cyanide, and volatile organic compounds).

Table 1. Klamath Basin Public Water Systems

Contaminant	# of systems detected	# of Wells Over MCL	Maximum Value Detected (mg/L)	NPDW MCL* (mg/L)
Nitrate	120	1	11	10
Bacteria	50	50	N.A.	5% positive/per month
Lead	3	3	0.071	0.015 (Action Level)
Cadmium	8	5	0.014	0.005
Thallium	1	1	0.002	0.002
Arsenic	1	1	0.048	0.01
Mercury	1	0	0.0012	0.002
Beryllium	1	1	0.500	0.004
Nickel	1	0	0.06	0.1
Cyanide	1	1	1.88	0.2
Pentachlorophenol	2	2	0.0021	0.001
Methylene chloride	2	1	0.0059	0.005
Chloroform	1	N.A.	0.3	N.A.
Xylenes	1	0	0.03	1
Toluene	1	0	0.0066	1
Phthalate	1	0	0.0019	0.006
Dibromomethane	1	N.A.	0.011	N.A.
Tetrachloroethylene	2	0	0.0016	0.005
Diquat	1	0	0.009	0.02

*NPDW MCL = National Primary Drinking Water Maximum Contaminant Level (mg/L = milligrams per liter = parts per million)

N.A. = Not Available or Not Applicable.

Locations of Public Water Supply Wells with Nitrates

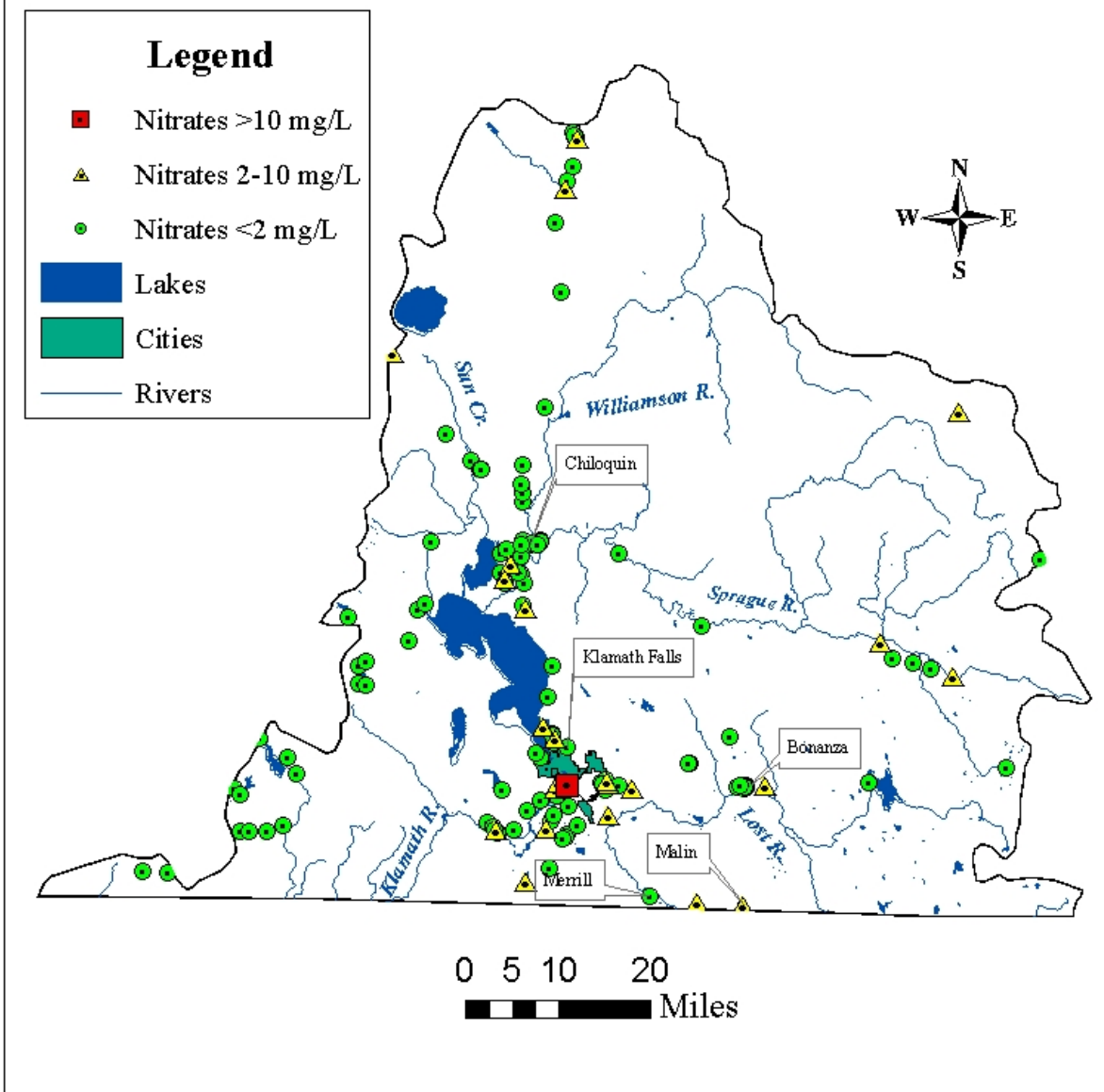


Figure 13. Nitrate levels in Klamath Basin Groundwater-Based Public Water Systems.

Locations of Public Water Supply Wells where Bacteria Has Been Detected

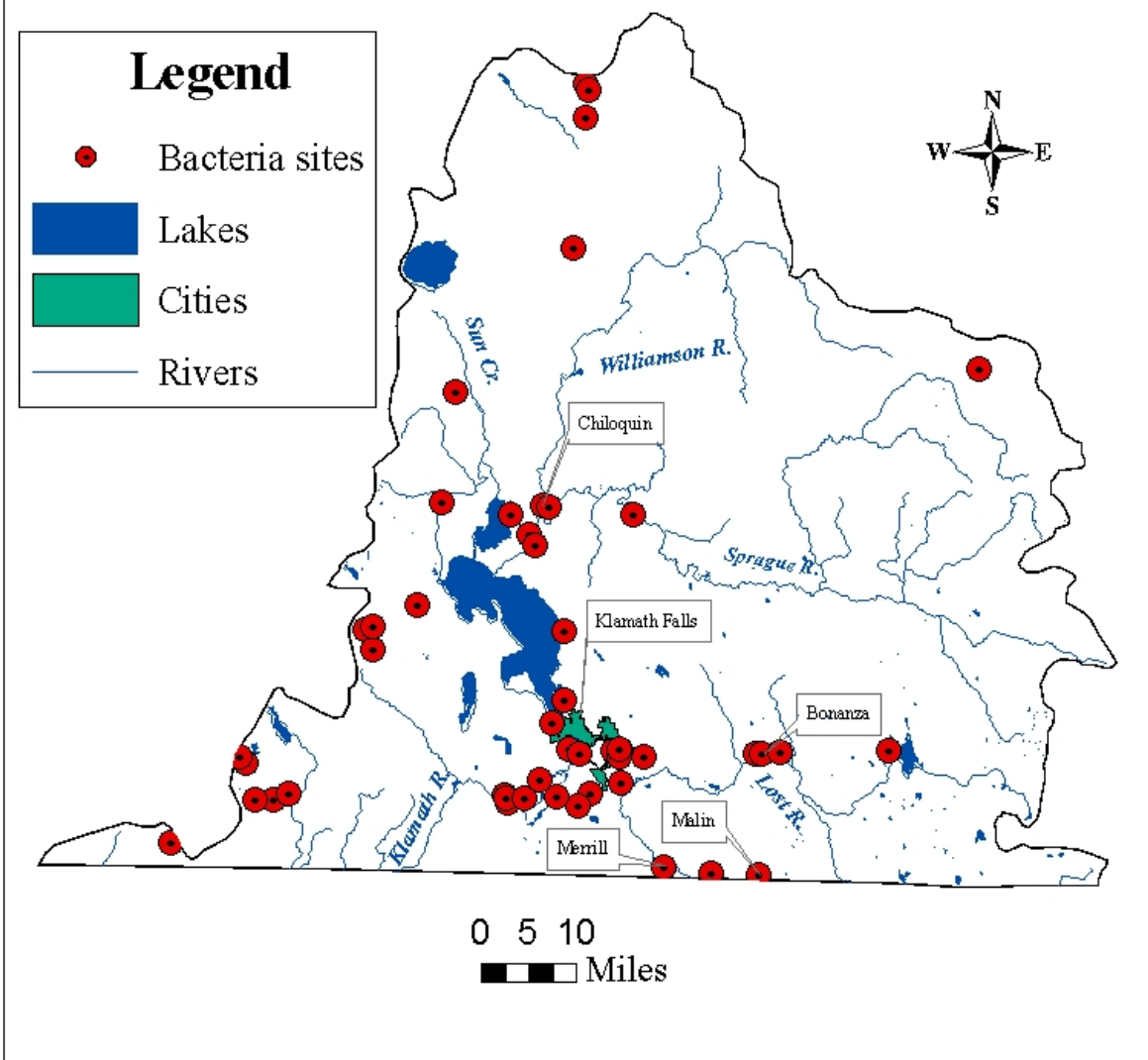


Figure 14. Locations of Groundwater-Based Public Water Systems with Bacteria Detections.

Locations of Public Water Supply Wells with Exceedances other than Nitrates and Bacteria

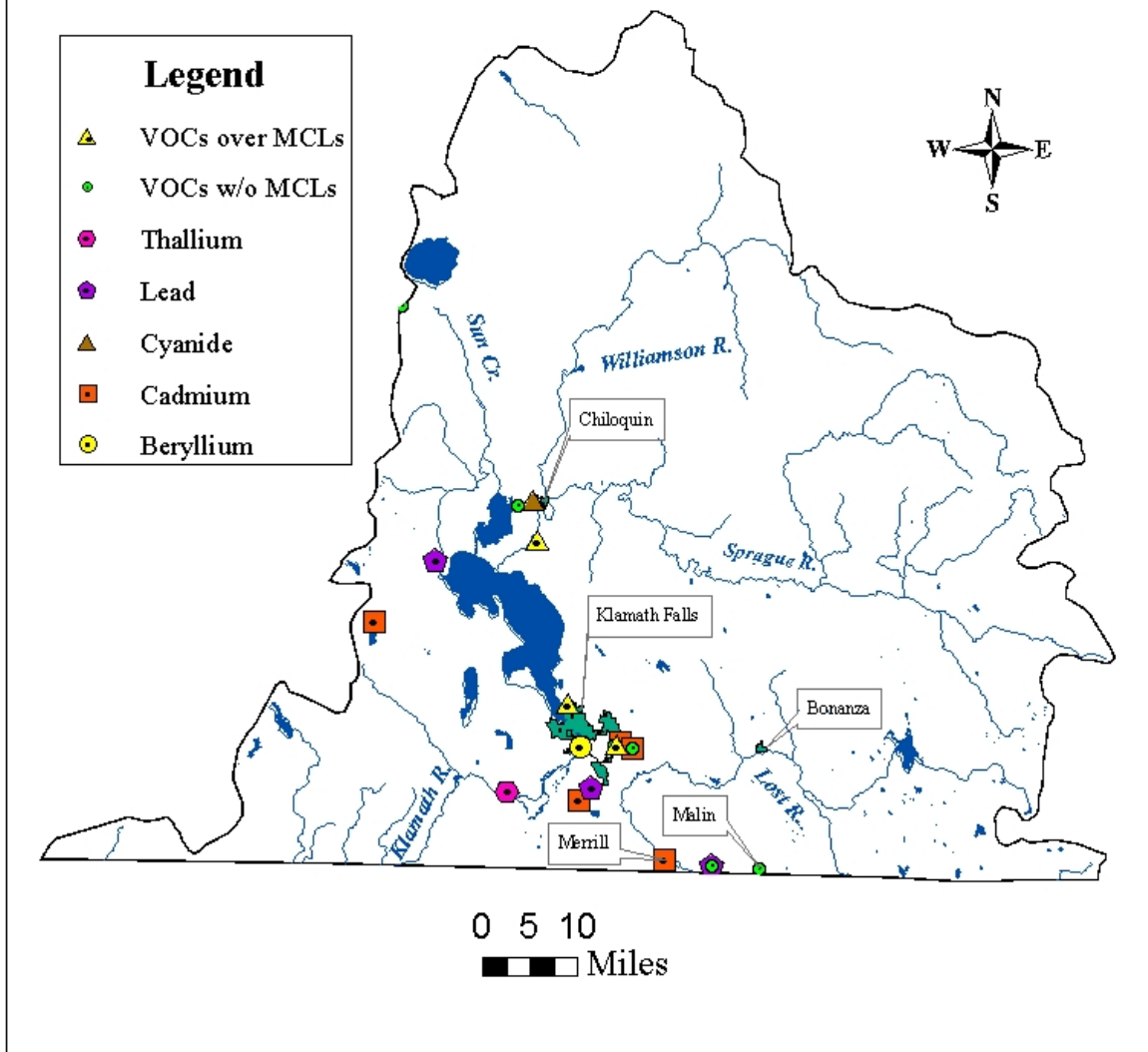


Figure 15. Klamath Basin Public Water System Exceedances other than Nitrate and Bacteria.

Area Studies

Klamath Falls Groundwater Study (1987)

Oregon Department of Environmental Quality

Summary

In February 1987, as part of the DEQ's Assessment of Oregon's Groundwater for Agricultural Chemicals, the DEQ conducted groundwater quality sampling in the Klamath Falls area. The DEQ collected groundwater samples from 51 wells. At each site the DEQ measured pH, temperature, and specific conductance. The DEQ also collected samples for laboratory analysis of nitrate and ammonia.

One month later, in March 1987, the DEQ returned to sample a 15 well subset of the original network. This second sampling event was much more extensive than the first. In addition to measuring field parameters and performing lab testing of nitrate and ammonia, the DEQ also analyzed for additional physical parameters, common ions, metals, other nutrients, pesticides, and volatile organic compounds (VOCs).

[Table 1](#), Appendix 1, lists the method detection limits and applicable drinking water standards for the VOCs tested in this study. [Table 2](#), Appendix 1, lists the method detection limits and applicable drinking water standards for the individual pesticides tested in this study. [Table 3](#), Appendix 1, summarizes the method detection limits and applicable drinking water standards for the metals, nutrients, and physical parameters tested in this study.

Figure 16 shows the locations of 29 of the 51 wells sampled. Location information is unavailable for the remaining 22 wells.

Results

[Table 1](#), Appendix 2, details all the sampling results from the February 1987 Klamath Falls sampling event.

The results of the February 1987 sampling include the following:

- Five of the sites (10%) had nitrate values exceeding the drinking water standard of 10 mg/L.
- The maximum nitrate value detected was 42 mg/L.
- Two wells had nitrate values between 2 mg/L and 10 mg/L, indicating anthropogenic activities had affected the groundwater.

Klamath Falls Area 1987 Groundwater Well Network

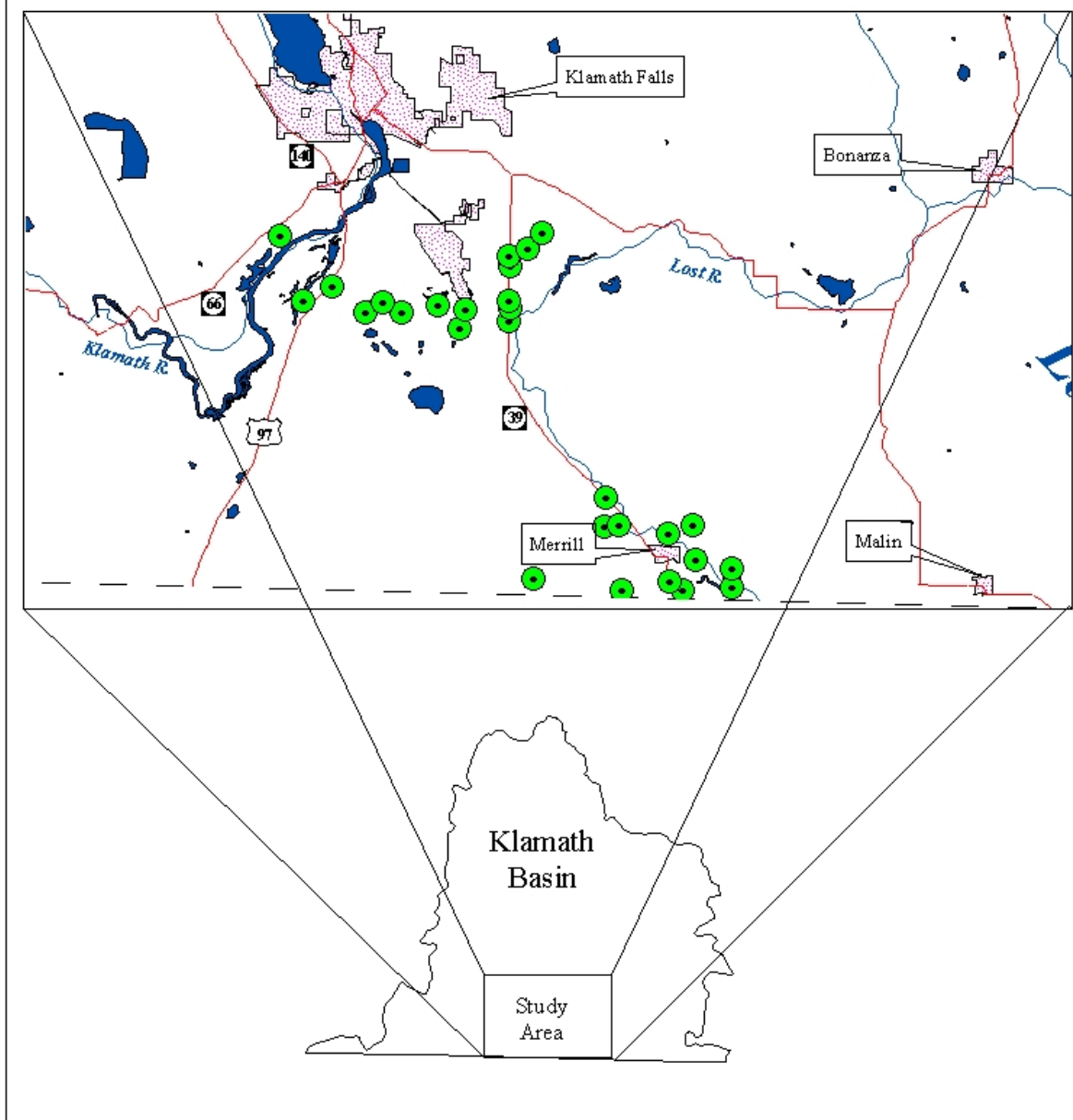


Figure 16. Location of the 1987 Klamath Falls Well Network in the Klamath Basin.

Figure 17 shows the nitrate distribution for the wells with location information, sampled in February 1987.

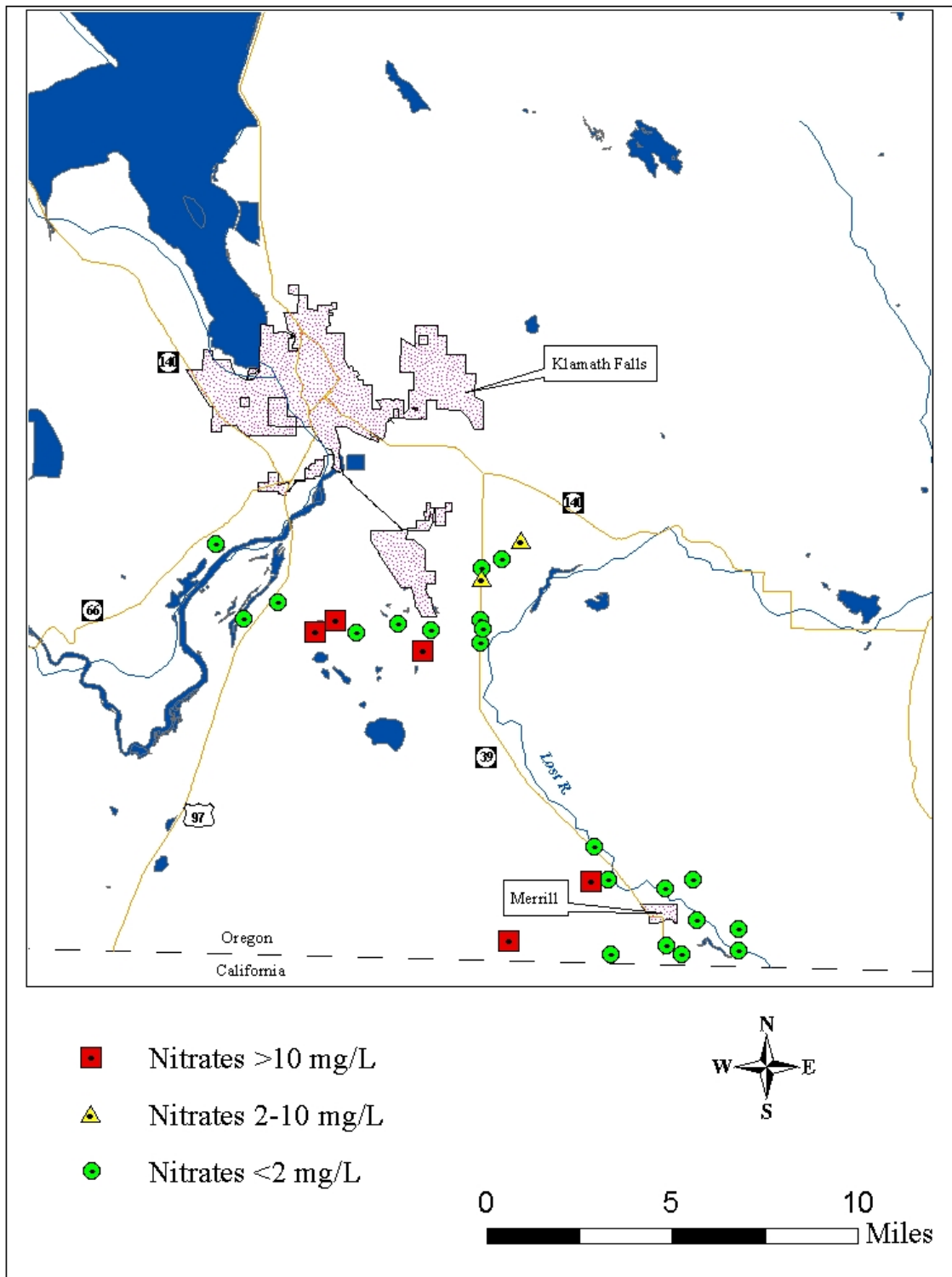


Figure 17. Nitrate distribution for the February 1987 Klamath Falls sampling.

Table 2, Appendix 2, details all analytical results from the March 1987 sampling. The results from the March 1987 sampling include the following:

- Four out of 15 wells (27%) had nitrate values over the drinking water standard of 10 mg/L.
- The maximum nitrate value detected was 39 mg/L.
- Two wells (13%) had nitrate values between 2 mg/L and 10 mg/L, indicating anthropogenic activities had affected the groundwater.
- Four wells (27%) had arsenic, two of which were over the drinking water standard of 0.010 mg/L.
- The maximum arsenic value detected was 0.015 mg/L.
- Nine wells (60%) had copper detected, none of which exceeded the Action Level of 1.3 mg/L.
- The maximum copper value detected was 0.057 mg/L.
- No volatile organic compounds or pesticides were detected.

Table 2, Appendix 2, details the results of the March 1987 Klamath Falls area sampling event. Table 2, below, summarizes the contaminants found during the March 1987 sampling event.

Table 2. Klamath Falls Groundwater Study (March 1987).

Contaminant	No. of wells detected out of 15 wells	Maximum Concentration (mg/L)	Detection Limit (mg/L)	NPDW MCL* (mg/L)	Number of Wells Over MCL
Nitrate	14	39	0.02	10	4
Arsenic	4	0.015	0.005	0.010	2
Copper	9	0.057	0.002	1.3 (Action Limit)	0

*NPDW MCL = National Primary Drinking Water Maximum Contaminant Level (mg/L = milligrams per liter = parts per million)

Data from DEQ's sampling are available in the Laboratory Analytical Storage And Retrieval (LASAR) database through the internet at: [LASARWeb](#).

Figure 18 shows the nitrate distribution for the wells sampled in March 1987. The figure also shows the two well locations where arsenic was detected above the drinking water standard. Note that both arsenic sites also coincide with sites where nitrate were detected, one of which was over the drinking water standard.

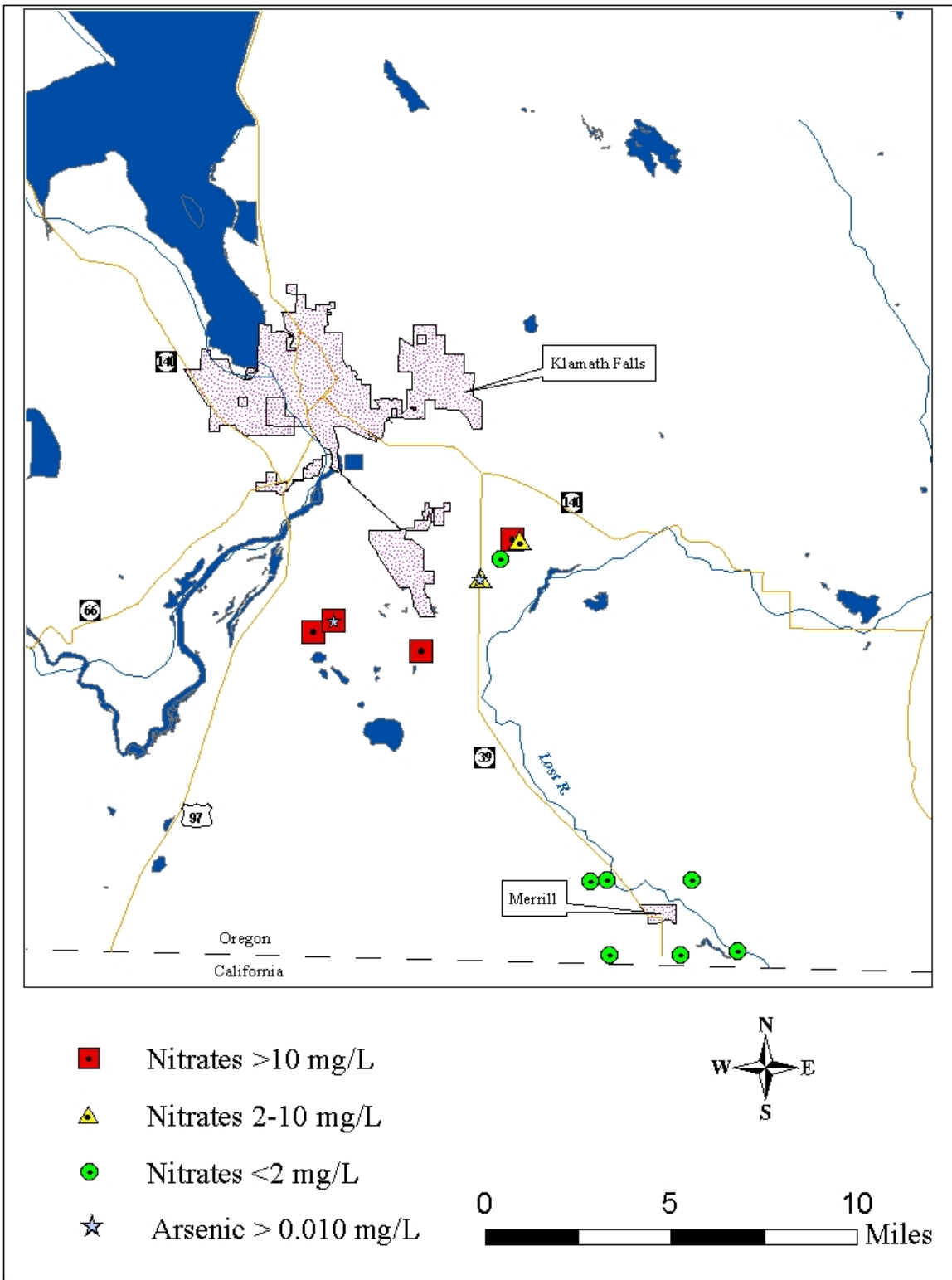


Figure 18. Nitrate and Arsenic distribution from March 1987 Klamath Falls Groundwater Study.

Klamath Falls Groundwater Study (1989)

Summary

In November of 1989 the DEQ conducted a groundwater sampling event in the Klamath Falls area. This event collected and analyzed groundwater from a 27 well subset of the original 51 wells sampled in February of 1987.

Table 1, Appendix 1, lists the method detection limits and applicable drinking water standards for the volatile organic compounds (VOCs) tested in this study. In addition to this list, the DEQ also analyzed two more VOCs: 1,4-Dimethylbenzene and 1,3-Dimethylbenzene/1,2-Dimethylbenzene, both with same detection limits as all the others VOCs (0.001 mg/L).

The Oregon Department of Agriculture lab ran the following pesticide screens on the samples: Organophosphate/nitrogen, Organochloride, Carbamate, Phenoxy, and Dacthal. Since no pesticides were detected, no detection limits are available for any specific compound included with any of the screens. **Table 4**, Appendix 1, summarizes the method detection limits and applicable drinking water standards for the metals, nutrients, and physical parameters tested in this study.

Results

The results include the following:

- Nitrate was detected in all 27 wells.
- Nitrate in 4 wells (15%) exceeded the drinking water standard of 10 mg/L.
- Nitrate in 4 wells (15%) ranged in concentration between 2 and 10 mg/L, indicating anthropogenic activities had impacted the groundwater.
- Arsenic was detected in 4 wells (15%), three of which (11%) exceeded the drinking water standard of 0.050 mg/L.
- No volatile organic compounds were detected.
- No pesticides were detected.

Table 3, Appendix 2, details all analytical results from the Klamath Falls 1989 sampling. The following table summarizes the results from the 1989 sampling event.

Table 3. Klamath Falls November 1989 Groundwater Study Summary

Contaminant	No. of Wells Detected out of 27 wells	Maximum Concentration (mg/L)	Detection Limit (mg/L)	NPDW MCL* (mg/L)	Number of Wells Over MCL
Nitrate	27	23	0.02	10	4
Arsenic	4	0.015	0.005	0.010	3

*NPDW MCL = National Primary Drinking Water Maximum Contaminant Level (mg/L = milligrams per liter = parts per million).

Figure 19 shows the November 1989 Klamath Falls well network, including the nitrate distribution, and the wells where arsenic was detected above the drinking water standard. Note that at one of the locations both nitrate and arsenic exceeded the drinking water standard.

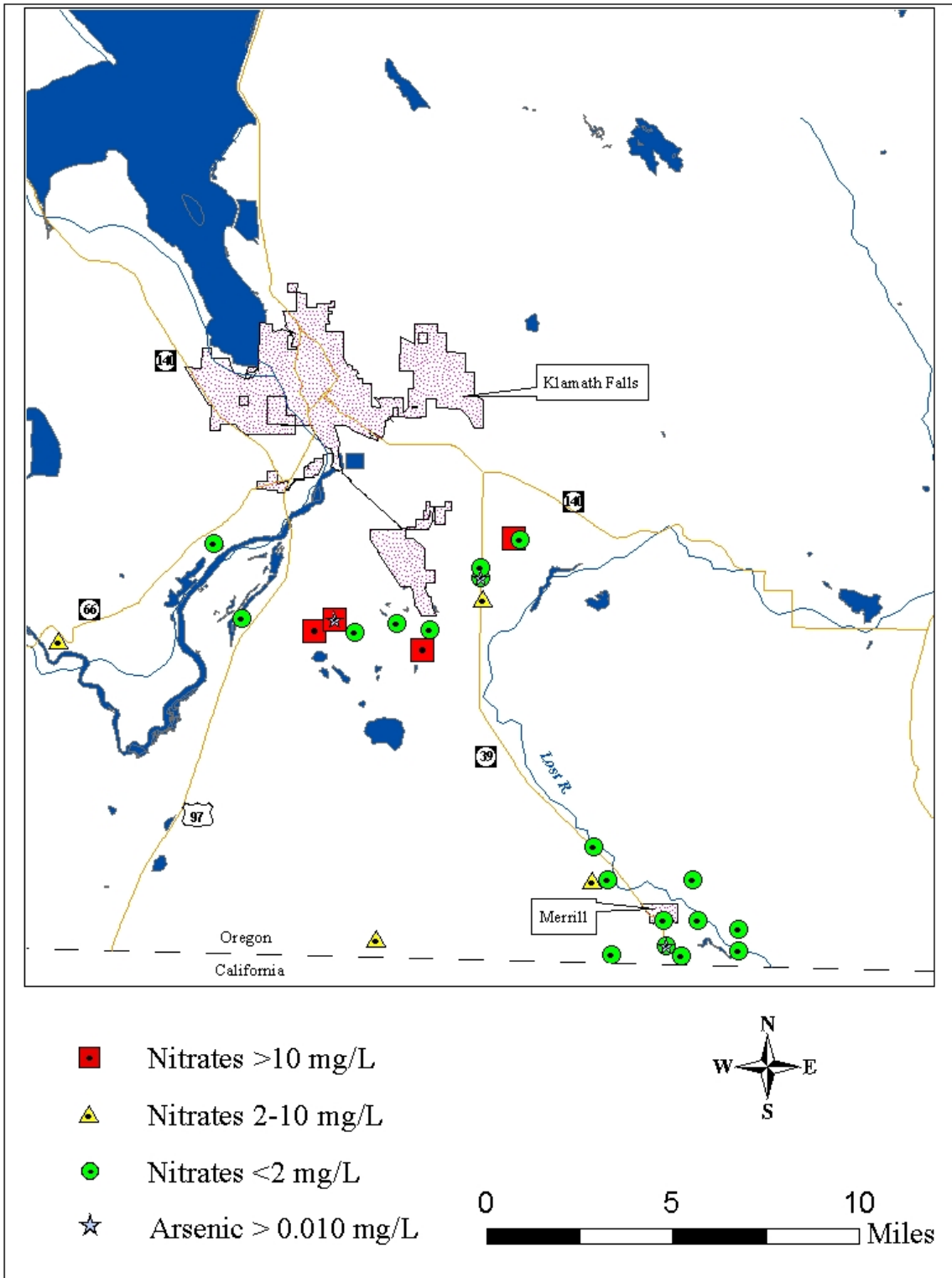


Figure 19. November 1989 Klamath Falls Well Network, showing Nitrate Distribution and Locations of Arsenic Exceedances.

Keno Area Groundwater (1995)

Summary

In September 1995 the Klamath County Environmental Health Department contacted the DEQ about an objectionable odor in the Whoa Tavern's water. Water sample test results revealed the presence of Benzene, in concentrations up to 0.35 mg/L. This concentration was 70 times the federal drinking water standard of 0.005 mg/L. The DEQ's Underground Storage Tank (UST) program identified the following three potential sources of the contamination:

1. USTs located at the Keno Elementary School,
2. USTs at the present site of the Keno Garage, and
3. at the tavern itself, which was the former Keno Garage location (1930s – 1950s).

In November 1995 two USTs were removed from the Keno Elementary School property. Evidence indicated one of these tanks had leaked. While the leak had contaminated the soil, the contamination had apparently not reached the local area's groundwater. Tests of the Keno Garage tanks showed no apparent leaks. Tanks at the Whoa Tavern (the former Keno Garage site) were allegedly removed in the 1950s, although no records exist to corroborate this.

The evidence led the DEQ's UST program to conclude the Whoa Tavern site as the contamination source. The program referred the Whoa Tavern to the DEQ's Site Assessment program for prioritization and cleanup in February 1997. The DEQ conducted a Site Investigation from April 1997 to March 1998.

In November 1997 the DEQ provided wellhead treatment systems to owners of affected wells. All known tanks in the area have since been removed or replaced. More information on this project is available on-line, through the DEQ's Environmental Cleanup Site Information (ECSI) web site at the following address: [ECSI Web Page](#).

Results

Over the course of the investigation, samples have been collected from 10 different sites. Many of these sites had multiple sample points, such as pre-treatment and post-treatment locations. Figure 20 shows the locations of these sites, in relation to the Klamath Basin.

The treated water quality has been monitored quarterly since July 1998. In 1999 methyl tert-butyl ether (MTBE), a gasoline additive, was detected in the tavern's water, at a concentration of 0.062 mg/L. No MCL exists for MTBE. The DEQ upgraded the treatment system in January 2000. Water treatment and monitoring is ongoing.

Keno Area Groundwater Network

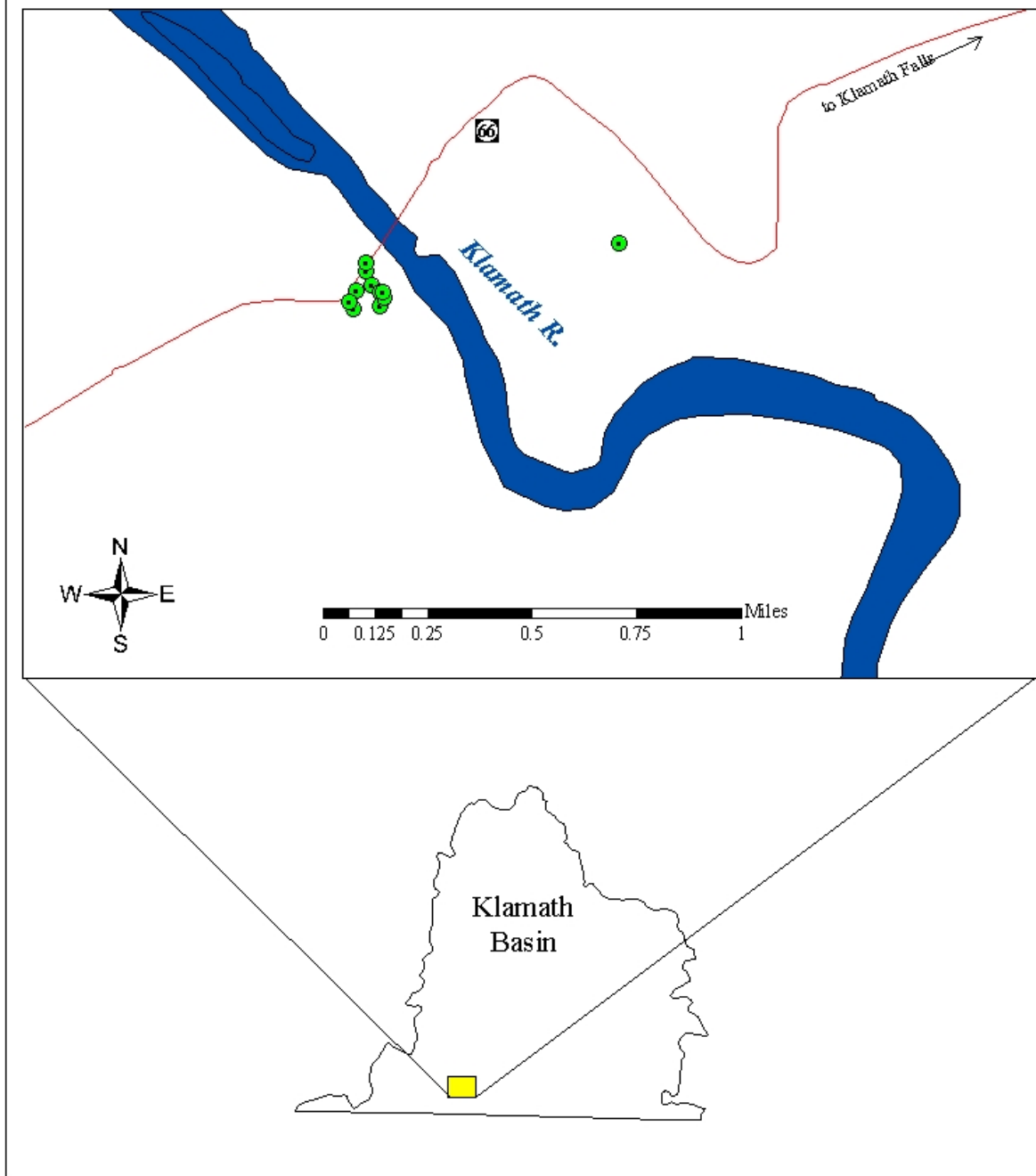


Figure 20. Keno Area Groundwater Sites in the Klamath Basin.

Masami Foods Groundwater Study (1995)

Summary

Masami Foods is a meat processing facility, located in Klamath Falls. The Masami Foods site had been a slaughter facility for a long time, before Masami Foods bought the property. A Water Pollution Control Facility (WPCF) permit, allows Masami Foods to land apply processing wastewater. The permit specifies the wastewater is to be applied in such a manner as to not adversely affect waters of the state.

In May 1995, the DEQ collected groundwater samples from 13 private domestic water wells, located adjacent to the Masami Foods property. The analytical results showed one well had bacteria in it, and two wells had nitrate values exceeding the drinking water standard of 10 mg/L. Figure 21 shows the locations of the 13 wells in relation to their position within the Klamath Basin. Figure 22 shows the well locations relative to the wastewater irrigation areas.

In September 1997 Masami Foods initiated a Remedial Investigation and Feasibility Study (RI/FS) to address environmental impacts their wastewater discharge practices were having on the local resources.

Discharge monitoring reports from Masami Foods showed that between December 2000 and November 2002, several permit parameters were consistently exceeded. These parameters include total dissolved solids, chloride, sulfate, and nitrate. Masami Foods reported a crop yield of 19.15 tons for the year 2000. The crop yield for 2001 was 6.5 tons, and by the end of crop year 2002, 0 tons were reported, despite increasing the land application area from 7 to 16 acres. Before the 2001 irrigation season, nitrate levels in monitoring wells #1 and #5 were below 10 mg/L. After the 2001 irrigation season, the monitoring wells had nitrate levels of 48.3 mg/L, and 87.2 mg/L, respectively. During the 2002 crop year, Masami Foods continued to irrigate over 5 million gallons of industrial processing wastewater effluent to the land application sites, even though the crop was not responding.

In February 2003 the DEQ issued a Notice of Noncompliance (NON) to Masami Foods for permit violations. The NON also required corrective actions associated with the violations.

Results

As of December 2005, the RI/FS was still incomplete. Groundwater flow directions appear to change over the season, so the DEQ has asked Masami Foods to install three additional monitoring wells, and measure water levels on a monthly basis, to help clarify existing groundwater data, and to determine actual groundwater flow directions.

Masami Food's land application practices have reduced salt concentrations in their wastewater by half, and have instituted more precise agricultural management activities. Masami Foods has obtained additional land for their land application activities, and are reclaiming those sites that were affected. Masami Foods has installed moisture monitoring devices in their fields to let them know how much and when to irrigate. Following wastewater application, Masami Foods

applies Klamath Irrigation District water to keep their land application sites productive. Masami Foods also collects soil samples at the beginning and end of each crop year to monitor various soil constituents. Additionally, Masami Foods is now conducting crude protein analysis to determine how much nitrogen their crop is physically removing.

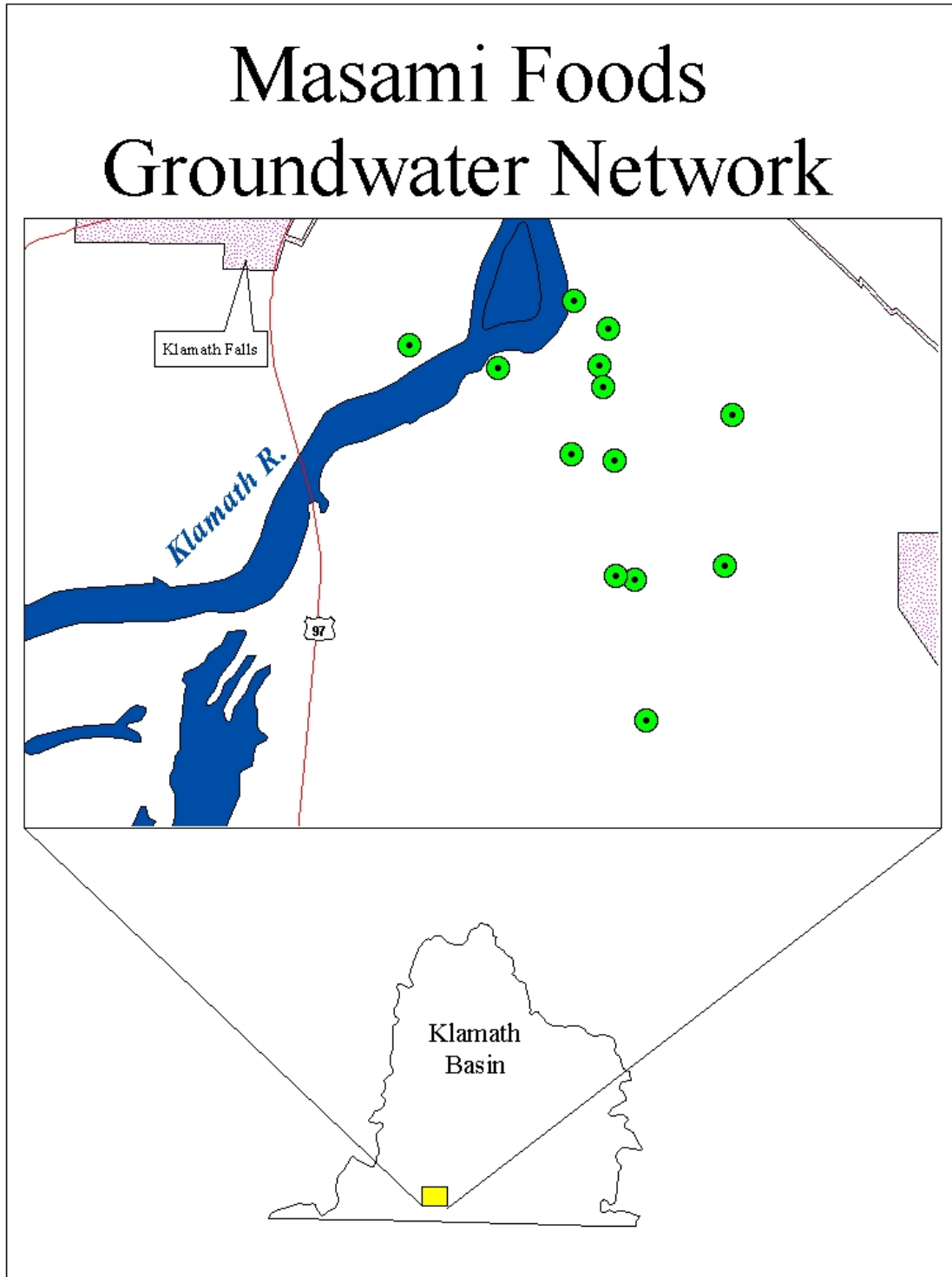


Figure 21. Masami Foods Groundwater Network in the Klamath Basin.

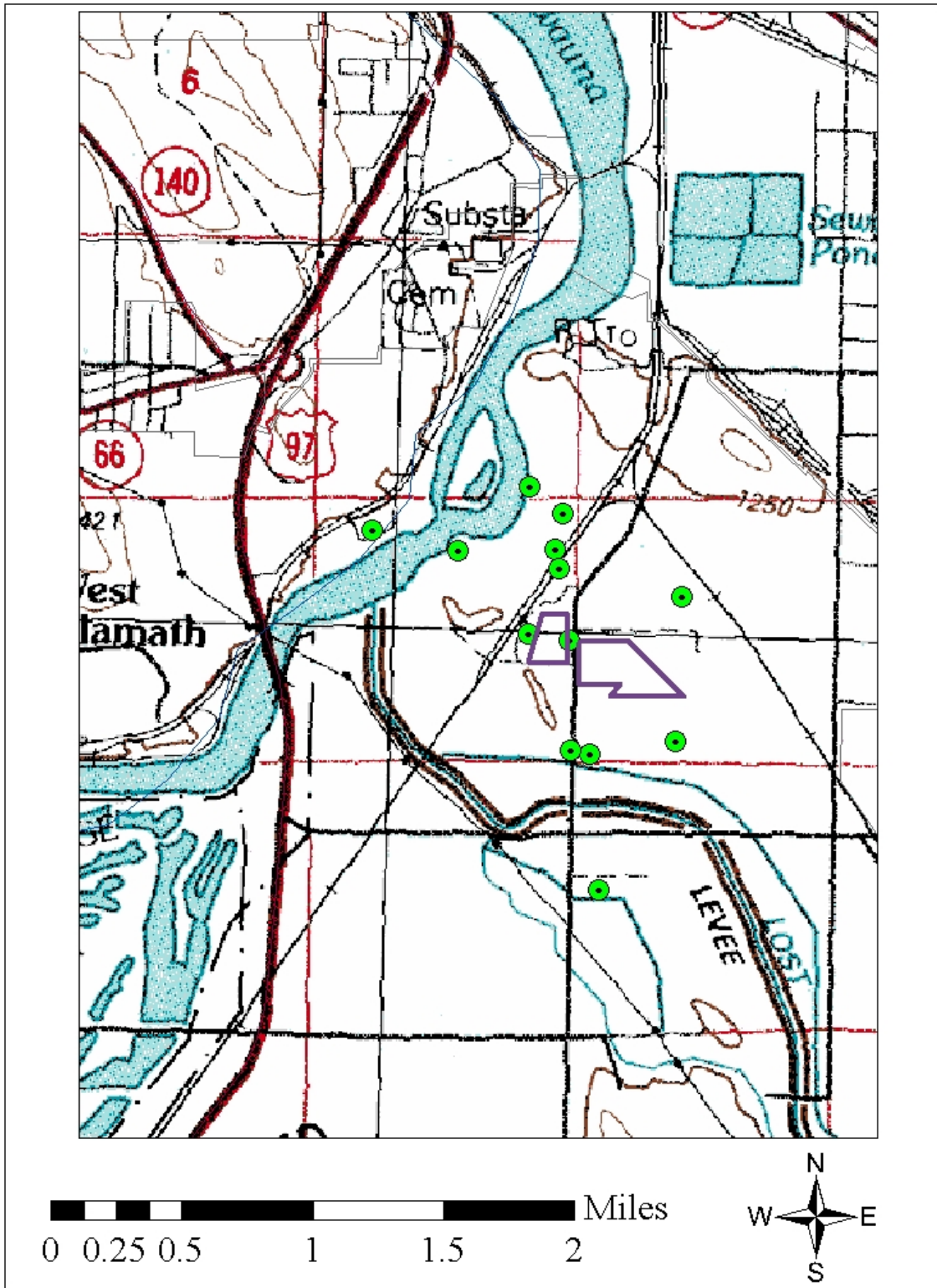


Figure 22. Location of Well Network in relation to the Masami Foods Wastewater Irrigation Areas (purple outline).

Overall Status of Klamath Basin Groundwater

Nitrate

Klamath Basin studies have found areas with nitrate in the groundwater. Nitrate levels above 2 mg/L indicate anthropogenic activities have adversely affected the groundwater. Nitrate sources include dispersed non-point sources such as agricultural activities and land application of waste products. Point sources of nitrate include on-site septic systems, and individual generators of nutrient rich waste products.

Some Public Water Systems (PWS) in the region have reported nitrate levels between 2 and 10 mg/L. One PWS in the Klamath Basin has reported nitrate levels above the Maximum Contaminant Level (MCL, 10 mg/L). Some of the PWS treat the water prior to distribution. Many of the PWS do not treat the water prior to distribution. The treatment types include chlorination and ultraviolet radiation for disinfection purposes, particulate filtration, and activated granular carbon for organics removal. For domestic wells sampled as part of real estate transactions, two percent of the nitrate tests exceeded the MCL.

In February of 1987, the DEQ sampled 51 wells in the Klamath Falls area. Five of those wells (10%) had nitrate levels above the MCL. In March of 1987, the DEQ resampled a 15 well subset of the original 51 wells. The DEQ found that four of the five wells in the original study with nitrate levels exceeding the MCL, still had nitrate levels exceeding the MCL. Two-and-a-half years later, in November of 1989, the DEQ sampled 27 of the original 51 wells, and found four of the wells (15%) had nitrate levels exceeding the MCL. Three of these four wells were the same wells with nitrate exceedances found in the March 1987 study. Four percent of the February 1987 wells, 13% of the March 1987 wells, and 15% percent of the November 1989 wells had nitrate levels between 2 mg/L an 10 mg/L, indicating contamination from anthropogenic activities.

Bacteria

Positive groundwater bacteria detections may indicate contamination from non-point sources, including on-site septic systems, or point sources, including facilities handling or disposing septage or manure. Bacteria from well water usually indicates substandard well construction and poor maintenance practices, rather than an area-wide aquifer problem.

On a regional scale, the domestic well real estate transaction data collected throughout the Klamath Basin showed 37 tests out of 501 (7%) were positive for bacteria. Fifty Public Water Supplies, out of 134 (37%), also reported positive tests for bacteria. Eleven of these 50 PWS have treatment systems of various types in place.

Toxics – Pesticides

No pesticides were detected in either of the 1987 or the 1989 DEQ Klamath Falls groundwater studies. However, one Public Water Supply reported a detection of Diquat below the Maximum

Contaminant Level (MCL). Another PWS reported detecting Dibromomethane at a concentration of 0.011 mg/L. Dibromomethane has no established MCL.

Toxics – Volatile Organic Compounds

No volatile organic compounds (VOCs) were detected in either of the 1987 or the 1989 DEQ Klamath Falls groundwater studies. However, several VOCs were detected in various Public Water Supplies (PWS). Two PWS reported detecting methylene chloride, one of which exceeded the Maximum Contaminant Level (MCL). Two PWS reported detecting pentachlorophenol, both of which were over the MCL. One PWS reported detecting chloroform at a concentration of 0.3 mg/L. chloroform has no established MCL. One PWS reported detecting xylenes, below the MCL. One PWS reported detecting toluene, below the MCL. One PWS reported detecting phthalate, below the MCL. One PWS reported detecting tetrachloroethylene, below the MCL.

Toxics - Metals

Three Public Water Systems (PWS) reported lead at or above the federal Action Level of 0.015 mg/L. One PWS reported thallium at the MCL of 0.002 mg/L. One PWS reported arsenic below the MCL of 0.01 mg/L. cadmium was detected in eight PWS, exceeding the MCL in five of the PWS. One PWS detected mercury below the MCL. cyanide was detected in one PWS above the MCL of 0.2 mg/L. beryllium was detected in one PWS, above the MCL of 0.004 mg/L. Nickel was detected in one PWS below the MCL.

POLLUTANT SOURCES

Overview

Various state and federal programs regulate pollution sources in Oregon. Point sources are confined or discrete pollution sources where contaminants can enter into public waters ([OAR 340-040-0010\(14\)](#)). Nonpoint sources are diffuse or unconfined pollution sources ([OAR 340-040-0010\(12\)](#)). The state and federal regulatory goal is to prevent or minimize adverse impacts to groundwater quality from surface activities. Several types of point sources in the Klamath Basin are discussed below.

Waste Dischargers

The DEQ regulates waste discharges through permits. Permit types include the following:

- National Pollutant Discharge Elimination System (NPDES) - These permits must meet Federal Water Pollution Control Act requirements and procedures ([OAR 340-045](#)). NPDES permits generally cover all discharges, whether direct or indirect, to surface waters of the United States. NPDES permits cover direct discharges into a river or

stream, or indirect discharges into a drain or ditch conveying wastewater to a river or stream, and may also cover discharges to land.

- Water Pollution Control Facilities (WPCF) - These permits regulate disposal system construction and operation with no discharge to navigable waters (340-045-0010(31)). State requirements and procedures (OAR 340-045 or OAR 340-071) distinguish these facilities from those discharging to navigable waters. The DEQ issues WPCF permits for discharges not covered by an NPDES permit. WPCF permitted facilities may discharge wastewater onto land through irrigation, into drain fields, or into lagoons and holding ponds.

NPDES and WPCF permitted facilities discharge a variety of wastewater including sewage, pulp and paper waste, food processing waste, smelting/refining waste, cooling water, industrial storm water, mining waste, municipal wastewater, and others.

The DEQ has regional offices in various locations around the state. Eastern Region offices in The Dalles and Bend manage permits within the Klamath Basin. Information on NPDES and WPCF permits is available on-line at the following web site:

<http://www.deq.state.or.us/wq/SISData/FacilityHomenew.asp>.

Figure 23 shows the locations of 97 facilities with active permits in the Klamath Basin.

Permitted Facility Locations in the Klamath Basin

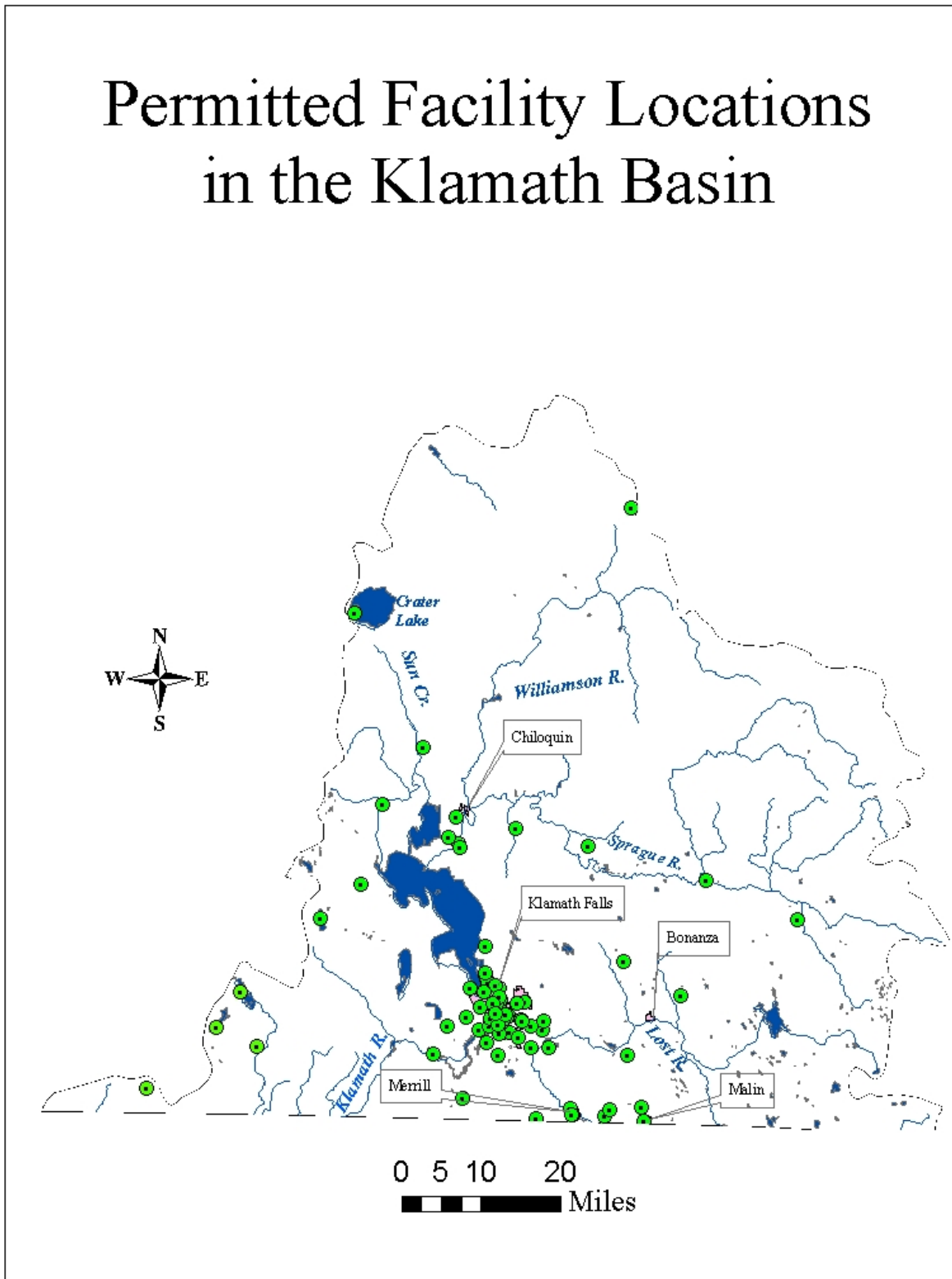


Figure 23. Locations of Permitted Waste Discharge Facilities, Klamath Basin, Oregon.

Underground Injection Control (UIC)

The DEQ Underground Injection Control (UIC) program regulates subsurface waste injection to protect groundwater quality. A UIC is any system, structure, or activity that is created to place fluid below the ground or sub-surface. Due to budget constraints, the DEQ will no accept new and revised UIC registration applications on September 1, 2006. The EPA is expected to take over the administrative duties. At this time, EPA has not specified how it would implement the UIC Program in Oregon. The DEQ believes that EPA is likely to have a greater presence in Oregon around UIC issues.

Common existing underground injection systems or activities in Oregon include the following:

- Stormwater systems: typical designs include but are not limited to sumps, infiltration galleries, drywells, trench drains, and drill holes.
- Domestic onsite septic systems and cesspools that serve more than 20 people or have a design capacity of 2,500 gallons per day or more.
- All sewage drill holes.
- Industrial/commercial process and wastewater disposal (includes drainfields of any size).
- Cooling water return flows.
- Aquifer storage and recharge.
- Aquifer remediation systems.
- Geothermal heat pump re-injection systems.
- Motor vehicle waste (floor drains, auto drains).
- Agricultural drainage.

Disposal practices releasing wastewater directly into the ground can pollute groundwater and surface water if not properly designed, sited, and operated. This is one reason the DEQ monitors underground injection and requires registration of all Oregon injection systems. State and federal law prohibits motor vehicle waste drains ([OAR 340-044-0014](#) and CFR 144.85(b)).

The DEQ maintains a database of known UIC systems. This database is available at <http://www.deq.state.or.us/wq/groundwa/UIChome.htm>. As of January 2006, the database provides status information for 45 UIC facility locations within the Klamath Basin.

Figure 24 is a map of the Klamath Basin showing the locations of 27 of the 45 UIC locations. The remaining 18 locations have missing or incorrect location information, so these facility locations are not shown on the map.

Underground Injection Control Facility Locations in the Klamath Basin

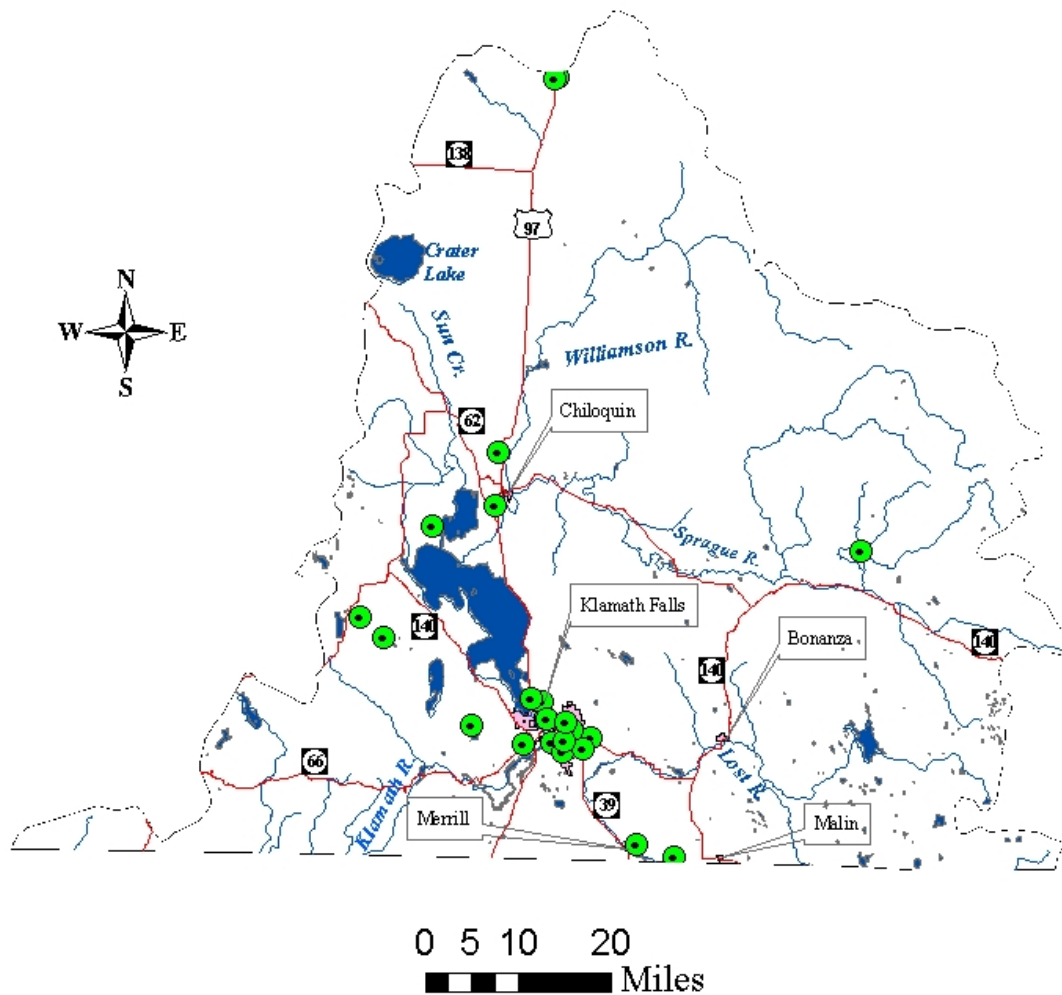


Figure 24. Underground Injection System Locations in the Klamath Basin.

Confined Animal Feeding Operations (CAFOs)

The 2001 Oregon legislature, through HB 2156 (2001 Oregon Laws, Chapter 248), directed the Oregon Department of Agriculture (ODA) to seek approval from the federal Environmental Protection Agency (EPA) to transfer the CAFO portion of the National Pollution Discharge Elimination System (NPDES) permitting program from DEQ to ODA. This program allows the DEQ to review CAFO plans, and to designate a CAFO as a significant contributor of pollutants needing an NPDES permit, pursuant to 40 CFR §122.23(c).

The types of CAFO facilities include the following:

- Production areas such as animal confinement areas;
- Manure storage areas such as lagoons, runoff ponds, storage sheds, stockpiles, and liquid impoundments; and
- Waste containment areas such as settling basins.

The waste management systems may also include land application areas. Without proper waste containment and processing systems, CAFOs can concentrate and introduce nitrate and bacterial contamination into underlying groundwater aquifers.

Figure 25 shows the locations of the 11 permitted CAFOs in relation to the sensitive aquifers in the Klamath Basin. These 11 CAFOs account for a total of 7,700 animals, all of which are used in dairy operations. The largest of these CAFOs has 2,350 animals.

CAFO Locations and Sensitive Aquifers in the Klamath Basin

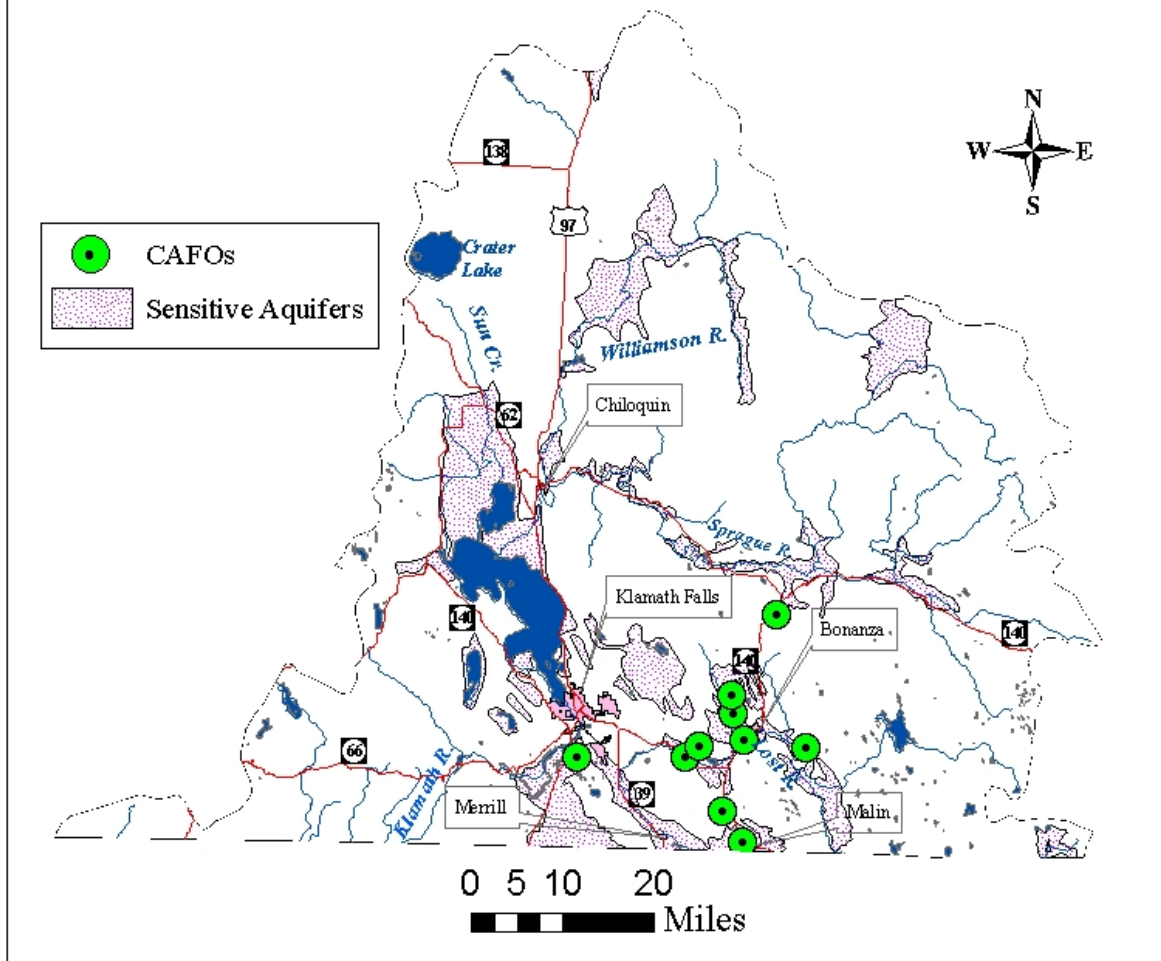


Figure 25. Confined Animal Feeding Operations in the Klamath Basin.

Hazardous Substance Release Sites

The DEQ maintains a list of known hazardous substance release sites in the Environmental Cleanup Site Information (ECSI) database. Information on specific sites is available through on-line queries at <http://www.deq.state.or.us/wmc/ECSI/ecsiquery.htm>. As of January 2006, the database shows 205 sites in the Klamath Basin. Figure 26 shows the site locations, in relation to the basin's sensitive aquifers. The map shows the site locations in terms of the following three site categories:

1. LIS = Site listed on the Confirmed Release List/Inventory (28 sites).
2. SUS = Site contamination suspected but not confirmed (162 sites).
3. NFA = Unconditional "No Further Action" site (15 sites).

Some of the sites are very close to each other, causing some symbols to overlap and hide others.

Hazardous Waste Sites and Sensitive Aquifers in the Klamath Basin

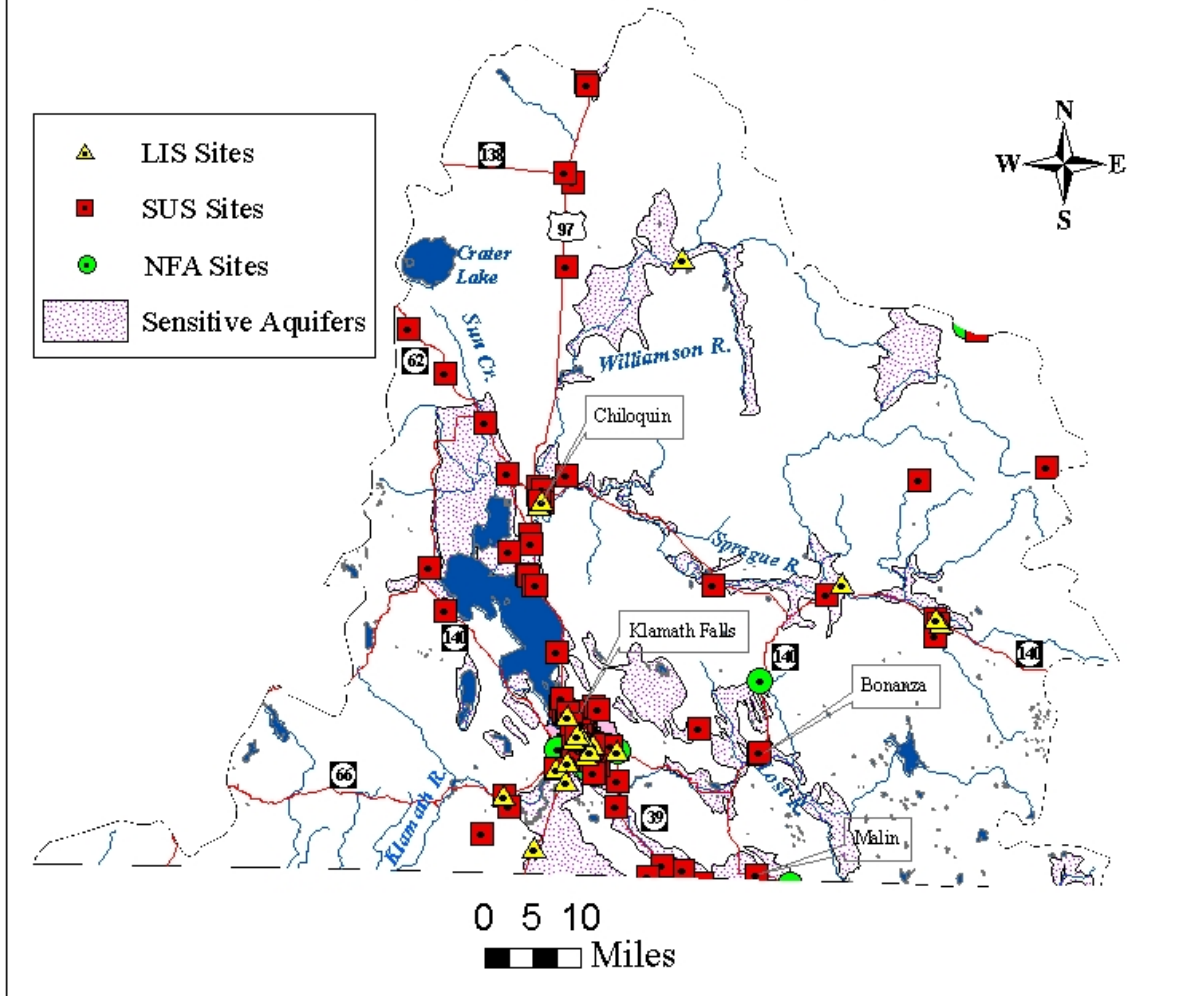


Figure 26. Hazardous substance release sites in the Klamath Basin.

Underground Storage Tanks (USTs) and Leaking Underground Storage Tanks (LUSTs)

The DEQ Underground Storage Tank (UST) program regulates tanks storing petroleum or certain hazardous substances, and regulates tank release cleanups, including home heating oil tanks. The DEQ maintains the UST list for regulated underground storage tank facilities in Oregon. This list is available on-line at: <http://www.deq.state.or.us/wmc/tank/ustfaclist.htm>. The UST program also maintains a database of Leaking Underground Storage Tanks (LUST), where releases from tanks have been reported. This database is available on-line at: <http://www.deq.state.or.us/wmc/tank/LustPublicLookup.asp>.

As of January 2006 the database has 217 records on file for LUST sites in the Klamath Basin. Active sites account for 67 of these sites, and the remaining 150 sites are closed. Figure 27 shows the site locations in the Klamath Basin, in relation to the basin's sensitive aquifers.

LUST Sites and Sensitive Aquifers in the Klamath Basin

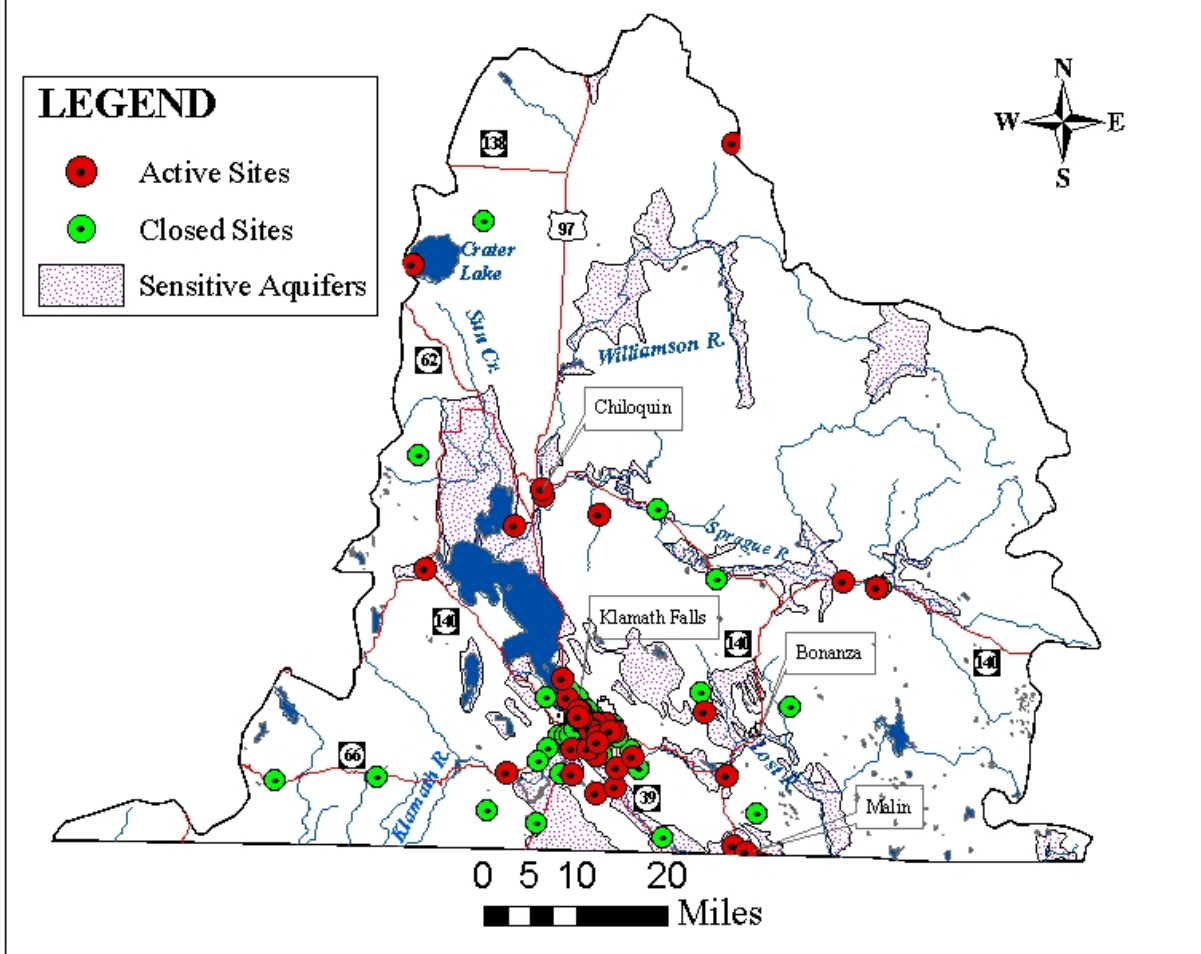


Figure 27. Locations of LUST sites in the Klamath Basin.

Solid Waste Facilities

The DEQ has collected groundwater and leachate monitoring data at two landfills in the Klamath Basin. These landfills are the Klamath Falls Landfill, in the northeast outskirts of Klamath Falls, and the Collins Forest Products Landfill, southwest of Klamath Falls. [Figure 28](#) shows the monitoring well locations at each landfill, as well as their proximity to sensitive aquifers, shown in a stippled pattern. The DEQ Eastern Region office in The Dalles has information about landfill status, monitoring results, and annual reports.

Releases of any contaminant from the landfills to the groundwater poses little or no risk to humans, because no one uses the groundwater for drinking water in the vicinity of the landfills.

Klamath Falls Landfill Summary

Solid Waste Permit Number 302 regulates activities at the Klamath Falls Landfill. The DEQ collected and analyzed groundwater samples from landfill monitoring wells MW-1, MW-2, MW-3, and MW-4 in 1998, 1999, 2001, 2002, and 2004. During the 2002 and 2004 sampling events, the DEQ also collected samples from the landfill leachate sump. The depth to water in the monitoring wells ranges from about 100 feet to 150 feet below ground level.

The DEQ Lab analyzed the samples, using EPA-approved Standard Methods for the Analysis of Water and Wastewater. The analytical data from the DEQ sampling events are available from the DEQ Laboratory in Portland (503-229-5983).

Results

Since 1998, the DEQ has conducted six sampling events at the landfill. Analytical results from the 2000 sampling event detected Thallium over the MCL in the monitoring wells. Neither the landfill owner's contract lab, nor the DEQ Lab, have detected Thallium, or any other constituent, over the MCL in previous, or subsequent sampling events.

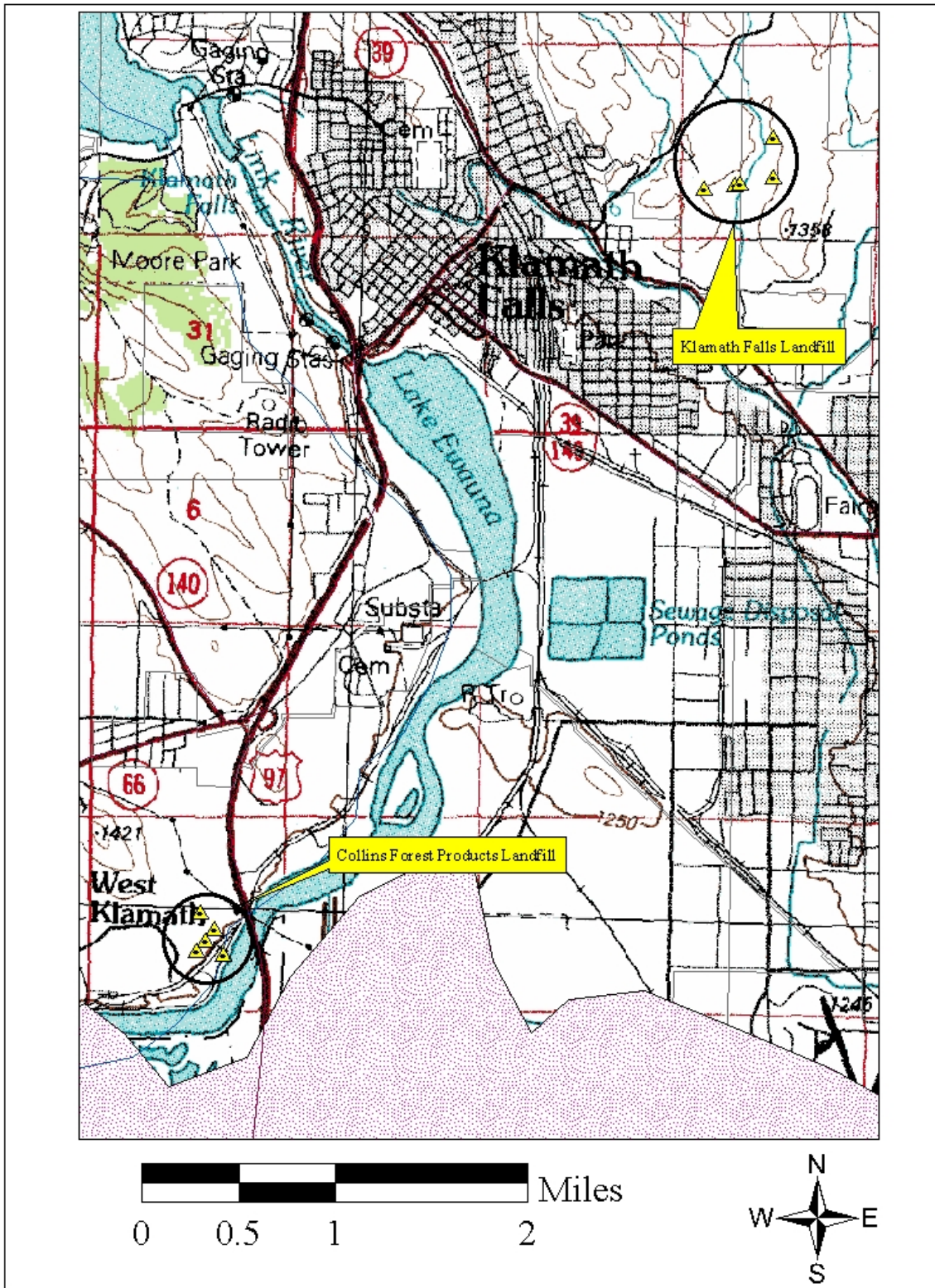


Figure 28. Landfill Locations in the Klamath Basin. The triangles with the dots in their centers mark the landfills' monitoring well locations.

*Collins Forest Products Landfill
Summary*

Solid Waste Permit number 1106 regulates activities at the Collins Forest Products landfill. The DEQ collected and analyzed groundwater samples from the landfill's monitoring wells in 2001, 2002, and 2004. The depth to groundwater ranges from about 4 feet to 40 feet below ground surface.

The DEQ Lab analyzed the samples, using EPA-approved Standard Methods for the Analysis of Water and Wastewater. The analytical data from the DEQ sampling events are available from the DEQ Laboratory in Portland (503-229-5983).

Results

The DEQ Laboratory detected numerous constituents in the monitoring wells, including aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, nitrate, selenium, vanadium, uranium, and zinc.

The DEQ Lab detected Arsenic in one monitoring well, just slightly above the MCL, in the January 2001 sampling event. Neither the landfill owner's contract lab, nor the DEQ, has detected Arsenic over the MCL in any previous or subsequent sampling event.

The DEQ Lab detected Cadmium in one monitoring well, just over the MCL, in the August 2002 sampling event. Neither the landfill owner's contract lab, nor the DEQ, has detected Cadmium over the MCL in any previous or subsequent sampling event.

CONCLUSIONS

Productive basin aquifers occur in shallow alluvial sediments, and deep basalt bedrock. These aquifers are vulnerable to pollution from human activities on the land surface. Groundwater studies in the Klamath Basin have focused on the areas with the highest population and commercial and agricultural activity.

Groundwater in the Klamath Basin is a significant natural resource. There are 829 water rights for groundwater use in the basin. Over 130 public water systems, serving over 60,000 people in the basin, use groundwater, either exclusively, or in combination with surface water. For those basin residents without access to public water systems, approximately 9,000 domestic water wells provide these residents with their drinking water.

Groundwater quality studies in the Klamath Basin have shown the presence of contaminants over established drinking water standards or federal Action Levels. These contaminants include the following:

- Nitrate
- Bacteria
- Lead
- Thallium

- Arsenic
- Pentachlorophenol
- Methylene Chloride
- Cyanide
- Beryllium
- Cadmium

Potential sources for the nitrate and bacteria contamination in areas within the Klamath Basin include high densities of on-site septic systems, and large areas where industrial and commercial wastewater is applied. Substandard well construction and poor maintenance practices increases a well's vulnerability to contamination, particularly from bacteria.

RECOMMENDATIONS

Additional investigation and action are warranted in parts of the Klamath Basin where nitrate, bacteria, heavy metal, pesticide, and volatile organic compound contamination occur. Specific recommendations are as follows:

- Conduct public outreach to educate private well owners how to protect and maintain their wells.
- Provide owners of property with septic systems information on maintaining and improving system performance.
- Provide industrial and commercial businesses with best management practices for land application of process wastewater.
- Provide agricultural businesses with best management practices for fertilization processes.
- Provide livestock businesses with best management practices for waste handling.
- Establish a well monitoring network in the Klamath Falls area and conduct monitoring on a periodic basis to track groundwater quality changes over time
- Establish a well network and implement a sampling event in the Klamath Falls – Merrill area, as directed in the Statewide Ambient Groundwater Monitoring Program's Master Plan.
- The Aquifer Sensitivity Study needs to be reviewed, and possible revised, incorporating current information and understandings of the aquifer system, including the change in aquifer pumping.

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APPENDIX 1

SAMPLE PARAMETER TABLES

Each table in this appendix provides sample parameter information for the groundwater studies discussed in this report including:

- Sample parameter names.
- Sample parameter CAS Number in brackets.
- Sample parameter measurement units.
- Sample parameter detection or reporting limits.
- Sample parameter drinking water standard (if applicable).

Table 1
Klamath Falls Groundwater Study (1987 & 1989)
Volatile Organic Compounds

Notes:

- All measurements in mg/L.
- N.A. = Not Available or Not Applicable.

Constituent	CAS Number	Method Reporting Limit	Drinking Water Standard
Benzene	71-43-2	0.001	0.005
Bromodichloromethane	75-27-4	0.001	0.08
Bromoform	75-25-2	0.001	0.08
Bromomethane	74-83-9	0.001	N.A.
Carbon Tetrachloride	56-23-5	0.001	0.005
Chlorobenzene	108-90-7	0.001	0.1
Chloroethane	75-00-3	0.001	N.A.
2-Chloroethyl Vinyl Ether	110-75-8	0.001	N.A.
Chloroform	67-66-3	0.001	0.08
Chloromethane	74-87-3	0.001	N.A.
Dibromochloromethane	124-48-1	0.001	0.08
1,2-Dibromoethane (EDB)	106-93-4	0.001	0.00005
1,2-Dichlorobenzene	95-50-1	0.001	0.6
1,3-Dichlorobenzene	541-73-1	0.001	N.A.
1,4-Dichlorobenzene	106-46-7	0.001	0.075
1,1-Dichloroethane	75-34-3	0.001	N.A.
1,2-Dichloroethane	107-06-2	0.001	0.005
trans-1,2-Dichloroethylene	156-60-5	0.001	N.A.
1,1-Dichloroethylene	75-35-4	0.001	0.007
1,2-Dichloropropane	78-87-5	0.001	0.005
cis-1,3-Dichloropropene	10061-01-5	0.001	N.A.
trans-1,3-Dichloropropene	10061-02-6	0.001	N.A.
Ethylbenzene	100-41-4	0.001	0.7
Methylene Chloride	75-09-2	0.001	0.005
1,1,2,2-Tetrachloroethane	79-34-5	0.001	N.A.
Tetrachloroethene	127-18-4	0.001	0.005
Toluene	108-88-3	0.001	1
1,1,1-Trichloroethane	71-55-6	0.001	0.2
1,1,2-Trichloroethane	79-00-5	0.001	0.005
Trichloroethylene	79-01-6	0.001	0.005
Trichlorofluoromethane	75-69-4	0.001	N.A.
Vinyl Chloride	75-01-4	0.001	0.002

Table 2
Klamath Falls Groundwater Study (1987)
Pesticides

Notes:

- All measurements in mg/L.
- N.A. = Not Available or Not Applicable.

Constituent	CAS Number	Method Reporting Limit	Drinking Water Standard
Aldicarb	116-06-3	0.0004	0.003
Aldicarb Sulfoxide	1646-87-3	0.0004	N.A.
Aldicarb Sulfone	1646-88-4	0.001	N.A.
2,4-D	94-75-7	0.00006	N.A.
Bravo	1897-45-6	0.0025	N.A.
Bromoxynil	1689-84-5	0.00001	N.A.
Captan	133-06-2	0.0022	N.A.
Carbofuran	1563-66-2	0.0004	0.04
Carboxin	5234-68-4	0.002	N.A.
Chlorpyrifos	2921-88-2	0.0004	N.A.
Dicamba	1918-00-9	0.00003	N.A.
Dimethoate	60-51-5	0.00022	N.A.
Disulfoton	298-04-4	0.00001	N.A.
Diuron	330-54-1	0.0004	N.A.
Eptam	759-94-4	0.002	N.A.
Ethoprop	13194-48-4	0.00033	N.A.
MCPA	94-74-6	0.005	N.A.
Me-parathion	298-00-0	0.00023	N.A.
Parathion	56-38-2	0.00007	N.A.
Phosmet	732-11-6	0.001	N.A.
Pronamide	23950-58-5	0.0012	N.A.
Propham	122-42-9	0.002	N.A.
Sencor	21087-64-9	0.0007	N.A.
Simazine	122-34-9	0.002	0.004

Table 3
Klamath Falls Groundwater Study (1987)
Metals, Nutrients, Physical Parameters

Notes:

- Limits and standards in mg/L, unless otherwise noted.
- N.A. = Not Available or Not Applicable.

Constituent	CAS #	Reporting Limit	Drinking Water Standard
Alkalinity	N.A.	1	N.A.
Ammonia	7664-41-7	0.02	N.A.
Calcium	7440-70-2	0.2	N.A.
Chemical Oxygen Demand	N.A.	5	N.A.
Chloride	16887-00-6	0.2	N.A.
Conductivity	N.A.	1 μ Mhos/cm	N.A.
Hardness	N.A.	1	N.A.
Iron	7439-89-6	0.05	N.A.
Magnesium	7439-95-4	0.1	N.A.
Manganese	7439-96-5	0.05	N.A.
Nitrate/Nitrite-N	N.A.	0.02	10
pH	N.A.	0.1 S.U.	6.5-8.5
Potassium	7440-09-7	0.1	N.A.
Sodium	7440-23-5	0.1	N.A.
Sulfate	N.A.	0.5	N.A.
Temperature	N.A.	1°C	N.A.
Total Dissolved Solids	N.A.	1	N.A.
Total Kjeldahl Nitrogen	N.A.	0.2	N.A.
Total Organic Carbon	N.A.	1	N.A.
Total Organic Halides	N.A.	0.005	N.A.
Total Phosphate	N.A.	0.01	N.A.
Turbidity	N.A.	1	N.A.

Table 4
Klamath Falls Groundwater Study (1989)
Metals, Nutrients, Physical Parameters

Notes:

- Limits and standards in mg/L, unless otherwise noted.
- N.A. = Not Available or Not Applicable.

Constituent	CAS #	Reporting Limit	Drinking Water Standard
Alkalinity	N.A.	1	N.A.
Aluminum	7429-90-5	0.1	N.A.
Ammonia	7664-41-7	0.02	N.A.
Arsenic	7440-38-2	0.005	0.010
Boron	7440-42-8	0.03	N.A.
Calcium	7440-70-2	0.2	N.A.
Chemical Oxygen Demand	N.A.	5	N.A.
Chloride	16887-00-6	0.5	N.A.
Conductivity	N.A.	1 μ Mhos/cm	N.A.
Copper	7440-50-8	0.05	1.3 (Action Level)
Hardness	N.A.	3	N.A.
Iron	7439-89-6	0.05	N.A.
Magnesium	7439-95-4	0.5	N.A.
Manganese	7439-96-5	0.02	N.A.
Nitrate/Nitrite-N	N.A.	0.02	10
pH	N.A.	0.1 S.U.	6.5-8.5
Potassium	7440-09-7	0.5	N.A.
Silicon	7631-86-9	0.3	N.A.
Sodium	7440-23-5	0.5	N.A.
Sulfate	N.A.	0.5	N.A.
Temperature	N.A.	1°C	N.A.
Total Dissolved Solids	N.A.	1	N.A.
Total Kjeldahl Nitrogen	N.A.	0.2	N.A.
Total Organic Carbon	N.A.	1	N.A.
Total Phosphate	N.A.	0.01	N.A.
Turbidity	N.A.	1	N.A.
Zinc	7440-66-6	0.05	N.A.

Table 6
Klamath Falls Groundwater Study (1989)
Metals, Nutrients, Physical Parameters

Notes:

- Limits and standards in mg/L, unless otherwise noted.
- N.A. = Not Available or Not Applicable.

Constituent	CAS #	Reporting Limit	Drinking Water Standard
Alkalinity	N.A.	1	N.A.
Aluminum	7429-90-5	0.1	N.A.
Ammonia	7664-41-7	0.02	N.A.
Arsenic	7440-38-2	0.005	0.006
Boron	7440-42-8	0.03	N.A.
Calcium	7440-70-2	0.2	N.A.
Chemical Oxygen Demand	N.A.	5	N.A.
Chloride	16887-00-6	0.2	N.A.
Copper	7440-50-8	0.05	1.3 (Action Level)
Conductivity	N.A.	1 μ Mhos/cm	N.A.
Hardness	N.A.	1	N.A.
Iron	7439-89-6	0.05	N.A.
Magnesium	7439-95-4	0.1	N.A.
Manganese	7439-96-5	0.05	N.A.
Nitrate/Nitrite-N	N.A.	0.02	10
pH	N.A.	0.1 S.U.	6.5-8.5
Potassium	7440-09-7	0.1	N.A.
Silicon	7440-21-3	0.3	N.A.
Sodium	7440-23-5	0.1	N.A.
Sulfate	N.A.	0.5	N.A.
Temperature	N.A.	1°C	N.A.
Total Dissolved Solids	N.A.	1	N.A.
Total Kjeldahl Nitrogen	N.A.	0.2	N.A.
Total Organic Carbon	N.A.	1	N.A.
Total Phosphate	N.A.	0.01	N.A.
Turbidity	N.A.	1	N.A.
Zinc	7440-66-6	0.05	N.A.

APPENDIX 2

Sample Results

Table 1.
Results from February 1987 Klamath Falls Sampling Event

Analyte (1) Station (LASAR or STORET)	15042	15043	KLA003	15045	15046	KLA006	15048	KLA008	KLA009	15051 (2)
Sample Date	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987	2/4/1987
<i>Physical/Chemical Properties</i>										
Conductivity (umhos/cm)	655	460	2451	632	1300	553	3564	945	270	618
pH (S.U.)	7.8	7.9	7.7	7.9	7.7	8	7.9	7.4	8.4	7.9
Temperature	14.0	14.3	13.2	13	12	14.5	11.7	9.5	13.5	11.3
<i>Nutrients</i>										
Ammonia as N	3.1	8.5	1.9	902	8.5	12.4	12.1	0.06	0.12	22
Nitrate & Nitrite as N	0.14	0.54	0.18	<0.02	0.02	<0.02	0.19	0.02	<0.02	<0.02

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 1, continued

Analyte (1)										
Station (LASAR or STORET)	15052	KLA012	KLA013	KLA014	15056	? (3)	15071	15072	?	15065
Sample Date	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987
<i>Physical/Chemical Properties</i>										
Conductivity (umhos/cm)	1229	988	416	409	909	1350	1212	214	540	358
pH (S.U.)	7.3	9.1	8.7	8.1	7.4	7.8	7.8	8.2	8	7.9
Temperature	11.2	35	9	7.5	12.5	11	8	6	9	13.5
<i>Nutrients</i>										
Ammonia as N	4.6	0.92	<0.02	0.52	0.06	15	0.53	3.1	2	10.5
Nitrate & Nitrite as N	17	0.05	0.27	0.56	42	0.08	0.38	0.02	0.44	<0.02

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 1, continued

Analyte (1) Station (LASAR or STORET)	15075	15076	?	?	?	15080	?	?	?	15084
Sample Date	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987
<i>Physical/Chemical Properties</i>										
Conductivity (umhos/cm)	755	1292	335	367	368	300	258	223	232	270
pH (S.U.)	7.6	7.7	8	7.8	8	7.5	8.1	8	8	8.1
Temperature	13.5	15	12.5	5.5	10	15.5	15	5	11	9
<i>Nutrients</i>										
Ammonia as N	21	11.8	4	0.03	1.7	6.3	4.2	1.37	1.26	1.15
Nitrate & Nitrite as N	<0.02	0.22	0.02	<0.02	<0.02	0.1	<0.02	<0.02	<0.02	0.05

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 1, continued

Analyte (1)									
Station (LASAR or STORET)	?	?	?	15088	?	?	15091	15092	15093
Sample Date	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987
<i>Physical/Chemical Properties</i>									
Conductivity (umhos/cm)	243	270	614	533	517	542	428	358	503
pH (S.U.)	8.1	8	7.1	8	7.8	7.8	7.8	8.1	7.9
Temperature	10	9	10.5	12.5	14	10	6	11	10
<i>Nutrients</i>									
Ammonia as N	0.85	0.85	0.53	11.4	1.5	1.07	0.74	3.3	3.5
Nitrate & Nitrite as N	0.02	0.05	<0.02	<0.02	0.14	0.11	0.16	<0.02	1

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 1, continued

Analyte (1)									
Station (LASAR or STORET)	?	15095	15096	15057	15058	15059	15060	15061	15062 (2)
Sample Date	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987	2/5/1987
<i>Physical/Chemical Properties</i>									
Conductivity (umhos/cm)	225	518	780	579	261	229	966	388	1394
pH (S.U.)	7.4	7.5	7	7.5	8	8.4	7.6	7.9	7.5
Temperature	15	7.5	16	12.5	12	21	8.4	9.8	9.9
<i>Nutrients</i>									
Ammonia as N	9	<0.02	0.02	0.02	4.7	1.02	0.02	6.9	6.3
Nitrate & Nitrite as N	0.06	7.1	15	13	0.23	<0.02	29	0.08	0.02

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 1, continued

Analyte (1)			
Station (LASAR or STORET)	15063	15064	15065
Sample Date	2/6/1987	2/6/1987	2/6/1987
<i>Physical/Chemical Properties</i>			
Conductivity (umhos/cm)	778	575	373
pH (S.U.)	7.8	7.4	7.6
Temperature	8.4	10.2	10.1
<i>Nutrients</i>			
Ammonia as N	0.1	6.5	0.05
Nitrate & Nitrite as N	7.7	0.79	1.4

NOTES:

(1) Values are in mg/L (parts per million).

(2) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(3) Not all stations have verifiable LASAR or STORET numbers.

Table 2.
Results from March 1987 Klamath Falls Sampling Event

Analyte (1)	Well I.D. (LASAR No.)						
LASAR Station Number	15042	15048	15045	15072	15051	15052	15057
Sample Date	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987
<i>Physical/Chemical Properties</i>							
Alkalinity	290	398	276	115	339	277	204
COD	<5	12	<5	<5	19	16	<5
Conductivity (umhos/cm)	677	3553	655	219	585	1914	545
Hardness	190	1100	97	62	170	880	240
pH (S.U.)	7.9	7.9	7.9	8.3	7.9	7.3	7.6
Temperature	15.5	13.3	13.0	10.0	11.6	12.0	12.0
Total Dissolved Solids	408	2573	391	139	326	1483	387
Total Organic Carbon	<1	8	<1	<1	3	8	<1
Total Organic Halides	<0.005	0.008	<0.005	<0.005	0.005	0.029	0.007
Turbidity (NTU)	3	6	1	<1	2	14	<1
<i>Common Ions</i>							
Calcium, Total	38	110	11	10	22	120	43
Chloride	57	470	20.0	3.3	6.3	87	11
Iron, Dissolved	<0.05	0.44	0.3	0.12	0.34	1.1	<0.05
Magnesium, Total	24	190	17	9.1	28	140	32
Manganese, Dissolved	0.06	1.2	0.22	0.13	0.06	2.1	<0.05
Potassium, Total	6.9	27	7.6	5.0	6.8	10.2	5.1
Sodium, Total	72	417	108	22	55	91	29.0
Sulfate	59.0	970	76	2.9	2.3	770.0	39
<i>Metals</i>							
Arsenic, Total	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	0.015
Barium, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium, Total	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper, Total	<0.002	<0.002	0.010	<0.002	<0.002	0.005	0.004
Lead, Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Total	0.1	0.18	<0.05	<0.05	<0.05	<0.05	<0.05
<i>Nutrients</i>							
Ammonia as N	3.1	12.1	9.6	3.2	18	9.2	0.06
Nitrate & Nitrite as N	0.15	0.22	0.03	0.02	<0.02	0.13	13
Phosphate, Total	0.38	0.18	2.6	0.40	1.7	0.48	0.32

Total Kjeldahl Nitrogen	3.1	12	8.8	2.7	18	9.0	0.5
<i>Pesticides</i>	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
<i>Volatile Organic Compounds</i>							
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 2, continued

Analyte (1)							
LASAR Station Number	N.A.	15056	15060 (3)	15096	15065	N.A.	15063
Sample Date	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987	3/4/1987
<i>Physical/Chemical Properties</i>							
Alkalinity	N.A.	213	247	298	176	2000	339
COD	N.A.	<5	6	<5	<5	94	9
Conductivity (umhos/cm)	568	858	1029	689	363	3290	792
Hardness	N.A.	370	435	320	120	1000	380
pH (S.U.)	8.1	7.2	7.4	7.4	7.5	7.5	7.8
Temperature	16.5	12.0	9.9	10.5	10.5	12.5	9.0
Total Dissolved Solids	N.A.	566	666	459	247	1675	534
Total Organic Carbon	N.A.	2	4	<1	<1	<1	3
Total Organic Halides	N.A.	0.23	0.024	0.019	0.013	0.013	0.018
Turbidity (NTU)	N.A.	<1	<1	<1	<1	16	<1
<i>Common Ions</i>							
Calcium, Total	N.A.	76	95	60	21	46	75
Chloride	N.A.	32	88	7.5	3.8	38	14
Iron, Dissolved	N.A.	0.16	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium, Total	N.A.	44	50	41	16	220	47
Manganese, Dissolved	N.A.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium, Total	N.A.	4.2	3.3	4.0	4.9	20.0	2.6
Sodium, Total	N.A.	31	35	30	36	247	33
Sulfate	N.A.	59	54	27	14	11	72
<i>Metals</i>							
Arsenic, Total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011
Barium, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium, Total	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper, Total	<0.002	0.013	0.057	0.017	0.006	0.022	0.018
Lead, Total	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver, Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Zinc, Total	<0.05	<0.05	<0.05	1.3	<0.05	0.20	<0.05
Nutrients							
Ammonia as N	N.A.	<0.02	<0.02	<0.02	<0.02	131	0.32
Nitrate & Nitrite as N	N.A.	31	32	14	1.5	0.05	7.0
Phosphate, Total	N.A.	0.12	0.14	0.10	0.23	8.2	0.42
Total Kjeldahl Nitrogen	N.A.	0.6	0.9	0.4	<0.2	160	1.0
Pesticides							
	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Volatile Organic Compounds							
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 2, continued

Analyte (1)	
LASAR Station Number	15095
Sample Date	3/4/1987
Physical/Chemical Properties	
Alkalinity	190
COD	<5
Conductivity (umhos/cm)	436
Hardness	180
pH (S.U.)	7.5
Temperature	10.5
Total Dissolved Solids	298
Total Organic Carbon	<1
Total Organic Halides	0.013
Turbidity (NTU)	<1
Common Ions	
Calcium, Total	30
Chloride	7.4
Iron, Dissolved	<0.05
Magnesium, Total	25
Manganese, Dissolved	<0.05
Potassium, Total	4.7
Sodium, Total	30
Sulfate	28
Metals	
Arsenic, Total	0.009
Barium, Total	<0.1
Cadmium, Total	<0.001
Chromium, Total	<0.002

Copper, Total	<0.002
Lead, Total	<0.01
Mercury, Total	<0.001
Selenium, Total	<0.005
Silver, Total	<0.001
Zinc, Total	0.05
Nutrients	
Ammonia as N	0.02
Nitrate & Nitrite as N	4.9
Phosphate, Total	0.25
Total Kjeldahl Nitrogen	0.3
Pesticides	N.D.
Volatile Organic Compounds	
EPA 8260 VOCs	N.D.

NOTES:

(1) Values are in mg/L (parts per million).

(2) N.D. = None Detected.

(3) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(4) N.A. = Not Available.

Table 3.
Results from 1989 Klamath Falls Sampling Event

Analyte (1)	Well I.D. (LASAR No.)					
	15064	15098	15099	15097	15043	15042
Cases 19891202, 1208, 1209	15064	15098	15099	15097	15043	15042
Sample Date	11/28/1989	11/28/1989	11/28/1989	11/28/1989	11/28/1989	11/28/1989
Physical/Chemical Properties						
Alkalinity	283	223	250	162	233	291
COD	15	<5	10	<5	<5	13
Conductivity (umhos/cm)	582	570	554	406	442	695
Hardness	240	280	170	140	93	180
pH (S.U.)	7.4	7.8	7.8	7.5	8.0	7.8
Temperature	11.0	13.0	13.0	15.0	14.2	12.0
Total Dissolved Solids	370	340	390	290	270	440
Total Organic Carbon	<1	1	4	2	2	5
Turbidity (NTU)	4	<1	1	<1	<1	1
Common Ions						
Calcium, Total	45	63	26	26	11	31
Chloride	7.3	42	9.5	7.7	7.5	20

Iron, Total	0.34	<0.05	0.20	<0.05	<0.05	0.08
Magnesium, Total	32	30	26	18	16	24
Manganese, Total	0.09	<0.02	0.08	<0.02	0.07	0.11
Potassium, Total	3.0	0.9	2.8	7.2	6.2	7.6
Sodium, Total	31	16	71	41	61	92
Sulfate	34	13	46	34	8.8	60
<i>Metals</i>						
Aluminum, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic, Total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron, Dissolved	0.07	<0.03	0.0	0.03	0.11	0.1
Copper, Total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silicon, Dissolved	58	27.0	46.0	51	46	49
Zinc, Total	0.23	<0.05	0.08	<0.05	0.12	0.19
<i>Nutrients</i>						
Ammonia as N	9.0	<0.02	0.11	0.03	7.9	4.9
Nitrate & Nitrite as N	1.1	2.4	2.1	4.6	0.25	0.49
Phosphate, Total	0.88	0.04	0.35	0.27	1.1	1.3
Total Kjeldahl Nitrogen	9.3	0.2	0.4	0.2	7.7	4.7
<i>Pesticides</i>						
<i>Volatile Organic Compounds</i>						
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 3, continued

Analyte (1)						
Cases 19891202, 1208, 1209	15045 (3)	15046	15063	15100	15061	15060 (3)
Sample Date	11/28/1989	11/28/1989	11/28/1989	11/29/1989	11/29/1989	11/29/1989
<i>Physical/Chemical Properties</i>						
Alkalinity	272	257	308	81	193	236
COD	<5	<5	12	<5	<5	8
Conductivity (umhos/cm)	630	1217	619	167	376	852
Hardness	94	350	310	62	77	380
pH (S.U.)	8.0	7.7	7.8	8.3	8.0	7.6
Temperature	11.0	11.5	8.0	15.0	11.0	11.0
Total Dissolved Solids	400	810	430	120	230	510
Total Organic Carbon	3	4	6	<1	3	5
Turbidity (NTU)	1	2	<1	1	3	<1
<i>Common Ions</i>						
Calcium, Total	9.5	55	57	12	11	76
Chloride	22	43	13	1.3	7.8	58

Iron, Total	0.25	0.42	<0.05	0.20	0.23	<0.05
Magnesium, Total	17	53	40	7.7	12	47
Manganese, Total	0.15	0.72	0.10	<0.02	0.14	<0.02
Potassium, Total	6.7	12	2.1	1.7	5.3	2.3
Sodium, Total	105.0	130	32	10	53	32
Sulfate	52	330	40	3.1	2.9	34
Metals						
Aluminum, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic, Total	<0.005	0.0	0.012	<0.005	<0.005	<0.005
Boron, Dissolved	0.26	0.14	0.07	<0.03	<0.03	<0.03
Copper, Total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silicon, Dissolved	48	49	57.0	38	49	60
Zinc, Total	<0.05	0.09	<0.05	<0.05	<0.05	<0.05
Nutrients						
Ammonia as N	8.5	3.4	0.30	0.03	6.7	0.04
Nitrate & Nitrite as N	0.05	1.2	1.2	0.50	0.09	22
Phosphate, Total	2.8	0.47	0.40	0.04	2.0	0.15
Total Kjeldahl Nitrogen	9.2	5.6	0.9	<0.2	6.8	0.8
Pesticides						
Volatile Organic Compounds						
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 3, continued

Analyte (1)						
Cases 19891202, 1208, 1209	15069	15048	15051	15052	15057	15058
Sample Date	11/29/1989	11/29/1989	11/29/1989	11/29/1989	11/29/1989	11/29/1989
Physical/Chemical Properties						
Alkalinity	88	432	360	286	257	130
COD	<5	12	11	15	6	<5
Conductivity (umhos/cm)	329	405	607	1760	596	271
Hardness	58	1200	180	890	290	58
pH (S.U.)	8.2	7.9	7.9	7.5	7.6	7.9
Temperature	6.0	10.0	12.0	11.0	11.0	17.0
Total Dissolved Solids	230	3000	340	1400	400	160
Total Organic Carbon	<1	9	6	9	3	1
Turbidity (NTU)	<1	5	2	9	<1	4
Common Ions						
Calcium, Total	13	120	21	110	50	8.7
Chloride	32	380	6.9	76	6.3	7.5

Iron, Total	<0.05	0.56	0.52	1.6	<0.05	0.39
Magnesium, Total	6.1	230	32	150	40	8.9
Manganese, Total	<0.02	1.3	0.04	1.9	<0.02	0.13
Potassium, Total	3.9	28	6.5	10	5.3	5.0
Sodium, Total	50	540	59	94	31	33
Sulfate	41	1200	2.4	670	38	1.7
Metals						
Aluminum, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic, Total	<0.005	<0.005	<0.005	<0.005	0.015	<0.005
Boron, Dissolved	<0.03	0.51	<0.03	<0.03	<0.03	<0.03
Copper, Total	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05
Silicon, Dissolved	48	53	61	59	55	50
Zinc, Total	<0.05	0.16	<0.05	0.11	0.11	0.34
Nutrients						
Ammonia as N	1.7	12.8	18	8.1	0.02	4.8
Nitrate & Nitrite as N	0.35	0.06	0.07	2.1	10	0.38
Phosphate, Total	0.03	0.14	1.6	0.50	0.34	0.45
Total Kjeldahl Nitrogen	1.6	14	19	8.6	0.4	4.5
Pesticides						
Volatile Organic Compounds						
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 3, continued

Analyte (1)						
Cases 19891202, 1208, 1209	15075	15080	15056	15088 (3)	15062	15095
Sample Date	11/30/1989	11/30/1989	11/30/1989	11/30/1989	11/30/1989	11/30/1989
Physical/Chemical Properties						
Alkalinity	378	155	242	309	506	132
COD	9	<5	<5	13	26	<5
Conductivity (umhos/cm)	668	304	674	538	1358	285
Hardness	160	50	340	115	710	130
pH (S.U.)	7.8	8.0	7.3	8.1	7.5	7.7
Temperature	13.5	14.0	10.0	11.3	8.0	12.0
Total Dissolved Solids	360	200	490	340	1000	210
Total Organic Carbon	6	2	4	6	13	1
Turbidity (NTU)	1	<1	<1	1	19	<1
Common Ions						
Calcium, Total	28	7.8	63	14	120	20
Chloride	5.9	5.3	17	4.4	18	3.3
Iron, Total	0.34	0.05	<0.05	0.10	1.6	<0.05

Magnesium, Total	26	7.4	45	20	100	19
Manganese, Total	0.07	0.09	<0.02	0.05	0.28	0.09
Potassium, Total	7.3	4.5	3.3	6.0	2.9	3.6
Sodium, Total	71	47	29	80	62	18
Sulfate	2.2	1.6	43	2.0	320	17
Metals						
Aluminum, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic, Total	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
Boron, Dissolved	<0.03	<0.03	<0.03	0.05	0.05	<0.03
Copper, Total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silicon, Dissolved	56	63	61	58	52	43
Zinc, Total	<0.05	0.09	<0.05	<0.05	0.05	<0.05
Nutrients						
Ammonia as N	18	5.9	0.06	13	0.27	0.06
Nitrate & Nitrite as N	0.07	0.23	23	0.09	0.05	1.7
Phosphate, Total	1.0	0.21	0.13	0.40	0.24	0.27
Total Kjeldahl Nitrogen	19	6.6	0.9	11	5.4	0.3
Pesticides						
Volatile Organic Compounds						
EPA 8260 VOCs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Table 3, continued

Analyte (1)			
Cases 19891202, 1208, 1209	15096	15072	15076
Sample Date	11/30/1989	11/30/1989	11/30/1989
Physical/Chemical Properties			
Alkalinity	290	117	495
COD	<5	<5	17
Conductivity (umhos/cm)	639	222	1270
Hardness	330	65	300
pH (S.U.)	7.4	8.3	7.8
Temperature	10.0	10.0	13.0
Total Dissolved Solids	460	150	730
Total Organic Carbon	3	<1	9
Turbidity (NTU)	<1	<1	2
Common Ions			
Calcium, Total	57	9.7	30
Chloride	6.8	3.8	84
Iron, Total	<0.05	0.12	0.21
Magnesium, Total	46	10	54

Manganese, Total	<0.02	0.10	0.04
Potassium, Total	3.5	4.7	11
Sodium, Total	31	22	150
Sulfate	27	2.5	89
<i>Metals</i>			
Aluminum, Total	<0.1	<0.1	<0.1
Arsenic, Total	<0.005	<0.005	<0.005
Boron, Dissolved	<0.03	<0.03	<0.03
Copper, Total	<0.05	<0.05	<0.05
Silicon, Dissolved	55	42	62
Zinc, Total	1.3	<0.05	0.18
<i>Nutrients</i>			
Ammonia as N	0.04	2.9	23
Nitrate & Nitrite as N	15	0.07	1.1
Phosphate, Total	0.10	0.37	1.2
Total Kjeldahl Nitrogen	0.4	2.8	23
<i>Pesticides</i>	N.D.	N.D.	N.D.
<i>Volatile Organic Compounds</i>			
EPA 8260 VOCs	N.D.	N.D.	N.D.

NOTES:

(1) Values are in mg/L (parts per million).

(2) N.D. = None Detected.

(3) Results from duplicate samples (i.e., two samples from one well) were averaged into one number for inclusion in this table.

(4) N.A. = Not Available.
