Columbia Slough
TOTAL MAXIMUM DAILY LOADs (TMDLs)
For:
Chlorophyll *a*, Dissolved Oxygen, pH, Phosphorus, Bacteria, DDE/DDT, PCBs, Pb, Dieldrin and 2,3,7,8 TCDD

Oregon Department of Environmental Quality
Northwest Region
September 1998

Columbia Slough TMDLs

<u>WQ Concerns at a Glance:</u>

Water Quality Limited?	Yes
Segment #	22P-COLSO, mouth to Fairview Lake
Water Quality Standards:	Willamette Basin, OAR 340-41-442, OAR 340-41-445
Parameters with Season Water Quality Limited:	Bacteria -annual pH -spring through fall dissolved oxygen (cool water aquatic life) - annual chlorophyll a -spring through fall phosphorus- spring through fall temperature - spring through fall Pb - water column DDE, DDT - fish tissue PCBs- fish tissue 2,3,7,8 TCDD - fish tissue dieldrin - fish tissue (preventative TMDL)
Uses Affected:	Salmonid fish rearing, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality
Known Sources:	Industrial discharges, combined sewer overflows, groundwater, urban storm water, landfill leachate, airport de-icing, clean up sites
Suspected Sources:	Sediments, agricultural runoff, failing septage fields, air deposition

Water quality in the Columbia Slough is affected in a complex manner by sources such as combined sewer overflow events, groundwater, landfill leachate, airport de-icing fluids, urban runoff, past practices and industrial runoff, as well as conventional National Permit Discharge Elimination System (NPDES) point sources. The Total Maximum Daily Load (TMDL) strategy will be to identify the loading capacity of the Slough for the pollutants of concern and implement a water quality management plan (WQMP) to control the identified sources and achieve the TMDLs. The WQMP will incorporate load allocations and waste load allocations, water level management and implementation of storm water Best Management Practices (BMPs). The TMDL will utilize a phased approach through which the effectiveness of controls will be assessed with a monitoring program and additional controls required if waste loads, loads and TMDLs are not being achieved. The controls will be implemented via Memorandums Of Agreement (MOAs) with the designated management agencies (DMAs). For most of the Municipal Separate Storm Sewer System (MS4) permit holders the permit incorporates the agreements in the MOAs as a permit condition. Requirements for urban storm water control for Multnomah County, however, will be implemented via revisions to their MS4 permits since their permit does not incorporate the TMDL requirements of the MOA.

BACKGROUND INFORMATION

The Columbia Slough is a 19 mile long complex of narrow and shallow channels located on the southern floodplain of the Columbia River between Fairview Lake and the Willamette River. The Slough was originally a series of wetlands and marshes; it is now a highly managed water system with dikes and pumps to provide watershed drainage and flood control for the lowlands surrounding it. The management of the Slough can have a significant impact on the water quality and uses supported by the Slough.

The Slough drains approximately 40,000 acres of land. Many kinds of land use are found within the watershed including heavy and light industries, residential areas, vegetable farming and the Portland International Airport. The Slough also serves as one of the City's largest open space and wildlife habitat areas.

Water Quality Concerns

The Columbia Slough, from the mouth to Fairview Lake, has been placed on DEQ's 1994/1996 303(d) list for multiple parameters. The Slough is water quality limited for chlorophyll *a*, pH and phosphorus from spring through fall, because of algal growth. This algal growth affects the aesthetic quality of the Slough and may affect such beneficial uses as fishing and boating. The dissolved oxygen criteria for cool water aquatic life is violated throughout the year; diurnal swings in dissolved oxygen during the summer months are most likely the result of algal growth, while winter violations are likely due to storm water runoff, including de-icing fluid. These dissolved oxygen criteria violations may prevent the Slough from supporting salmonid fish rearing as well as resident fish and aquatic life. Elevated bacteria levels through all seasons impact the water contact recreation use (swimming). In the spring through fall, high temperatures are also a concern, affecting salmonid fish rearing.

The Slough is water quality limited for DDE, DDT, PCBs and dioxin due to elevated levels found in fish tissue, impairing the use of the Slough for fishing. The State of Oregon Health Division and the City of Portland have issued recommendations against eating fish from the Slough due to contamination by PCBs, DDE and DDT. Review of data also indicates that dieldrin is present in fish tissue at elevated levels. The Slough is water quality limited for lead (Pb) because of levels above the fresh water chronic criteria for the protection of aquatic life.

Beneficial Uses Affected

The affected beneficial uses for the Columbia Slough, as identified in Oregon Administrative Rules, include salmonid fish rearing, resident fish and aquatic life, fishing, hunting, boating, water contact recreation and aesthetic quality.

Slough Hydrology and Segmentation

The Slough has been divided into five reaches (Figure 1, CH2MHill, 1995), based primarily on hydraulic characteristics. The reaches of the Slough are generally shallow with variable widths.

The Lower Slough (Reach 1) extends from the Willamette River to the Multnomah County Drainage District Pump Station No.1 at NE 13th Avenue (MCDD1) and includes the North Slough. The Lower Slough is tidally influenced, so the water quality in the Lower Slough is heavily influenced by that in the Willamette River. At MCDD1 there is a dike that physically separates the Lower and Middle Sloughs. Potential sources of pollutants to Reach 1 include sediments, combined sewer overflow events, groundwater, storm water, leachate from St. Johns landfill, industrial discharges, and water from Reach 2 and the Willamette River.

The Middle Slough (Reach 2) extends from MCDD1 to a cross levee (mid-dike) which has slide gates that can hydraulically isolate flows between the Middle and Upper Sloughs. About half the annual flow in the Middle Slough is due to groundwater. Potential sources of pollutants to Reach 2 include sediments, groundwater, storm water, illicit discharges, and contamination from the NuWay Oil Site and water from Reach 3.

The Upper Slough (Reach 3) extends from the mid-dike to the outlet of Fairview Lake. The Upper Slough receives considerably less groundwater than the Middle Slough. West of Four Corners, the Slough is subject to reversal of flows due to the operations of the Multnomah County Drainage District Pump Station No.4 (MCDD4) located on Marine Drive. MCDD4 discharges directly to the Columbia River. The arm of the Slough to MCDD4 often has little or no flow exchange with other portions of the reach. During the summer it is basically a stagnant waterbody. The Middle and Upper Slough are not driven by tidal influences or affected by CSO discharges. The system hydraulics are influenced by the MCDD pump stations and inflow of groundwater. Potential sources of pollutants include sediments, groundwater, storm water, industrial discharges and water from Reach 4.

Fairview Lake (Reach 4) is a shallow lake that covers about 105 acres. The lake is not considered part of the Slough, but contributes to the flow of the Slough. During the summer months, however, flow from Fairview Lake to the Upper Slough is negligible compared to the flow from groundwater (CH2MHill, Part 2, 1995). The flow from Reach 5 (Fairview Lake drainage basin, not pictured) includes the tributaries of Fairview Lake, which are composed of Fairview Creek, Osborn Creek, and No Name Creek. This reach is not part of the Slough, but it discharges to Fairview Lake.

Available Monitoring Data

The Columbia Slough has been monitored sporadically. Metropolitan Service District (METRO) has been conducting water quality monitoring near St. John’s landfill in the Lower Slough since the 1970’s. Portland State University (PSU) conducted water quality monitoring in 1992-1994 for dissolved oxygen (DO), temperature and pH. The City of Portland Bureau of Environmental Services (BES) has conducted monitoring in the Slough since 1992, including hydrolab data for pH, temperature and DO. Additional water quality monitoring has been conducted by the City of Gresham and the US Environmental Protection Agency (EPA). Toxics data for the Columbia Slough includes water column data, fish tissue data and sediment data. Toxics for which the Slough is routinely monitored include the following metals: cadmium, chromium, copper, nickel and lead.

Most of the fish tissue data available for the Columbia Slough was collected as part of the Screening Level Risk Assessment done on Slough sediments as part of the Sediment Remediation Project. As part of this study, fish and crayfish were collected during the summer of 1994 at 10 different locations in the Columbia Slough, and tested for 110 different chemicals. Historical fish tissue data was collected by DEQ as part of a larger investigation of the Lower Willamette River.

The following sections discuss the results of monitoring of the Slough, and the allocations and strategies developed to attain water quality standards for each 303(d) list parameter.

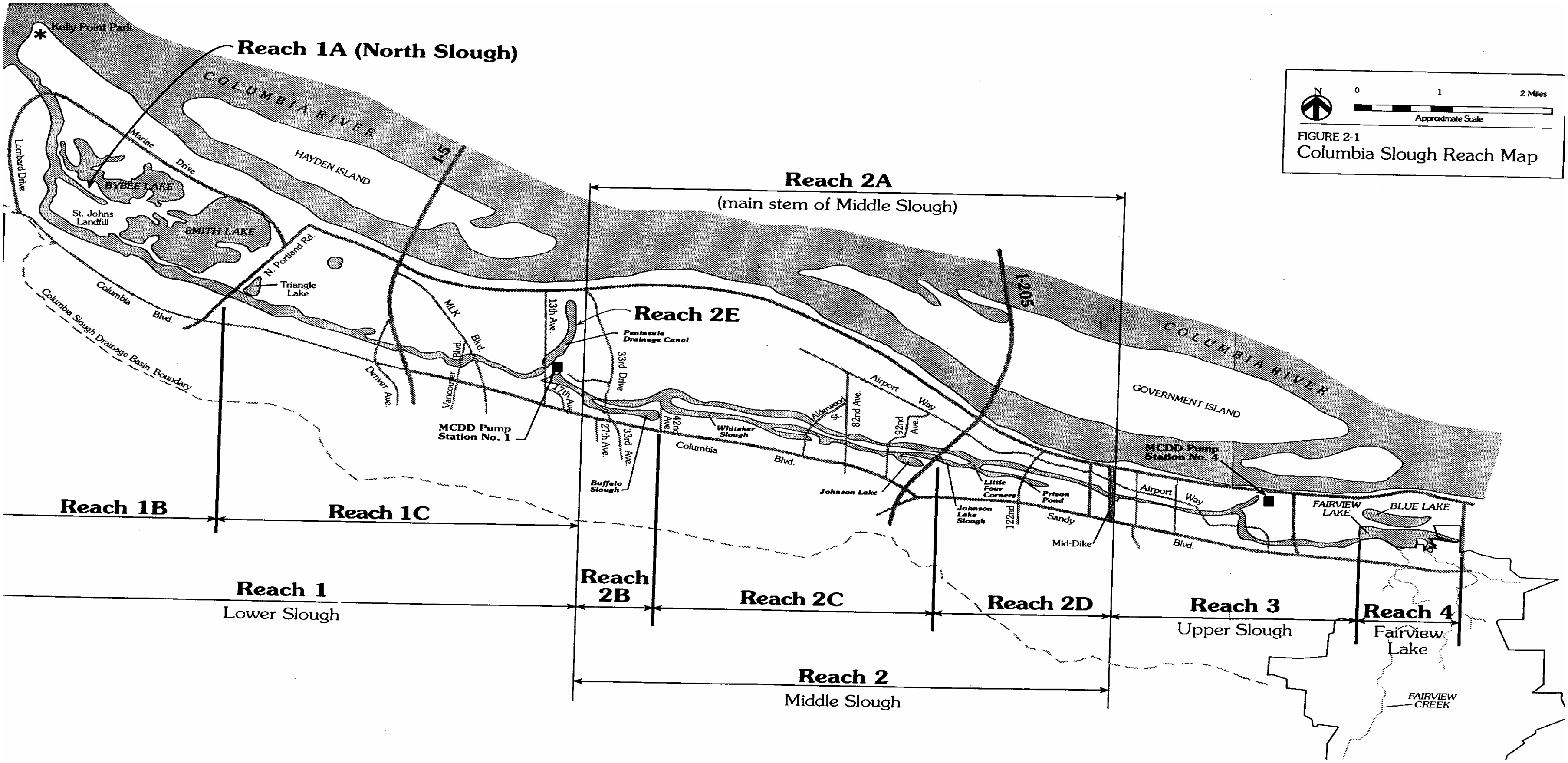

Figure 1: Columbia Slough

DISSOLVED OXYGEN

Water Quality Criteria

Dissolved oxygen (DO) is important for maintaining a healthy and balanced distribution of aquatic life. Salmonid species are the most sensitive beneficial use affected by dissolved oxygen concentration. For waterbodies, such as the Columbia Slough, identified by the Department of Environmental Quality (DEQ) as providing cool water aquatic life, the dissolved oxygen must not be less than 6.5 mg/L. When DEQ determines that adequate information exists, the dissolved oxygen may not fall below 6.5 mg/L as a 30-day mean minimum, 5.0 mg/L as a seven day minimum mean, and may not fall below 4.0 mg/L as an absolute minimum (OAR 340 - 41-445).

Monitoring

Synoptic water quality data show DO criteria violations throughout the Slough. During winter, DO criteria violations occur frequently and the DO concentrations are the lowest in the Lower Slough and the main stem of the Middle Slough. During the winters of 1990 - 1994 there were frequent exceedances of the DO criteria at reaches 2A and 1B (CH2MHill, Part 1, 1995). A severe DO depletion problem was recorded in February 1995 in the Middle and Lower Slough. DO in the Lower Slough was recorded as zero for almost two days. This severe oxygen depletion occurred after a severe winter storm hit Portland on February 12th, 1995. Significant snow and ice accumulation lasted until February 15th or 16th. Portland International Airport (PDX) used de-icing and anti-icing chemicals (ethylene glycol and urea) with high BOD (biochemical oxygen demand) values during this time period. The severe oxygen depletion appears to be a result of the de-icing activities (Wells 1995). The dissolved oxygen sag in the Lower Slough, at the St. John's landfill bridge (SJB), is presented graphically in Figure 2:

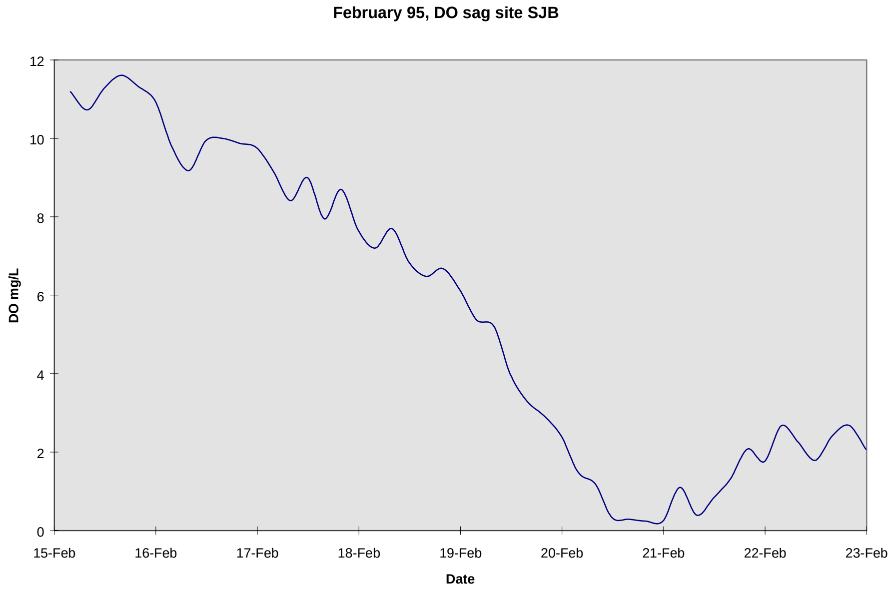

Figure 2: February 95 Dissolved Oxygen Lower Slough

Another incident of dissolved oxygen depression occurred during February 1996. The DO was below 4 mg/L for almost 10 days at the North Denver Bridge (NDB) in the Lower Slough. This DO drop occurred after about 8 days of freezing weather. At MCDD1 (main stem, Middle Slough) DO concentrations were below 4 mg/L for about 3 days. No impacts of depressed dissolved oxygen were seen above the airport's discharge at NE 92 $^{\mathrm{ND}}$, NE 158 $^{\mathrm{Th.}}$, nor at MCDD4 (main stem, Upper Slough) (Wells, 1996). This data suggest de-icing and anti-icing loads dominate the BOD load to the Slough, resulting in oxygen standard violations with anoxic conditions.

There are limited DO data available for Reaches 2B, 2C and 2D during the winter months. Data from Reach 3 did not indicate any water quality problems related to DO (CH2MHill, Part 1, 1995).

Summer violations of the DO criteria occur much less frequently than winter violations and may be due to stagnant water and algal processes. Because the DO criteria violations which occur in the summer appear to be caused by algal processes, they are addressed in the eutrophication section. The following discussions of modeling efforts, loading capacity and implementation strategy only address the winter dissolved oxygen criteria violations.

Modeling

A water quality model has been used to estimate the effects of winter weather and wet weather loads, particularly from Combined Sewer Overflows (CSOs) and storm water. The water quality and hydrodynamics model is an adaptation of the Corps of Engineers' model CE-QUAL-W2 (Corps of Engineers, 1986, 1990; Cole and Buchak, 1994). Event based pollutant loads from storm water were estimated, including de-icing loads from PDX. Model calibration is described in Wells, 1995.

Modeling conclusions:

- The major components affecting DO in Reach 1 are upstream discharges from Reach 2, storm water, CSOs and sediment oxygen demands.
- De-icing materials from PDX contribute to severe oxygen depletion in the Middle and Lower Slough in the late fall and winter.
- De-icing loads from PDX will have to be reduced significantly to meet dissolved oxygen criteria in the Slough (Wells, October 1996).
- Flood events in the Willamette and/or Columbia River worsen the oxygen depression because they stagnate the water in the Lower Slough (Wells, October 1996).

Monitoring data has indicated that low DO levels in the Slough are of concern primarily in the winter months. Because of this, the loading capacity and allocations will be defined for the wet weather BOD loads only. Data analysis and modeling has demonstrated that de-icing and anti-icing activities at PDX are the dominant source of BOD to the Slough. Anoxic conditions are observed in the Slough when de-icing and anti-icing loads are coupled with stagnant water conditions. Model calibration by Wells (1995) indicates that the BOD load from urban runoff is less than 1/2 the concentration reported in the municipal separate storm sewer (MS4) permits. The implementation strategy will require the DMAs to refine estimates of the BOD load to the Slough and the effect on water quality. The strategy will also require PDX to reduce the de-icing and anti-icing load.

Loading Capacity Defined

The ambient DO criteria concentration is used to determine the loading capacity (LC) of the Slough for BOD materials. The LC is expressed as an ultimate biochemical oxygen demand. The BOD LC is dependent on the deoxygenation (K_d) and aeration (K_a) rate. The resulting load allocations are for the winter months of November through March. Allocations are not defined for BOD loads during the summer months.

Analysis of data provided by Union Carbide and PDX resulted in a range of possible K_d values for the Slough. Values for K_a were calculated using the Banks and Herrera formula using wind speed and waterbody depth. See Appendix B for a detailed description of this analysis. Once the appropriate K_a and K_d values were chosen, a dissolved oxygen balance (Streeter Phelps equation) was used to determine a range of ultimate BOD (L_o) that would result in the attainment of the DO criteria of 6.5, 5.0 and 4.0 mg/L DO. The Streeter Phelps equation is given as :

$$D = \left\{ \frac{K_d}{K_a - K_d} \left[\exp(-K_d t) - \exp(-K_a t) \right] \right\} L_o + (C_s - C_0) \exp\left[-(K_a t) \right]]$$

Where:

D = DO deficit (mg/L)
K_d = decay rate (/day)
K_a = aeration rate (/day)
t = time (days)

L_o = instream BOD (BOD ultimate) (mg/L)
C_s = DO at saturation (mg/L)
C_o = DO initial (mg/L)

(Thomann et al, 1987)

The Streeter-Phelps equation contains several assumptions; there is one dominant source of BOD, DO of a stream is unaffected by nitrification and algal respiration, replacement of oxygen is affected by reaeration and not by algal photosynthesis, there are steady state conditions along the river channel. During the winter months, when de-icing influences water quality, algal photosynthesis processes will be negligible. PDX has stopped using urea in its de-icing operations, so nitrification is not a significant BOD load.

In response to comments from PDX, the oxygen analysis was expanded to include dispersion. Dispersion acts to spread the plug of high strength BOD out as it moves down the Slough. By adding dispersion it was no longer assumed that the discharge was continuous or that steady state conditions exist. The de-icing discharge was assumed to occur for 1 day per event. Dispersion is represented by the following equation (Chapra, 1997):

$$E_x = 0.011 \frac{U^2 B^2}{H \sqrt{gHS}}$$

where:

E_x = longitudinal dispersion coefficient (m^2/s)
U = velocity (m/s)

B = width (m)
H = depth (m)
g = acceleration due to gravity (m/s^2)
s = channel slope (dimension less)

A one dimensional dissolved oxygen model was used (LTI, July, 1997) to represent the influence of dispersion on the Streeter Phelps model predictions. The model divided the Columbia Slough into a one dimensional series of completely mixed reactors of constant volume. The model solves two differential mass balance equations; one each for BOD and DO.

Conditions in the Lower Slough appear critical because this is where the BOD plug can stagnate when the Willamette flows are high. The BOD calculations simulated conditions as measured in the field when the anoxic DO levels were recorded; temperatures were near 8°C. The five day BOD (BOD_5) limits should be expressed in the terms that they would be measured at the laboratory, at standard temperature of 20°C. The laboratory measure, and TMDL, will be presented as BOD_5. The conversion is made in a two step process that is consistent with how the samples would be handled. First the BOD sample is taken from the field to the laboratory and allowed to equilibrate to 20°C which increases the decay rate and is represented as: $k_T = k_{20}\theta^{T-20}$ (Tchobanoglous et al, 1985). By rearrangement, $k_{20} = \frac{k_T}{\theta^{T-20}}$. The temperature adjustment factor (θ) is 1.102. The calculations to determine θ are contained in Appendix B.

The BOD_u is then converted to BOD_5 by the following equation:

$BOD_t = BOD_u(1-e^{-kt})$

Where:

t= time, 5 days
k = the decay rate, at 20°C

(Tchobanoglous et al, 1985)

The loading capacity was calculated using the following equation:

LC = (Q)(BOD_5)(conversion factor)

Where:

Q = river flow in cubic meters/second (m^3/sec)
BOD_5 = calculated BOD_5 in mg/L
conversion factor = to convert from m^3/sec and mg/L to kg/day

A portion of the loading capacity is set aside as the margin of safety (MOS). The margin of safety accounts for the uncertainty about the relationship between pollutant loads and water quality of the receiving water. A baseflow of 1.98 m^3/sec (groundwater flow only) and storm flows are used to calculate the loading capacity. The storm flows range from 2.83-11.33 m^3/sec, approximating the range of flows achieved by pumping at MCDD1.

The results of this analysis are summarized in Table 1.

Table 1: BOD_5 Loading Capacity

Flow, m3/sec	DO criteria (mg/L)	LC (BODu,mg/L)	LC (BOD5, mg/L)	LC (kg/day)	MOS (kg/day)
LC and MOS to meet 4.0 mg/L DO criteria					
2.83	4	48	24	5947	1189
5.66	4	64	33	16108	3222
8.5	4	61	31	22842	4568
11.33	4	69	35	34583	6917
LC and MOS to meet 5 mg/L DO criteria					
2.83	5	41	21	5170	1034
5.66	5	56	28	13893	2779
8.5	5	53	27	19920	3984
11.33	5	60	31	30262	6052
LC and MOS to meet 6.5 mg/L DO criteria					
2.83	6.5	32	16	4004	801
5.66	6.5	42	22	10571	2114
8.5	6.5	41	21	15537	3107
11.33	6.5	48	24	23782	4756

The DO water quality criteria has three tiers to recognize that the effect of reduced DO on fish and aquatic life is dependent on how low the DO gets as well as the duration and frequency of the low DO. Since the sources are non steady state pulse loads from runoff, the LC is identified for three specific conditions; an hourly maximum BOD load based on achieving the minimum DO criteria (4.0 mg/L), an event daily average maximum based on achieving the 7-day mean minimum DO criteria (5.0 mg/L), and a long term continuous average based on achieving the 30-day mean minimum DO criteria (6.5 mg/L).

Allocations

The TMDL is a matrix of flows and associated average, daily average maximum and hourly maximum BOD_5. The LC is distributed between the dominant sources of oxygen demanding material, which include PDX de-icing and urban runoff. The background (BKG) BOD_5 concentration is set to 2.5 mg/L (Appendix B). The WLA for CSOs is zero (except for a one in five year winter storm and one in ten year summer storm). A margin of safety (MOS) is set at 20% of the total BOD_5 load at each flow for each DO criteria (Appendix B).

The distribution between airport and urban runoff is based on a percent reduction equivalent to the relative contribution to the observed DO deficit. Modeling results from Wells (1995, EWR-2-95) were used to estimate the contributions. The modeling used measured discharge, DO, temperature and limited instream BOD. Storm water and de-icing BOD loads were adjusted to fit the measured data. This calibration effort indicated that de-icing and anti-icing loads contribute 3.8 lb. of BOD load for every 1 pound of urban storm water BOD. The waste load allocations incorporate the ratio of 3.8 lb/1 lb de-icing and anti-icing load removed to urban storm water removed. The loading capacity is therefore defined as:

$LC = QC_{bkg} + QC_{mos} + QC_{sw} + QC_{\text{de-icing}}$

where:

$C_{sw(WLA)} = C_{so}(1-\alpha)$ or the concentration of the storm water in the waste load allocation is equal to the initial storm water concentration times the reduction needed and:

$C_{\text{de-icing(WLA)}} = C_{\text{de-icingo}}(1-\alpha b)$, b= 3.8 or the de-icing waste load allocation is a function of the initial de-icing concentration, the reduction needed and the ratio between storm water and de-icing runoff.

The final formula is:
$LC = QC_{bkg} + QC_{mos} + Q(C_{so}(1-\alpha)) + Q(C_{de\text{-}icingo}(1-\alpha b))$

The constant α represents the % urban storm water reduction necessary to achieve the BOD loading capacity. This reduction was calculated by iteration.

The allocation for the airport is divided between the Port of Portland (PDX) and the Oregon Air National Guard (ANG). By analysis of the de-icing use estimates provided to DEQ by the Port and the Air National Guard, it was determined that the Port contributes about 89% of the de-icing load. The Port therefore receives 89% of the total airport waste load allocation (WLA). The Oregon Air National Guard receives 11% of the total airport allocation. This is represented mathematically as:

PDX = total airport LA x 0.89
ANG = total airport LA x 0.11

From application of SIMPTM (Simplified Particulate Transport Model) the City of Portland predicted a 150% increase in the storm water pollutant loading over current loads to the Columbia Slough (BES, 1989). SIMPTM is a continuous storm water quality program that can simulate the accumulation and washoff of total solids or particulates plus up to six different pollutants. Current storm water loads are given 2/3 of the BOD_5 allocation and future growth receives 1/3 of the allocation.

The storm water allocation includes storm water from two sources: industrial facilities that are required to have general industrial storm water permits, and urban runoff from areas in the Slough watershed that are managed by the designated management agencies. To estimate the area covered by the industrial permits, a review of general storm water permits in DEQ was conducted. The area covered by these permits was calculated. By assuming that 100% of the facilities that need industrial permits are covered in these files, the area was calculated to be 997 acres. Using an adaptation of the simple method (EPA 1992), the annual load of BOD_5 from industrial permitted sites can be calculated:

Area x Annual Rainfall x Runoff Coefficient x Pollutant Concentration = Annual Pollutant Load

area = 997 acres	runoff coefficient = 0.68[1]
annual rainfall =34.4 inches[2]	pollutant concentration = 68 mg/L BOD[3]

Using this equation, a value of 358, 342 lb/year of BOD_5 is obtained for permitted industrial sites. To estimate the BOD_5 load from the area managed by the designated management agencies (DMAs) (under MS4 permits), the BOD_5 load from the MS4 areas is used. An estimate of the total annual BOD_5 load from the area covered by the Portland MS4 permit is contained in Appendix C of the City of Portland MS4

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[1] Table 3-13, Part 2, City of Portland MS4 permit application, industrial land use runoff coefficient.
[2] Table 3-12, Part 2, City of Portland MS4 permit application, storm event statistics.
[3] Table 3-14, Part 2, City of Portland MS4 permit application, water quality pollutant concentrations utilized for land use pollutant loading model, industrial land use.

application. Using the values for runoff coefficients and pollutant concentrations for the subbasins that drain to the Slough, an annual BOD$_5$ load of 655,274 lb/yr is calculated. The Gresham MS4 report (Gresham 1996) estimated the annual BOD$_5$ load to the Slough as 115, 246, lb/yr. The total annual BOD$_5$ load from the areas managed by the DMAs (under the MS4 permits) is 770,520 lb/yr. The industrial load of 358,342 lb/yr is approximately 46.5% of the total urban load. The industrial sites are allocated 46.5% of the annual storm water BOD$_5$ allocation, after the allocation for future growth is set aside. This is represented mathematically as:

Future growth WLA = total urban storm water WLA x 0.333
DMA WLA = total urban storm water WLA x 0.6667 x 0.535
Industrial storm water WLA = total urban storm water WLA x 0.6667 x 0.465
BKG = 2.5 mg/L x 1.98 m^3/sec x conversion factor = 428 kg/day

The allocation for PDX includes several co-permittees.
The BOD$_5$ allocations are summarized in Table 2. Differences in the margin of safety (MOS) between Table 1 and Table 2 are due to rounding.

Table 2: BOD$_5$ Waste Load Allocations

Flow (m3/sec)	BKG	Future Growth	DMA	Industrial SW	PDX	ANG	MOS	TMDL
WLA to achieve 4.0 mg/L DO criteria, BOD5,kg/day								
2.83	428	188	201	175	3342	413	1200	5947
5.66	428	869	931	809	8752	1082	3237	16108
8.50	428	1585	1702	1479	11641	1439	4568	22842
11.33	428	2435	2608	2267	17679	2185	6981	34583
WLA to achieve 5.0 mg/L DO criteria, BOD5, kg/day								
2.83	428	187	200	174	2801	346	1034	5170
5.66	428	854	914	795	7225	893	2784	13893
8.50	428	1553	1664	1446	9645	1192	3992	19920
11.33	428	2361	2529	2198	14825	1832	6089	30262
WLA to achieve 6.5 mg/L, DO criteria, BOD5, kg/day								
2.83	428	183	198	172	1978	244	801	4004
5.66	428	822	889	773	4935	610	2114	10571
8.50	428	1500	1607	1396	6652	822	3132	15537
11.33	428	2251	2411	2095	10504	1298	4795	23782

Implementation Strategy

Airport storm water permit

PDX (and co-permittees) will be required to conduct additional instream and source load monitoring and modeling to refine estimates of the rates and loads used to generate the LC. Based on these efforts, the LC and WLA may change. The water quality monitoring is a joint effort with the City of Portland and the City of Gresham.

PDX will be required to develop and implement pollution control measures designed to achieve the WLA. The schedule to meet the WLA depends on the control option PDX selects. Option 1 is treatment and discharge from PDX to the Columbia River. Option 2 is treatment and discharge to the Columbia Slough. The specific timetable and requirements will be contained in an individual NPDES permit. The following schedule assumes that DEQ will issue the permit by summer 1998. Under the permit PDX will be required to:

1. Implement, during the winters of 1998/1999 and 1999/2000, a monitoring program for a series of de-icing events. The monitoring will include an approved Quality Assurance/Quality Control plan. The monitoring will provide synoptic data sets of

loads and instream response throughout the period of the de-icing event and the instream advection of the de-icing pulse to the Willamette River. Synoptic monitoring will include: temperature, BOD_5, dissolved oxygen, pH, stream flow, pumping rates at MCDD1, and Lower Columbia Slough stage. De-icing load monitoring will include BOD_5, dissolved oxygen and discharge.

2. By October 2000 provide DEQ with a final report describing model calibration efforts. The report will present the basis for the selection of rates and coefficients used in model calibration, a description of how the rates were derived and the precision of calibration.
3. By October 2000 identify the final TMDL BOD allocations to be achieved with implementation of controls.
4. Option 1: By winter 2003/2004 construct the treatment facilities and implement BMPs necessary to meet the final BOD allocations. Demonstrate compliance with the WLA or:
5. Option 2: By winter 2004/2005 conduct pilot testing of treatment facilities and implement BMPs. By winter 2005/2006 demonstrate compliance with the WLA.

Designated Management Agencies

The DMAs will conduct monitoring of storm water BOD_5 loads and the instream response to those loads. Previous monitoring under the MS4 permits has measured BOD_5 levels from urban runoff that do not correlate with the few instream BOD_5 samples taken during storm events. The discrepancy between loads and instream concentration is likely due to processes such as deposition and decay during the transport to the receiving water. The monitoring data will be used to calibrate a dynamic water quality model to simulate the Slough’s response to storm water and de-icing fluid. The DMA WLA will not be included as an effluent limit. Achievement of the WLA will be through implementation of BMPs. Municipal discharges will be required to implement BMPs and demonstrate that the BMPs achieve the WLAs established. The DMAs will be required, through MOAs, to:

1. Provide DEQ with a description of the program designed to reduce BOD_5 loads to the Slough.
2. Implement a program of BMPs that will reduce overall BOD_5 load to achieve the DMA WLAs.
3. Implement coordinated monitoring to define storm water loads to the Slough and the influence of storm water BOD_5 on receiving water quality.
4. Implement monitoring to demonstrate compliance with BOD_5 WLA targets. Instream monitoring will include grab samples of BOD_5 and DO and continuous hydrolab monitoring.
5. Implement water quality management plans as developed as part of the Lower Willamette Subbasin plan (projected completion spring 1999).

Table 3: BOD Control Strategy

Reach	Control Strategy	Responsible DMA
1	1,2,3,4,	City of Portland, PDX
2	1,2,3,4	City of Portland, PDX
3	1,2,3,4	City of Portland, City of Gresham
4	1,2	City of Fairview, Multnomah County
5	1,2	City of Fairview, City of Wood Village, City of Gresham,

		Multnomah County
1-5	5	Oregon Department of Agriculture
1-5	1,2,4	Oregon Department of Transportation

Industrial storm water permits

DEQ anticipates implementing storm water permits through application of BMPs. When storm water permits are renewed, a basin specific general storm water permit will be developed by DEQ to address BOD_5 loads as well as other 303(d) parameters. The permit will include monitoring and BMP requirements to reduce the BOD_5 load to the Slough. The WLA for industrial storm water will not be incorporated into NPDES industrial storm water permits as individual effluent limits.

New discharges

Future growth and development will either have to demonstrate that adequate reserve capacity exists in the TMDL or trade effluent with the City of Portland, PDX or other DMA.

Eutrophication (pH and nutrients)

Water Quality Criteria

Eutrophication is the increased primary productivity that occurs in an aquatic system as a result of nutrient input. Nutrients increase primary production and photosynthesis rates. The pH of water can be directly influenced by photosynthesis. Plant growth increases pH during the day as plants utilize carbon dioxide in the water during photosynthesis. At night, plants respire and produce carbon dioxide which decreases pH. pH outside the range in which the species evolved may result in both direct and indirect toxic effects. The water quality standard states that “pH values shall not fall outside the ranges identified in paragraphs (A), (B), and (C) of this subsection.
(A) Columbia River: 7.0 -8.5;
(B) All other basin waters (except Cascade lakes): 6.5 -8.5;
(C) Cascade lakes above 3,000 feet altitude: pH values shall not fall outside the range of 6.0 to 8.5.” (OAR 340-41-445 (2) (d))

Photosynthesis may also cause diurnal swings in the dissolved oxygen levels. The dissolved oxygen criteria are discussed in the dissolved oxygen TMDL.

Elevated nutrient levels also generate nuisance conditions due to algal growth. Chlorophyll *a* is an indirect measurement of algal biomass. Oregon rules (OAR-41-150(1)(b) cite an action level for average chlorophyll *a* concentrations of 15 ug/L (3 month average based on a minimum of 3 samples) to control growth of nuisance phytoplankton. When the action level is exceeded, DEQ will conduct studies to describe the water quality problem and develop a proposed control strategy.

DEQ has established interim targets of 0.1 mg/L total phosphorus (TP) and 0.02 mg/L ortho-phosphate ($O\text{-}PO_4$). These values are based on EPA guidelines (EPA Quality Criteria for Water, EPA, 1986) and Best Professional Judgment of DEQ staff. The CE-QUAL-W2 model has been calibrated to evaluate the influence of nutrient loads and hydraulics on water quality.

Monitoring

Continuous pH data on the Slough demonstrate large swings in pH on a diurnal basis in the summer (CH2MHill, Part 1, 1995). Values above 8.5 have occurred in the spring to fall. During the summer, reaches 1A and 2B frequently had pH levels above 8.5. Similar diurnal patterns between pH and DO suggest that eutrophication is the cause of the violations, as DO is produced by photosynthesis. Total phosphorus concentrations greater than the 0.1 mg/L guideline occur throughout the Slough, throughout the year. (CH2MHill, Part 1, 1995)

Sections of Reach 2 and Reach 1 showed frequent exceedance of the dissolved ortho-phosphate guideline. Exceedance of the nitrate guideline was found throughout the Slough during all seasons (CH2MHill, Part 1, 1995).

During the summer, spring and fall, the Columbia Slough also exceeds the action level for chlorophyll *a,* although the fall averages are often skewed due to high chlorophyll *a* values in the summer . Winter chlorophyll a values are generally low (CH2MHill, Part 1, 1995). The following graphs demonstrate this exceedance, at sites in the Lower and Upper Slough, respectively (1993-1997 grab data).

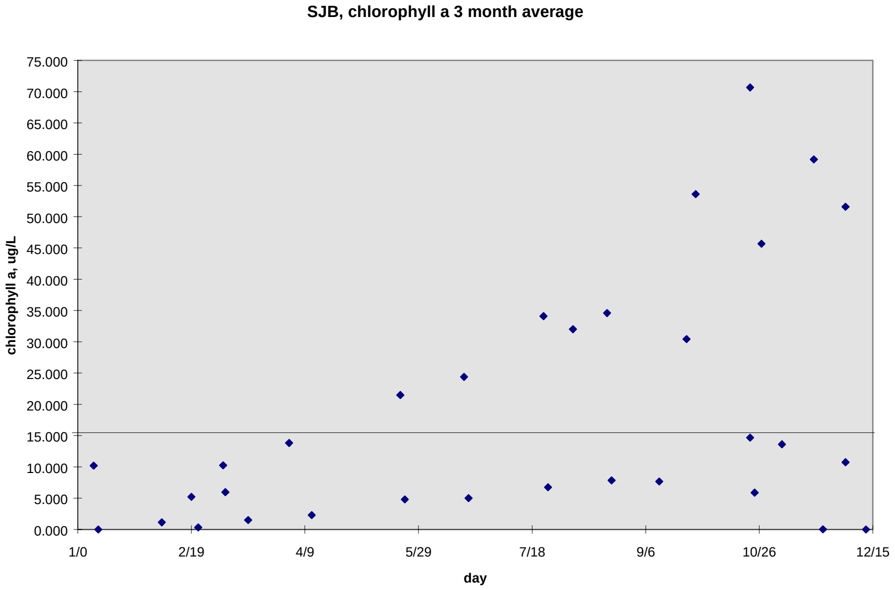

Figure 3: Site SJB chlorophyll *a* 3 month average

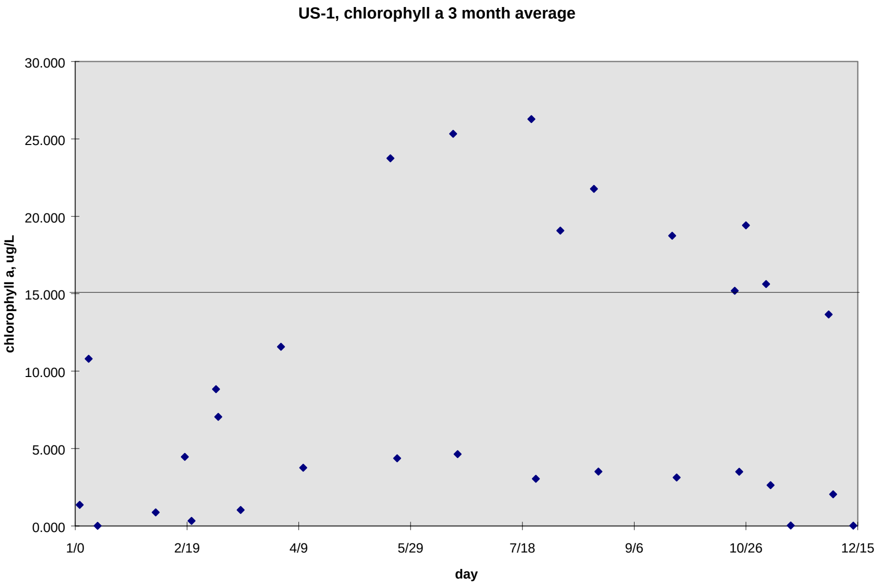

Figure 4: Site US-1, chlorophyll *a* 3 month average

Despite elevated average chlorophyll *a* values, summer chlorophyll *a* values have decreased recently (since 1992), although not to the action level. The following table shows data for July - September, when available.

Table 4: Summer Chlorophyll *a* values

	Site	
Year	**SJB (RM 2.9)**	**US-1 (RM 8.7)**
1992	53.6	35.9
1993	NA	NA
1994	NA	NA
1995	7.68	3.13
1996	30.43	18.75
1997	32.0	19.08

Improvements in pH variation have been observed in the summer of 1996 in the Slough. At St. John's Landfill Bridge (site SJB, main channel, Lower Slough, Reach 1) there has been significant improvement in pH since 1992, as seen in the following graphs generated from continuous Hydrolab data:

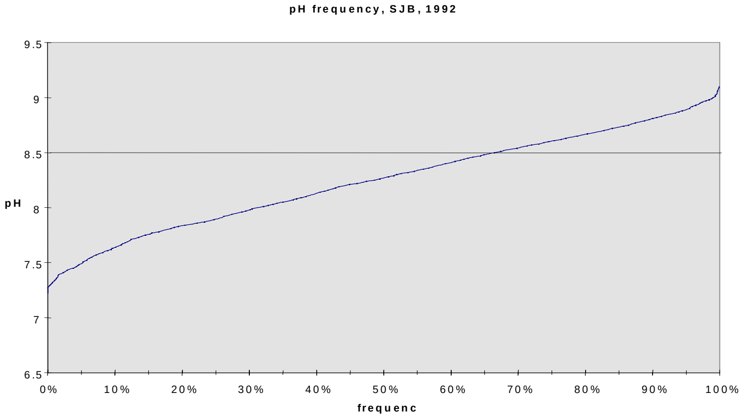

Figure 5: pH July – September 92

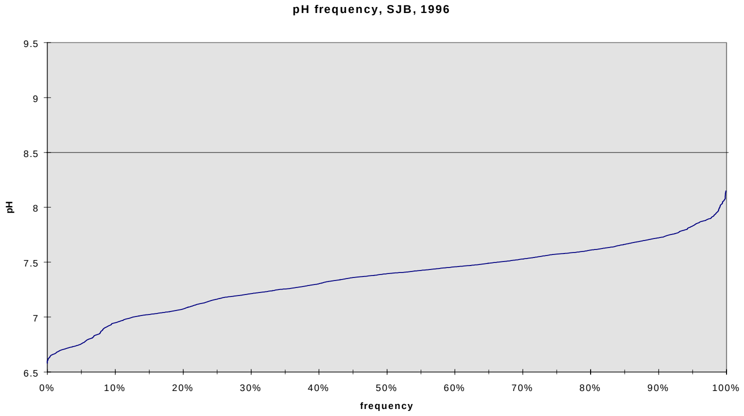

Figure 6: pH July – September 1996

At site MCDD1, summer 1996 pH levels were within the criteria, for data recorded when the hydrolab was properly calibrated. Additional pH data is contained in Appendix C, although data for summer 1993 and 1994 is limited. Dissolved ortho-phosphate values in both the Upper and Lower Slough were approximately 0.02 mg/L, or at the guideline level (summer 1996 grab data).

Examination of data from summer 1992 at sites SJB and MCDD1 did not indicate any violations of the 4 mg/L instantaneous minimum dissolved oxygen criterion (see Appendix C for data). Samples taken from a location near the outlet of Fairview Lake (Reach 3), showed frequent and long term oxygen depressions in the summer. The data presented below is from sampling site US-8, located at Fairview Lake outlet in the main channel in Reach 3. However, flow from Fairview Lake is limited by summer operations designed to keep the water level high in the Lake. Resulting stagnant water combined with a relatively high sediment oxygen demand (SOD) (1.9 mg/m^2/day - O, measured in the forebay to MCDD1, (Wells, personal communication, 1997) may be causing low DO readings in the sampling location on Reach 3. Additionally, there are no known sources of BOD discharge in this area. These DO concentrations may not be representative of the entire reach (CH2MHill, Part 1, 1995).

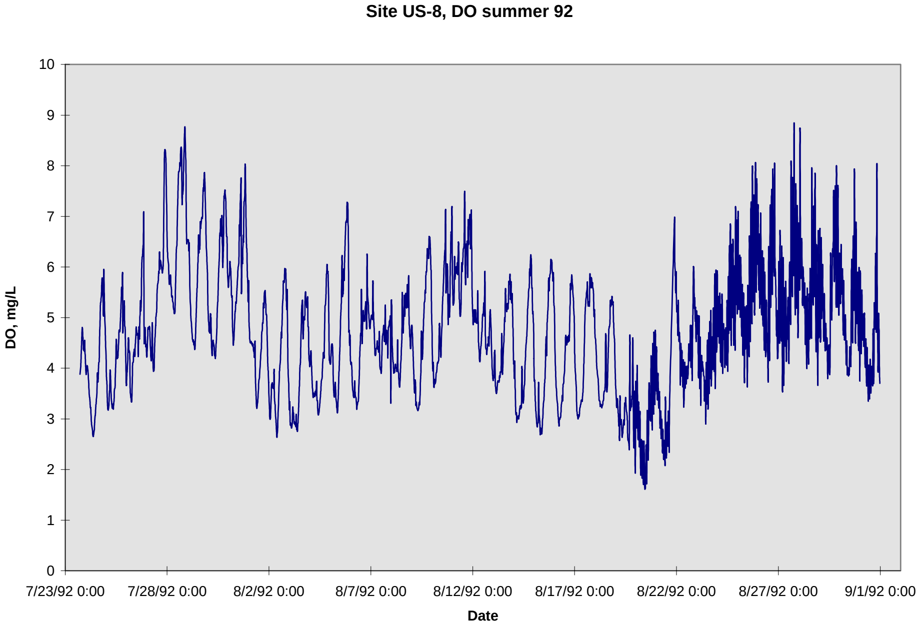

Figure 7: Reach 3 summer DO

The continuous monitoring equipment at Site US-8 is now placed within Fairview Lake. Currently, the closest continuous dissolved oxygen data is available from Site 158, approximately 2 miles west of the outlet of Fairview Lake. Data from summer 1996 indicates improvement in water quality, with dissolved oxygen levels above the 4.0 mg/L instantaneous minimum. Figures 8 and 9 summarize this information.

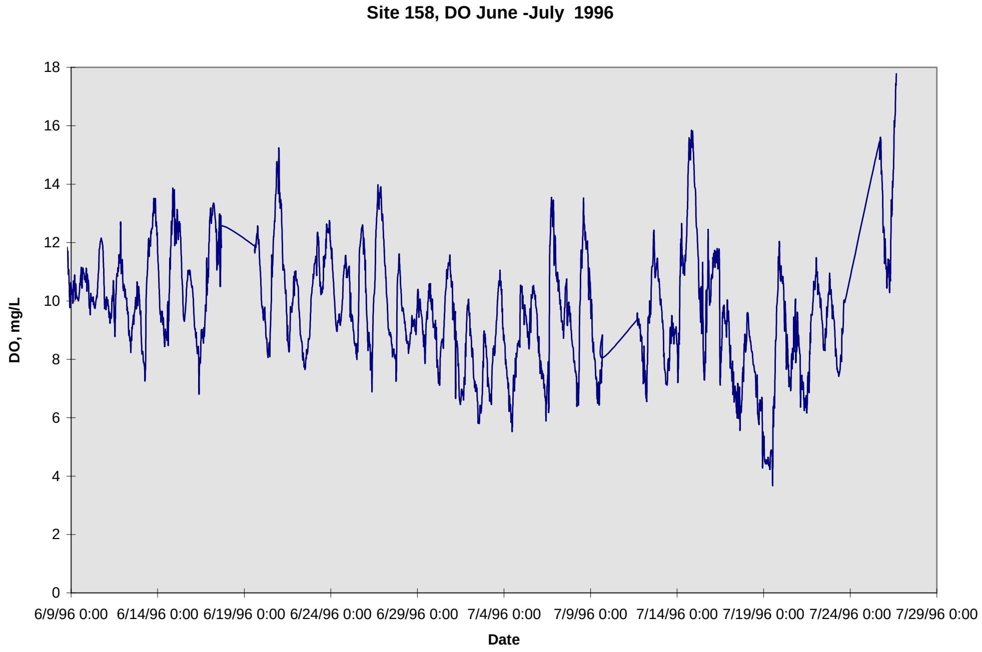

Figure 8: Site 158 June - July 1996

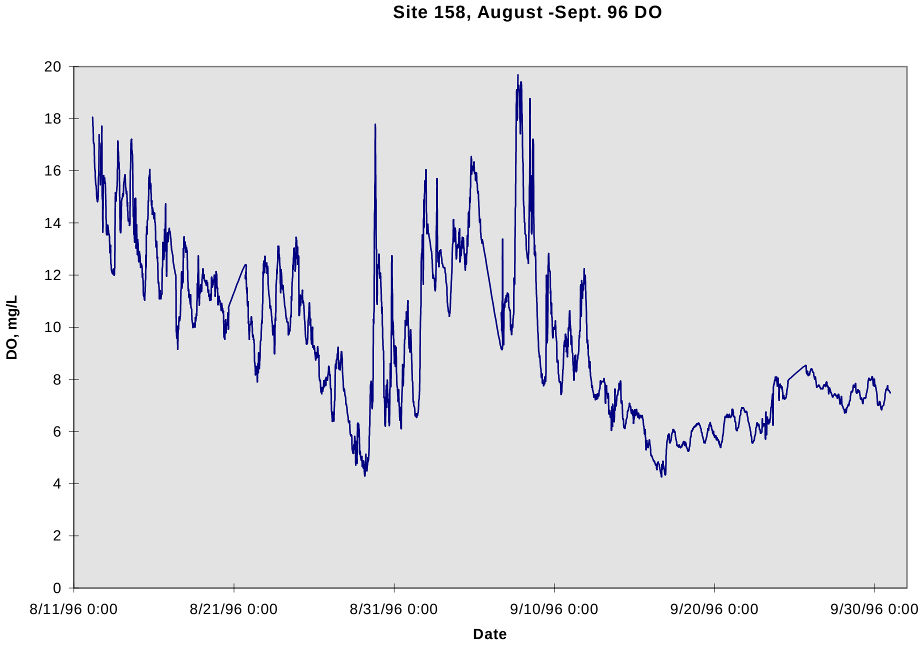

Figure 9: Site 158 August - September 1996

Water level management activities have led to this water quality improvement. However, as discussed previously, the chlorophyll *a* action level is still exceeded, throughout the year. The action level requires initiating studies to determine the cause of eutrophication. Achievement of the water quality criteria influenced by algal growth (DO and pH) provides the TMDL requirements. The implementation section describes the water level management activities to date, as well as additional controls that will be necessary to control algal growth.

Modeling

Using the CE-QUAL-W2 model, Wells and Berger (1994) demonstrated that a major cause of algal growth in the late summer (August -September) in the Upper Slough was excessive dissolved ortho-phosphate from groundwater and in Lower Slough was mainly from discharges of nutrients and algal rich water from the Upper Slough. Point source loads are minor. Most of the point source summer PO_4 loads are a byproduct of the origin of the water source, because the discharges are of cooling water.

Various management strategies have been simulated to evaluate their effect on water quality in the Slough. Wells (1995, EWR-2-95) simulated a 90% reduction in dissolved ortho-phosphate in groundwater and results demonstrated that this reduction would result in the lowest chlorophyll *a* concentration of all the simulations.

Modeling also indicated (Wells and Berger, 1993) that reducing the water level from 8 ft to 5 ft MSL (outflow of 70 CFS) would reduce the overall detention time from about 4 days to less than one day. Reducing the detention time decreased the time available for algal growth. The detention time determines the loading capacity of the Slough for nutrients. As a result of the modeling water level management was initiated in the Slough. Rooted aquatic vegetation is growing in the Upper Slough. A significant loss of the nutrients supplied by groundwater has been observed. The loss appears associated with greater settling of solids and uptake by epiphytes associated with the macrophytes. The effect of this vegetation on Slough water quality was modeled, as was the effect of increased total phosphate loads.

To account for the affect of macrophyte growth on Upper Slough water quality the base case simulations used the average 1996 data for inflow concentrations from the Upper Slough. The effect of groundwater and minor storm water inputs were simulated. Total phosphate loads were increased by increasing the ortho phosphate load. Additional simulations were conducted in which total phosphate was increased by increasing both the ortho-phosphorus and algae. The algae flowing from the Upper to the Lower Slough served as a seed for algae in the Lower Slough, so this was a conservative modeling approach. The total phosphate loads and the resulting pH are graphed below (memo from Chris Berger, Portland State University, to DEQ, draft, May 15, 1998). Simulations demonstrate that at current conditions (the first point on each graph) the maximum pH is about 8.14. The minimum dissolved oyxgen was 7.33 mg/L (memo from Chris Berger, Portland State University, to DEQ, draft, May 15, 1998). The effect of summer storm water loads was also modeled and compared to the base run, which simulates existing conditions. Results indicate that the effect of summer storm water loads is minimal, with the predicted DO and pH meeting the criteria.

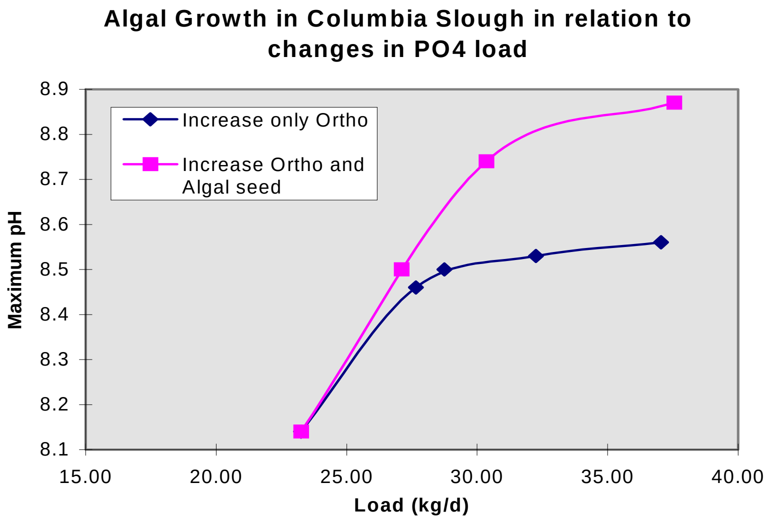

Figure 10: Total Phosphate Loads and pH

Loading Capacity and Margin of Safety Defined

A loading capacity is defined only for total phosphate because the Slough is so nitrogen rich that PO_4 is the limiting nutrient. A review of summer 1992 data at North Portland Bridge in the Lower Slough indicated that NO_3-N was present at levels 10 times greater than total phosphate levels.

As seen in Figure 10, the current load of total phosphate is 23.25 kg/day. With a total phosphate load of 27.1 kg/day (for simulations with both increasing ortho phosphate and algae seed) the pH will raise to 8.5. To set allocations and a margin of safety, the instream concentration which met this load was calculated by dividing the load by the estimated total flow simulated. The maximum instream concentration is 0.1549 mg/L total phosphate (to a pH of 8.5). To set allocations at flows of 1.98 m3/sec, 2.83 m3/sec and 5.66 m3/sec, the instream concentrations were multiplied by flow to calculate the allowable daily load. This calculation is as follows:

1.98 m^3/sec X 0.1549 mg/L X 1000L/m^3 X 1 kg/10^6 mg X 60 sec/min X 60 min/hr X 24 hr/day = 26.5 kg/day = loading capacity

The loading capacity was then divided between groundwater, storm water, one point source discharge, the margin of safety (MOS) and the loss due to macrophytes. The distribution between storm water and groundwater was calculated using the ratio of storm water to groundwater loads used in the modeling. The ratio is 0.27 storm water to 0.73 groundwater. The loss to macrophytes was calculated as the difference between concentrations measured upstream of MCDD1 and the concentrations at MCDD1 (memo from Chris Berger, Portland State University, to DEQ, draft, May 15, 1998).

The margin of safety is set by using the conservative modeling results in which total phosphorus is increased by increasing both ortho-phosphate and algae seed concentrations. Additionally, the remaining loading capacity, after allocation to the existing loads, is set aside as the numerical margin of safety.

Allocations

Allocations are set only for the spring through fall (April-October), when the Slough is water quality limited due to eutrophication. No allocations are set for the winter months. Uncontrolled sewage receives an allocation of zero. Additionally, by 2002, combined sewer overflows (CSOs) will receive a zero allocation except for a 1 in 10 year summer event. The 1 in 10 year storm event discharge is allocated at the current CSO load. Modeling shows that new waste water point source loads during periods of algal growth would increase productivity and standards violations, so a WLA of zero for new point source loads of PO_4 is established. One point source discharge may discharge phosphate and receives an allocation that results in no measurable increase above existing instream total phosphate levels. The calculation for this waste load allocation is discussed below.

Existing Point Source Discharge

Oregon Fresh Farms (OFF) operates a carrot packaging plant and discharges to the Whitaker Slough. The discharge occurs from July - December, and may extend into February. This discharge receives an allocation for total - phosphate that results in no measurable increase above current levels. Using data from BES, the median (approximate) value for total phosphate in Whitaker Slough is 0.14 mg/L (65 samples, March 1- June 30, 1995-1997). Upstream flow was calculated as the average of measured daily flow from July - February (161 samples. BES database). The flow from Oregon Fresh Farms was calculated as the average of the average daily flows recorded on the Discharge Monitoring Reports (DMRs) for the facility (DMRs dated September -November 1997.) The allocation is calculated as follows:

$(C_{ups})(Q_{ups}) + (C_{eff})(Q_{eff}) = (C_{mix})(Q_{mix})$

Where:

C_{ups} = upstream concentration = 0.14 mg/L
Q_{ups} = upstream flow = 27.2 CFS
C_{eff} = effluent concentration = X
Q_{eff} = effluent flow = 1.5 CFS
C_{mix} = concentration of mixed stream = $C_{ups} + C_{DL}$ = 0.16 mg/L
C_{DL} = 0.02 mg/L (DEQ detection limit for total phosphate analysis)
Q_{mix} = flow of mixed stream = 28.7 CFS

Solving for C_{eff}, yields a total phosphate concentration of 0.52 mg/L.
Using the average daily flow from the DMRs, the load allocation is:

$0.52 \text{ mg/L} \times 1.5 \text{ ft}^3/\text{sec} \times 1 \text{ m}^3/35.3 \text{ ft}^3 \times 1 \text{ kg}/10^6 \text{ mg} \times 60 \text{ sec/min} \times 60 \text{ min/hr} \times 24 \text{ hr/day} \times 1000\text{L/m}^3 = 1.91 \text{ kg/day}$

The loading capacity is allocated as follows:

LC = groundwater + storm water + OFF + MOS + Loss + CSO + untreated sewage

The results are summarized in Table 5.

Table 5: Total Phosphate Loading Capacity and Allocations

	Allocations (kg/day)							
Flow (m^3/sec)	Groundwater	Storm water	OFF	Loss	MOS	CSO	Sewage	LC
1.98	20.9	7.7	1.9	-5.9	1.9	0	0	26.5
2.83	29.9	11.1	1.9	-8.5	3.5	0	0	37.9
5.66	59.8	22.1	1.9	-16.9	8.9	0	0	75.8

Implementation Strategy

Groundwater Controls

Algal growth is controlled by several factors including solar radiation, stream flow and transport, nutrient cycling and nutrient loads. In the Columbia Slough the dominant factor influencing summer algal growth that can be managed and controlled is stream flow and transport, and to a lesser extent nutrient cycling and solar radiation. The previously described modeling demonstrates that the dominant source of nutrients is from groundwater.

Groundwater controls have already been established for the Slough, but the effectiveness at PO_4 reduction is uncertain. In 1984, a study concluded that more than 14 million gallons a day of waste from unsewered areas of Mid Multnomah County were discharged directly to the groundwater, which flowed toward the Slough (The East County Sanitary Sewer Consortium, June 1984). Sanitary sewers will be constructed in this area and all property owners connected to it by the year 2005 (East Multnomah County, 1995) (Findings and Order, Environmental Quality Commission, 1/30/86). With the removal of these cesspools, a significant source of nitrate to the Slough is expected to be removed, but it will take approximately 30 years for a reduction of 40 percent of nitrogen in groundwater (CH2MHill, Part 2, 1995). In addition, groundwater may continue to have high phosphorus concentrations (0.074 mg/L PO_4-P))[4]; other local aquifers that are unaffected by cesspools have high phosphorus content (CH2MHill, Part 2, 1995). The influence of sewering East Multnomah County on groundwater PO_4 concentration is not known.

Water level management

The management strategy for eutrophication focuses on water level management in the Slough. During the summer of 1996, water level management increased the flows through the Middle Slough (Reach 2) by decreasing water levels and increasing the groundwater inflow. The water level in the Middle Slough (Reach 2) was dropped to 6 feet MSL, down from 8 feet. The mid dike levee was closed. Gravity flow was also used between the Middle (Reach 2) and Lower Slough (Reach 1) to lower the water level. There was a visible reduction of algae in many parts of the Middle Slough, but there was an increase in rooted aquatic vegetation. This increase in

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[4] Average of 5 samples measured at NE112 from 7-9/96. NE112 is believed to be close to pure groundwater (Wells August 1997)

macrophytes is likely due to shallower depths and increased water clarity which allow sunlight to penetrate to the Slough bottom and rooted vegetation to grow. The establishment of macrophytes has resulted in reduced levels of dissolved ortho-phosphate, suspended solids and turbidity. The decrease of dissolved ortho-phosphate may be due to biological uptake by the macrophytes or algal epiphytes. Water level management demonstrated significant reduction of algae. The City of Portland will be required to continue instream monitoring to evaluate the effectiveness of water level management.

The increased macrophyte growth results in greater flood control management problems for the Multnomah County Drainage District (MCDD). The DEQ will work with MCDD to develop a management plan and to document the influence of the macrophyte growth on beneficial uses of the Slough.

Storm water Best Management Practices

Specific responsibilities for monitoring water quality and implementing BMPs to control storm water phosphate loading will be contained in MOAs DEQ will negotiate with each DMA. Instream water quality will continue to be monitored to help assess trends in water quality and determine if BMPs are improving water quality. General requirements that will be contained within the MOAs are summarized below:

Designated management agencies

1. Identify at least 3 representative sites for the Lower (Reach 1), Middle (Reach 2) and Upper (Reach 3) Slough for long term monitoring of water quality in the Slough to determine the effectiveness of the implementation strategy.
2. Identify representative site in Fairview Lake (Reach 4) and Fairview Creek (Reach 5) to characterize water quality in these water bodies and determine effectiveness of control strategies. Water quality parameters will include DO, pH, temperature, chlorophyll *a*, dissolved ortho phosphate, total phosphate and bacteria.
3. Maintain the hydrolab pH measurements as well as the grab samples of pH, dissolved ortho-phosphate, chlorophyll *a* , DO and temperature.
4. Identify BMPs in MS4 permits which may reduce contributions of phosphate via storm water.
5. Include PO_4 in assessment of BMP effectiveness by measurement of influent and effluent dissolved ortho phosphate concentrations and total phosphate concentrations.
6. Remove CSOs except for a 1 in 10 year summer event and one in five year winter event.
7. Implement water quality management plans as developed as part of the Lower Willamette Subbasin plan (projected completion spring 1999).

These requirements are listed by responsible DMAs, for each reach, below:

Table 6: Nutrient Control Summary

Reach	Control Strategy	Responsible DMA
1	1,3,4,5,6	City of Portland
1	1,3,4,5	PDX
2	1,3,4,5	City of Portland, PDX
3	1,3,4,5	City of Portland, City of Gresham
4	2,4,5	City of Fairview, Multnomah County
5	2,4,5	City of Fairview, City of Gresham, City of Wood Village, Multnomah County
1-5	7	Oregon Department of Agriculture
1-5	1,3,4,5	Oregon Department of Transportation

BACTERIA

Water Quality Criteria

The purpose of the bacterial water quality standard is to protect the most sensitive designated beneficial use, which is primary water contact recreation, such as swimming. Recreational exposure to water polluted with human pathogens can cause skin and respiratory ailments, gastroenteritis, and other illnesses. Certain species of bacteria are used as indicators for the presence of other microbes because of their common fecal origin and the relative ease by which they can be counted. The State of Oregon recently adopted a new bacteria criteria which changes indicator species from fecal coliform to E.coli and contains narrative provisions that describe the requirements for a water quality plan for water quality limited waterbodies.

Most of the available bacteria data for the Columbia Slough is fecal coliform, so the water quality limited designation for the Slough was determined by compliance with the historical standard. Under the historical criteria, samples may not exceed 200/100mL log mean based on a minimum of 5 samples in a 30-day period; no more than 10% of samples in a 30 day period may be >400/100mL. Because of the difficulty in sampling frequently enough to determine compliance with the criteria, DEQ has allowed flexibility in interpretation of available data. A waterbody is considered water quality limited for bacteria, and placed on the 303(d) list, when the geometric mean of fecal coliform bacteria exceeds 200 per 100 milliliters or more than 10% of the samples and a minimum of at least two samples exceed 400 per 100 milliliters for the season of interest. (DEQ, 1996)

Under the new criteria, samples may not exceed a 30-day log mean of 126 E.coli organisms per 100 mL, based on a minimum of 5 samples. No single sample may exceed 406 E.coli organisms per 100 mL. The criteria prohibits the discharge of raw sewage into waters of the State (OAR 340-41-445 (2) (e)). The sewage must be treated in a manner approved by DEQ. Current regulations describe the implementation requirements for water quality limited (WQL) waterbodies. Bacteria management plans must be developed for waterbodies that are water quality-limited for bacteria. These management plans will identify the specific technologies and BMPs to be implemented by point and nonpoint sources to limit bacterial contamination. For point sources, the bacteria management plan will be part of their NPDES permit. For nonpoint sources, the bacteria management plan will be developed by the DMAs which will identify the appropriate BMPs.

Additionally, the criteria state that domestic waste collection and treatment facilities are prohibited from discharging raw sewage during November 1 through May 21 except during a storm event greater than the one- in- five year, 24 hour duration storm. Facilities are prohibited from discharging raw sewage during the period of May 22 through October 31, except during a storm event greater than the one- in-ten year, 24 hour duration storm.

Monitoring

Due to the cost of collecting 5 samples in a 30 day period, insufficient fecal coliform data are available to evaluate historical compliance with the standard. Because of the scarcity of data and the change in the bacteria standard to E.coli, fecal coliform data are compared to the 303(d) listing criteria. Enterococci data are used only to provide evidence of fecal contamination. Fecal contamination appears throughout the Slough, although the magnitude of the contamination varies widely. Appendix C contains additional fecal coliform data.

The highest bacteria concentrations have been found in the Lower Slough in winter months, indicative of CSO events. In Reaches 1A and 1B, winter samples often had fecal coliform levels greater than 1000/100 mL. In Reach 1B, about 74% of the winter samples are greater than 400/100 mL. For the spring, there are few fecal coliform or enterococci samples, but the available data indicate fecal contamination. In the summer, Reaches 1B and 1C had fecal coliform values greater than 1000/100 mL. About 31% of the summer samples in Reach 1B had fecal coliform concentrations greater than 400/100 mL. Enterococci concentrations for these reaches also were high (>200/100 mL), indicating that the bacteria were of fecal origin. In the fall, Reaches 1B and 1C show elevated fecal coliform values (>1000/100 mL). Enterococci samples confirm the evidence of fecal contamination in these reaches in the fall (CH2MHill, Part 1, 1995).

Data for the Middle Slough (Reach 2) also indicates fecal contamination. About 14% of the winter samples for Reach 2A had values greater than 400/100mL. In the summer Reach 2A had fecal coliform values greater than 1000/100 mL. In the fall, Reaches 2A and 2C show elevated fecal coliform values(>1000/100 mL). Enterococci samples confirm the evidence of fecal contamination in these reaches in the fall (CH2MHill, Part 1, 1995*).* Data from 1995 -1998 does not indicate a violation of the fecal coliform criteria in Reach 3. The geometric mean of the samples from east of the mid-dike levee to the outlet of Fairview Lake is 73 CFU/100 mL. At the 90th percentile, the fecal coliform concentration is < 300 CFU/100 mL.

Data Analysis

Part II of the Water Body Assessment (CH2MHill, 1995) describes the modeling efforts that were undertaken in order to quantify pollutant loads to the Columbia Slough. The EPA storm water model SWMM (EPA 1992) was used to develop estimates of flows and pollutant loadings from the various land use categories and subbasins draining to the Slough. The data collected as part of the Portland storm water NPDES permit were used to calibrate flow contributions and derive land use based event mean pollutant concentrations (EMCs) for specific pollutants. Pollutant loads were based on land use. The basin's response to storm events was calibrated by comparing monitored flow rates for numerous storm events recorded between December 1991 and December 1994. Table 7 summarizes the results by reach for fecal coliform bacteria. Model predictions using E.coli are not available, but overall trends in loads are expected to be the same.

Table 7: **Estimated Percentage Breakdown of Fecal Coliform Loads**

Source	Lower Slough		Middle Slough		Upper Slough	
	summer	winter	summer	winter	summer	winter
storm water	1.1	1.3	4.8	21.4	90.9	90.9
CSO	67.0	84.3	NA	NA	NA	NA
unknown/uncontrolled	9.0	8.8	94.9	76.6	0.0	0.0
upstream	1.5	2.9	0.3	2.0	9.1	9.1
Smith & Bybee Lakes	0.3	0.1	NA	NA	NA	NA
Willamette River	21.1	2.6	NA	NA	NA	NA

NA = not applicable

These results indicate that Combined Sewer Overflows (CSOs) are the dominant source of bacteria in the Lower Slough. The Upper and Middle Slough contribute only <3% of bacteria loads to the Lower Slough. The Middle Slough is mainly affected by illicit sources such as failing septic systems and illicit connections. In the Upper Slough, the most significant source appears to be storm water.

There are 13 CSO outfalls located in the Lower Slough itself, and because the Lower Slough is tidally influenced, it is additionally impacted by the presence of CSOs in the Willamette River. CE-QUAL-W2 modeling indicates that removal of the CSOs will bring the Lower Slough into compliance with the bacteria standard. (Wells, EWR-2-95). Approximately 85-90% of CSOs in the Willamette will be removed when the CSO program for the Willamette River is complete.

The Middle Slough does not contain any CSOs, however there are indications that illicit discharges are taking place. These indications are:

- Measured instream concentrations are substantially higher than those predicted via modeling. This indicates the presence of previously unsuspected source(s) not incorporated into the model (CH2MHill, WBA, Part II).
- The staff of the Multnomah County Drainage District has observed conditions in the Middle Slough that they believe indicate houses in the area discharge directly to the Slough (Hayford, personal communication).
- A search of the City of Portland's records pertaining to the sewer system in the vicinity of the Middle Slough, indicates that there are houses for which no record of connection exists.

Table 8 compares existing instream summertime conditions to model predictions for the Middle Slough, which assumes no illicit discharges, to the fecal criteria. Comparison is of the predicted instream fecal coliform values to the two components of the criteria; 200/ 100 mL as the median value for compliance and 400/100 mL as the instantaneous maximum.

Table 8: **Comparison of Fecal Coliform Values in the Middle Slough**

Scenario	% of values that exceed 200/100 mL	% of values that exceed 400/100 mL.
1. Existing (with illicit discharge)	30.6	15.9
2. Proposed (with illicit discharge removed)	<1	<1

The existing case is based on sampling results. For the proposed case, they are based on modeled results (CH2MHill, 1995). Unknown sources appear to be the major sources of bacteria.

Modeling results indicate that the elimination of storm water from Reach 2 would not have a significant effect on bacteria. In contrast, the model predicted that elimination of fecal coliform in storm water in Reach 3 (Upper Slough) would reduce the frequency of exceedances of the fecal coliform standard from 16 percent to zero percent. Storm water was the only modeled source containing coliform in Reach 3. Because existing data on the Upper Slough is too limited to state whether or not there are problems with respect to bacteria, additional monitoring will be needed to confirm the modeling conclusions.

To implement the new bacteria standard, the TMDL requires development of bacteria management plans. The management plans will include detection and removal of illicit discharges, control of bacteria from storm water and monitoring to demonstrate compliance with the criteria. The TMDL also requires the removal of sources of raw human waste.

Margin of Safety

The Upper Slough is not impacted by CSOs, so the margin of safety is calculated by examination of modeling and monitoring results for the Upper Slough. Modeling of instream response to bacteria loads into the Upper Slough (Wells, EWR-2-95) has a precision of ± 15 fecal coliforms. This measurement of precision is used to define the margin of safety. Because the model results were for fecal coliform and the criteria is now E. Coli, data from the Upper Slough (1995 -1998) was reviewed to determine if their is a relationship between measured E.Coli data and measured fecal coliform data. The data sets are significantly related (probability < .01) and the ratio of E.Coli/fecal coliforms is 0.82. The ratio is multiplied by the precision to obtain the MOS:
15 fecal coliforms x (0.82 E. Coli/fecal coliforms) = 12.3 E Coli.

Loading Capacity Defined

The bacteria criteria contains two components; < 126 log mean based on a minimum of 5 samples in a 30 day period and no single sample > 406. To determine the loading capacity the E. coli log mean criterion is multiplied by the range of flow in the Slough.

Table 9: E.Coli Bacteria Loading Capacity

	Flow (m^3/s)	Criteria (MPN/100 mL)[5]	LC (MPN/day)	MOS (MPN/#100 mL)	MOS (MPN/day)	LC-MOS (MPN/day)
Base Flow	1.98	126	2.16×10^{11}	12.3	2.10×10^{10}	1.95×10^{11}
Storm Flow	2.83	126	3.08×10^{11}	12.3	3.01×10^{10}	2.77×10^{11}
	5.66	126	6.16×10^{11}	12.3	6.02×10^{10}	5.55×10^{11}
	8.50	126	9.25×10^{11}	12.3	9.03×10^{10}	8.34×10^{11}

Allocations

The untreated CSO discharges to Columbia Slough will be eliminated except during storms greater than or equal to a storm with a five year return frequency from November 1 through April 30 and except during storms greater than or equal to a storm with a ten year return frequency from May 1 through October 31. (Amended Stipulation and Final Order No. WQ-NWR-91-75). CSOs therefore receive a wasteload allocation of zero, except for the storms as stated in the Order. Raw sewage also receives an allocation of zero. As seen in Table 7, upstream sources contribute about 10% of the bacteria to the Slough and storm water 90%. The loading capacity (minus the margin of safety) is allocated to these two sources proportional to their contribution. Table 10 summarizes the allocations. The allocations are annual.

Table 10: E. Coli Allocations

	Allocations (MPN/day)			
	Flow			
Source	**1.98 m^3/sec**	**2.83 m^3/sec**	**5.66 m^3/sec**	**8.50 m^3/sec**
CSO	0	0	0	0
raw sewage	0	0	0	0
storm water	1.75×10^{11}	2.49×10^{11}	5.00×10^{11}	7.51×10^{11}
upstream	1.95×10^{10}	2.77×10^{10}	5.55×10^{10}	8.34×10^{10}
MOS	2.10×10^{10}	3.01×10^{10}	6.02×10^{10}	9.03×10^{10}
LC	2.16×10^{11}	3.08×10^{11}	6.16×10^{11}	9.25×10^{11}

Implementation Strategy

The narrative standard requires that the WLA for human sources be zero and that BMPs be implemented to the maximum extent practicable (MEP) for urban storm water. The designated management agencies (DMAs) will develop a bacteria management plan, as described in OAR 340-41-015, that will include:

1. CSO Program: This program will reduce the occurrence of CSO events in the Columbia Slough with a variety of projects, including roof drain disconnection,

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[5] log mean

sewer and storm water separation, and construction of a consolidation conduit and wet weather treatment facility to treat storm water.

2. Sanitary surveys of septic systems, removal of direct discharges of human waste to the Slough.
3. Detect and eliminate illicit discharges to the Slough
4. Establish adequate monitoring to demonstrate compliance with E.coli criteria, including measuring E.coli concentrations and distributions.
5. Implement BMPs to control anthropogenic source of bacteria in storm water.
6. Implement water quality management plans as developed as part of the Lower Willamette Subbasin plan (projected completion spring 1999).

Instream bacteria monitoring is intended to meet 3 goals:

1. assess long term trending
2. determine spatial distribution of bacteria
3. determine seasonal distribution of bacteria

Results of the monitoring will be used to identify bacteria "hot spots" that require further investigation.

Industrial storm water permittees will be required to detect and eliminate discharges of human waste to the Slough. They will also be required to implement BMPs to the MEP to control bacteria loads from other than human sources.

The responsibilities of each DMA are summarized below, by reach:

Table 11: Bacteria Control Summary

Reach	Control Strategies	Responsible DMA
1	1,2,3,4,5	City of Portland
1	2,3,4,5	PDX
2	2,3,4,5	City of Portland, PDX
3	2,3,4,5	City of Portland, City of Gresham
4	3,4,5	City of Fairview, Multnomah County
5	3,4,5	City of Fairview, City of Gresham, Multnomah County, City of Wood Village
1-5	6	Oregon Department of Agriculture
1-5	2,3,4,5	Oregon Department of Transportation

Toxics

Water Quality Criteria

The State has water quality criteria for toxics that are intended to protect both aquatic life and human health.

> OAR 340-41-445(2)(p)(A): Toxic substances shall not be introduced above natural background levels in the waters of the state in amounts, concentrations,

> or combinations which may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare; aquatic life; wildlife; or other designated beneficial uses;
>
> OAR 340-41-445(2)(p)(B): Levels of toxic substances shall not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted;
>
> OAR 340-41-445(2)(p)(C): . . . Where no published EPA criteria exist for a toxic substance, public health advisories and other published scientific literature may be considered and used, if appropriate, to set guidance values.

The Department has developed five conditions to interpret and apply the water quality criteria and determine impact on a beneficial use:

A. Water Quality Criteria Violations occur if:
   1. The freshwater chronic criteria for protection of aquatic life contained in OAR Table 20 is violated more than 10% of the time and for a minimum of two values. For hardness-dependent criteria, the criteria will be calculated based on the instream hardness measured at the time of sampling.
   2. The chemical is found in sediments at levels which analytical models demonstrate that water quality standards are violated. The analysis and modeling must be reviewed and approved by DEQ.

B. Measure of impairment of a Beneficial Use
   1. A fish or shellfish consumption advisory or recommendation issued by the Oregon State Health Division specifically refers to this chemical.
   2. The chemical has been found to cause a biological impairment via a field test of significance such as a bioassay. The field test must involve comparison to a reference condition.
   3. The chemical has been detected in more than 10% of available fish tissue samples, and the population mean[6] of the samples exceeds a screening value derived from Table 20. The screening value is developed as follows:

   Fish Tissue Screening Value (mg/kg) =

   Table 20 Criteria for Protection of Human Health(ng/l)$*$ BCF (l/kg) $*(\text{mg}/10^6 \text{ ng})$

where BCF = Bioconcentration Factor. BCFs were obtained from the EPA Region VIII Criteria Chart (July 1993).

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[6] Helsel's method is used for calculating the population mean when nondetects are present. This option is available on the software uncensored v4.0 by Michael C. Newman, K. Dawn Greene, & Phillip M. Dixon from Savannah River Ecology Laboratory, Aiken, South Carolina. To simplify the initial screening for the statewide 303(d) list the condition reads "...10% of available fish tissue samples, and the mean of the detects exceeds a screening level value from Table 20."

The OAR Table 20 criteria are total recoverable metal criteria for the protection of freshwater aquatic life. EPA has recommended the use of the dissolved fraction of the metal, as it is the most biologically available form of the metal. To calculate the dissolved Pb criterion, a two step calculation is necessary; adjust the criterion for hardness and utilize a conversion factor. The hardness correction is calculated as follows:

$$\text{total lead criteria} = e^{(1.273[\ln(\text{hardness})]-4.705)} \quad \text{(EPA 1986)}$$

A conversion factor (CF) for Pb is then calculated to convert the criteria to the dissolved form as follows:

$$CF = 1.46203 - [\ln(\text{hardness})(0.145712)] \quad \text{(EPA 1996)}$$

If the hardness is measured with each individual sample, a conversion factor and criterion can be calculated for each sample.

Pb Monitoring

Instream data

BES has collected 296 dissolved Pb and hardness samples from all reaches of the Slough, throughout all seasons.

Using the hardness measured with each individual sample, a conversion factor and criterion was calculated for each sample. The mean of the individual conversion factors is 0.82. From the frequency distribution of the criteria (Figure 11), the 5th percentile criterion was calculated to be 0.0012 mg/L Pb. The 5th percentile represents a "worst case" assumption (EPA, 1995). As seen in Figure 12, approximately 16.7% of the dissolved Pb samples exceed this criterion[7]. When the samples were compared with their respective criterion, 10.4% of the samples exceed the criterion.

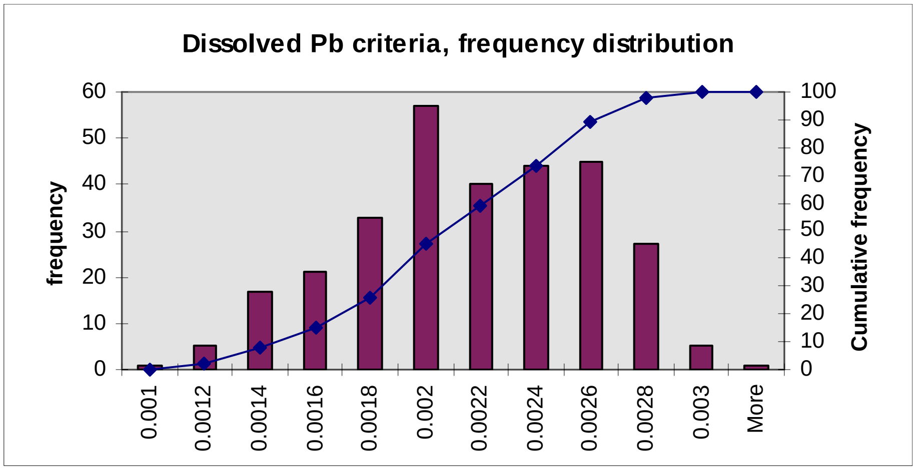

Figure 11: Dissolved Pb criteria, frequency distribution

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[7] 296 samples, non - detected values set at detection limit of 0.001 mg/L

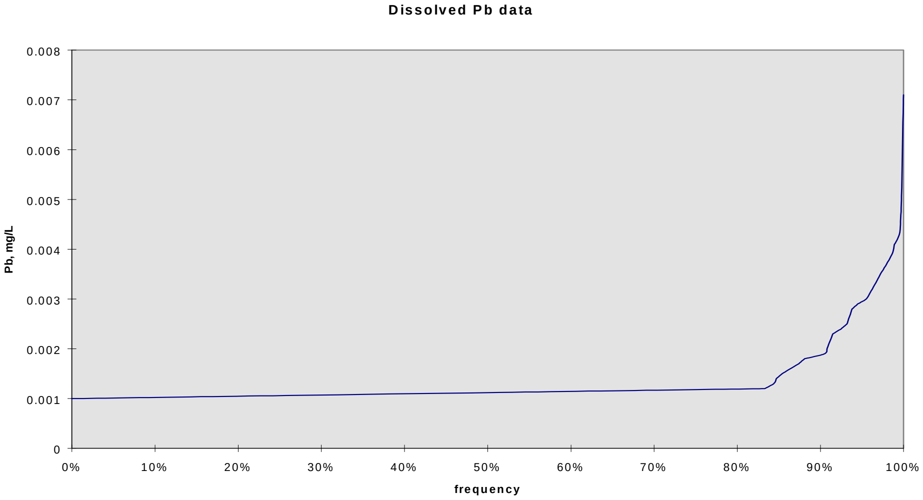

Figure 12: Instream dissolved Pb data frequency distribution (includes non detects)

The Columbia Slough is water quality limited for the metal lead (Pb) because of criteria exceedance in the water column.

Sources

Unlike the conventional pollutant analyses, detailed modeling for toxics with CE-QUAL-W2 has not been conducted. However, potential sources of Pb to the Slough have been analyzed. Such sources include; municipal and industrial storm water, industrial discharges, CSOs, contaminated sites, contaminated sediment, St. John's Landfill, and air emissions. The analyses to estimate the Pb loads from these sources are contained in Appendix A (sources document). Table 12 summarizes the estimates of total lead loads to the Columbia Slough.

Table 12: Summary of Total Pb loads to the Columbia Slough

Source	Lead (kg/yr)
Industrial Discharges	0.19
Combined Sewer Overflows	75.7
Storm water (total)	1131
MS4 area only	990[8]
Industrial permitted area only	141
Groundwater Overall loading	26
NuWay Oil Site (to Whitaker Slough)	
groundwater	1.65×10^{-5}
sediment partitioning	27.1
soil erosion- process area	0.438
soil erosion - non process area	0.005
St. John's Landfill	1.31
Miscellaneous	
Sediment Partitioning	0.030
Air Deposition[9]	
Oregon Steel wet deposition	0.014
Oregon Steel dry deposition	8.99×10^{-7}
Spills	estimate not available
Illicit Discharges	estimate not available
Total of Estimates:	1262

With non detected values set to the detection limit, instream Pb data appears to be close to the chronic criteria. Estimates of Pb loads to the Slough have been calculated primarily for total Pb, not dissolved. These estimates indicate that storm water from municipal and industrial property contributes most of the Pb load. However, the simple method (EPA 1992) used to develop the storm water load estimates does not account for processes that occur during transport of storm water to the Slough, such as sedimentation and resuspension. The TMDL will focus on refining estimates of loads from various land uses, including estimates of the dissolved Pb load.

Loading Capacity and Margin of Safety Defined

As stated previously, OAR Table 20 criteria are defined as total recoverable metal. In the monitoring data for the Columbia Slough, the predominant form of Pb is dissolved Pb. The loading capacity and allocations are calculated to meet the dissolved Pb criteria. To convert the allocations to total recoverable Pb, the values can be divided by the mean of the conversion factors calculated with each hardness value (0.82).

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[8] The calculated total Pb load minus the load associated with industrial areas.
[9] Using the 50th percentile mass load.

The loading capacity of the Columbia Slough for Pb is defined as the 5th percentile aquatic life chronic criteria (adjusted for hardness and converted to dissolved form) times the flow in the Columbia Slough. A baseflow of 1.98 m^3/sec (groundwater flow only) and storm flows are used to calculate the loading capacity. The storm flows range from 2.83-8.50 m^3/sec, approximating the range of flows achieved by pumping at MCDD1.

As described previously, the load estimates were calculated as average annual loads of total Pb. There is little data available to estimate the loads as dissolved Pb, or to model the fate and transport of Pb in storm drains and instream. In Phase I of the TMDL, the allocations are based on dissolved Pb and requirements to quantify the dissolved Pb load from the sources are outlined. Estimates of dissolved Pb loads will be refined in the next phase of the TMDL, and will allow for allocations based on these estimates.

LC (kg/day) = flow (m^3/sec) x 5th percentile criterion (mg/L) x conversion factor

Using the 5th percentile criterion means that 95% of the field samples should be < 0.0012 mg/L. The margin of safety is set to decrease that to 0.001 mg/L or the detection limit. This effectively means that only 5% of the samples to be measured can exceed the detection limit. The difference between the criterion of 0.0012 mg/L and the detection limit of 0.001 mg/L is 0.0002 mg/L. This concentration is multiplied by the flow and subtracted from the daily loading capacity.

Table 13: Dissolved Pb Loading capacity

	Flow (m^3/sec)	**5th percentile criteria (mg/L)**	**LC (kg/day)**	**MOS (mg/L)**	**MOS (kg/day)**	**LC -MOS (kg/day)**
Baseflow	1.98	0.0012	0.205	0.0002	0.034	0.171
Storm flow	2.83	0.0012	0.293	0.0002	0.049	0.244
	5.66	0.0012	0.587	0.0002	0.098	0.489
	8.50	0.0012	0.881	0.0002	0.147	0.734

Allocations

An analysis was performed to determine if there are obvious spatial trends with the Pb data. Figure 13 shows a comparison of dissolved lead levels in the different reaches of the Columbia Slough. Figure 14 shows the distribution of Pb levels in sediment in the Columbia Slough.

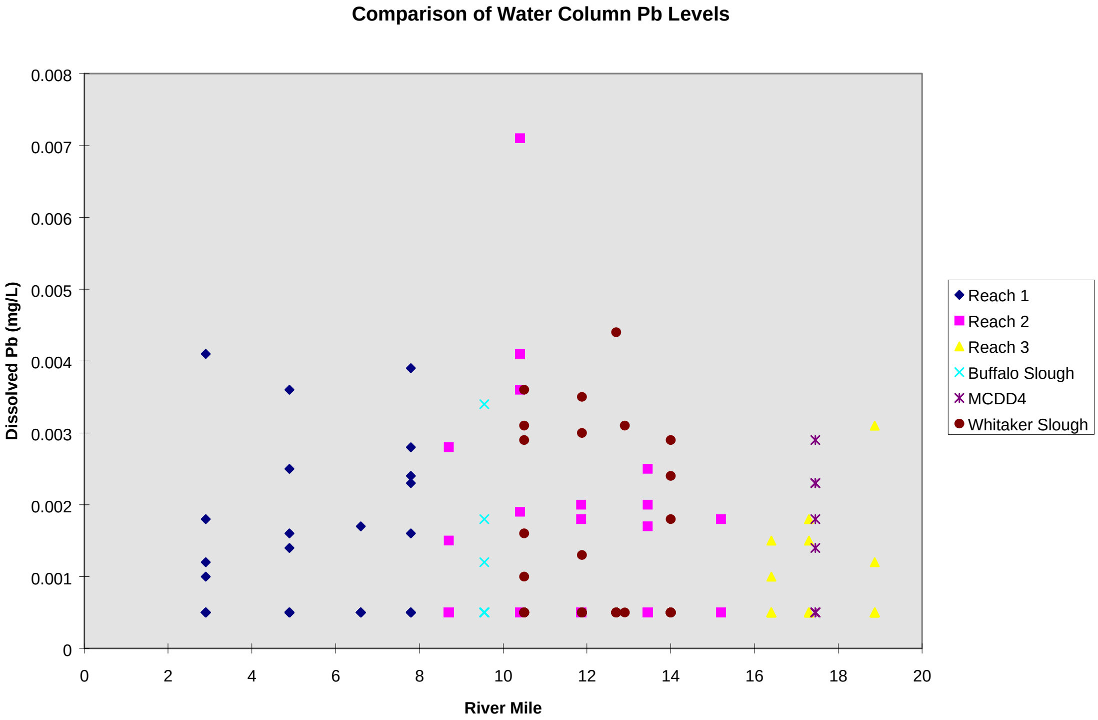

Figure 13: Instream dissolved Pb

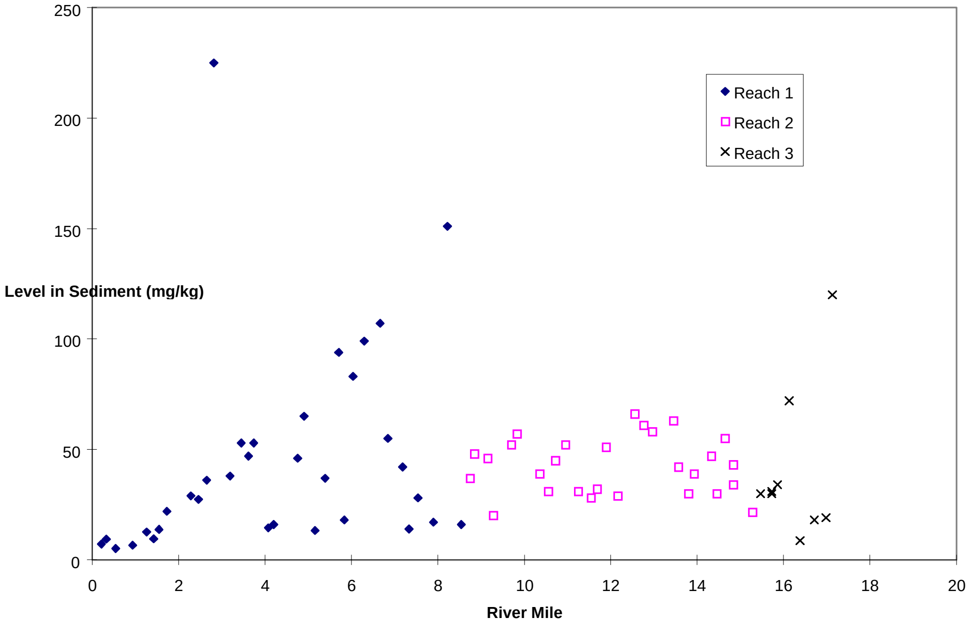

Figure 14: Pb levels in sediment in the Columbia Slough

Higher concentrations in the upper end of the Lower Slough (Reach 1) may be due to net inflow of sediment from the Willamette (Li, 1995). Allocations will be set for the entire Slough until spatial distribution can be better defined.

Allocations were calculated using flows, concentrations and estimates of annual loads as described in Appendix A. The allocations apply annually.

Industrial Point Source Discharge:
The waste load for the one point source discharge is set at the current estimated load of 5×10^{-4} kg/day.

CSOs: Because they are scheduled for removal, CSOs receive a waste load allocation of zero kg/yr except for one in 10 year summer event and 1 in 5 year winter event.

St. John's landfill:
Pb in ground water from St. John's landfill is set at the estimate of the current load of 3.6×10^{-3} kg/day.

Ground water: Pb in ground water is set at the current estimated load of 0.07 kg/day.

Sediment Partitioning: Sediment partitioning and diffusive flux allocation is set by multiplying the estimated water column concentration (in Table 15 in Appendix A) by the base flow and storm flows through the Columbia Slough. As stated in Appendix A, the estimated water column Pb concentration from partitioning is 2.056×10^{-7} mg/L.
$1.98 \text{ m}^3/\text{sec} \times 2.056 \times 10^{-7} \text{ mg/L} \times 1000 \text{ L/m}^3 \times 1 \text{ kg}/10^6 \text{ mg} \times 60 \text{ sec/min} \times 60 \text{ min/hr} \times 24 \text{ hr/day} = 3.52 \times 10^{-5}$ kg/day
This calculation is done for each of the storm flows as well.

Air deposition:
The allocation for the single air source is set at the estimate of the current load; wet and dry deposition. Total deposition = (0.014 kg/yr +8.99×10^{-7} kg/yr) =0.014 kg/yr = 3.84×10^{-5} kg/day

NuWay Oil Site:
The NuWay Oil Site receives an allocation for each of the contributing sources; groundwater, sediment partitioning and surface runoff. The surface runoff allocation is addressed in the storm water section.
Ground water from NuWay Oil is allocated at its current load of 4.53×10^{-8} kg/day. Sediment partitioning at the NuWay Oil Site receives an allocation with a concentration equivalent to the instream concentration contributed by the median of all the contaminated sediment in the Slough. The instream median concentration was 2.056×10^{-7} mg/L (see Appendix A). This concentration was multiplied by estimates of baseflow and storm flow within Whitaker Slough. These flows were 0.81 m^3/sec, 0.91 m^3/sec, 1.21 m^3/sec and 1.53 m^3/sec (corresponding to flows of 1.98, 2.83, 5.66 and 8.5 m^3/sec in the main stem of the Columbia Slough) (Scott Wells, personal communication)

Storm water:
The allocations that are set at current loads and the margin of safety were subtracted from the loading capacity. This remaining capacity is divided between future growth and storm water runoff. Current storm water loads are given 2/3 of the Pb allocation and future growth receives 1/3 of the Pb allocation. Individual storm water sources will calculate their allocation on a unit area basis.

For example, the sum of the allocations for the industrial discharge, ground water, St. Johns' landfill, air deposition, sediment partitioning, and groundwater and sediment partitioning at NuWay oil and the margin of safety equals 0.108 kg/day (for the allocations at 1.98 m^3/sec). Subtracting this from the loading capacity of 0.205 kg/day leaves 0.097 kg/day to be allocated to future growth and storm water. Future growth receives 1/3 of this allocation or 0.031 kg/day and storm water receives 2/3 or 0.065 kg/day.

Storm water allocations will be calculated on a unit area basis, for each flow. At 1.98 m^3/sec, the storm water allocation is 0.065 for the entire Slough drainage basin. The basin is about 40,000 acres or 1.62×10^8 m^2. The unit area allocation is then:

0.065 kg/day/1.62×10^8 $m^2 = 4.01 \times 10^{-10}$ kg/day/m^2

To determine an allocation for storm water runoff from the NuWay oil site, the area of the site is multiplied by the unit area allocation. The calculation is as follows:

NuWay Oil site process and non process area = 60, 000 ft^2 x $1m^2/10.76$ $ft^2 = 5576$ m^2

The allocation for surface runoff from NuWay Oil Site is:

(5576 m^2) x (4.01×10^{-10} kg/day/m^2) = 2.24×10^{-6} kg/day

Table 14: Pb allocations

Source	**Allocations (kg/day)**[10]			
	1.98 m^3/sec	**2.83 m^3/sec**	**5.66 m^3/sec**	**8.50 m^3/sec**
Industrial discharge	5.4×10^{-4}	5.4×10^{-4}	5.4×10^{-4}	5.4×10^{-4}
CSO	0	0	0	0
sediment partitioning	3.52×10^{-5}	1.0×10^{-4}	1.0×10^{-4}	2.0×10^{-4}
groundwater:				
overall	0.07	0.07	0.07	0.07
St. John's landfill	3.6×10^{-3}	3.6×10^{-3}	3.6×10^{-3}	3.6×10^{-3}
air deposition	3.84×10^{-5}	3.84×10^{-5}	3.84×10^{-5}	3.84×10^{-5}
NuWay Oil Site				
sediment partitioning	1.45×10^{-5}	1.6×10^{-5}	2.17×10^{-5}	2.7×10^{-5}
soil erosion	2.24×10^{-6}	2.24×10^{-6}	2.24×10^{-6}	2.24×10^{-6}
groundwater	4.53×10^{-8}	4.53×10^{-8}	4.53×10^{-8}	4.53×10^{-8}
Future growth	0.031	0.055	0.1382	0.2199
storm water	0.065	0.114	0.2765	0.4397
MOS	0.0348	0.0497	0.098	0.147
LC	0.205	0.293	0.587	0.881

Implementation Strategy

Pb levels in the Slough exceed the aquatic life chronic criteria, however, the instream Pb data include many values that are at the detection limit and are much lower than the practical quantification limit. As seen below, most of the samples (245/296) are lower than the criteria and the detection level.

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[10] Excess loading capacity was allocated to the margin of safety.

Table 15: **Comparison of detection level and criteria exceedance**

	detection level (0.001 mg/L)	
dissolved criteria	less than	greater than
less than	245	19
greater than	1	31

Additionally, an analysis of the relative criteria exceedance on wet and dry days revealed that the wet day exceedance rate (10.9%) was not different than the dry day exceedance (10.8%). In this analysis, a wet day was defined as one in which the cumulative rainfall on that day and the three days prior exceeded 0.25 inches.

Modeling of loads indicate that storm water is the largest contributor of Pb, however, the loads would be expected to result in higher instream Pb levels than what is observed. Modeling by Wells (1997) indicates that storm water is diluted about 2 times in the Slough.

There are no synoptic data sets linking storm water loads with instream values. Examination of the Portland MS4 permit reveals that commercial, industrial and traffic corridor land uses contribute the largest loads of Pb (unit load basis), respectively. BMPs should be developed based on land uses, but further delineation of sources based on land use must be done. Under Phase I of the Pb TMDL, DMAs will be required to develop the synoptic data sets. A lower detection limit for the analysis will also be required to gain a better understanding of when and how frequently the criteria is being violated. Phase I will also include measuring the effectiveness of controls at reducing the lead load from storm water. The requirements for all potential contributors of lead are outlined below.

Industrial permittee requirements

The DEQ anticipates requiring implementation of BMPs through storm water permits. A basin specific general storm water permit will be developed by DEQ to address all 303(d) pollutants. Requirements of this permit to reduce the lead load are as follows:

1. Monitoring for total and dissolved lead
2. Implementation of BMPs to control or remove metals.
3. Monitor effectiveness of BMPs.

Environmental Cleanup Sites

DEQ's Site Response section has conducted a review of the sites in the Environmental Cleanup Site Information (ECSI) database to determine which of those merit increased attention due to the presence of 303(d) chemicals and proximity to the Slough. High priority sites have been moved to the cleanup program. DEQ water quality program will develop a monitoring protocol to be included in the statement of work for site cleanup to estimate the load of 303(d) pollutants from individual sites. The individual project managers will select BMPs for surface runoff control and metals control and require BMP implementation.

Designated Management Agencies

1. Conduct instream dry and storm event monitoring for total lead, dissolved lead and hardness. Conduct lead analysis using detection levels which are lower than the water quality chronic criterion.

2. Conduct monitoring at outfalls to Slough, outfalls selected based on land uses known to have high lead levels or other metals.
3. Identify and implement BMPs in the municipal NPDES permits that will be effective in controlling lead storm water inputs.
4. Monitor to determine effectiveness of BMPs to remove total and dissolved lead from storm water.
5. Estimate the load reduction of lead achieved for storm water at the end of Phase I.
6. Estimate effectiveness of BMPs to remove TSS.

The responsibilities of the DMAs, by reach, is summarized below:

Table 16: Lead Control Summary

Reach	Control Strategy	Responsible DMA
1	1,2,3,4,5,6	City of Portland, PDX
2	1,2,3,4,5,6	City of Portland, PDX
3	1,2,3,4,5,6	City of Portland, City of Gresham
4	3,6	City of Fairview, Multnomah County
5	3,6	City of Fairview, City of Gresham, Multnomah County, City of Wood Village
1-5	1,2,3,4,5,6	Oregon Department of Transportation

Organics Monitoring

Fish tissue sampling

Fish tissue data provide the most extensive evidence of impairment of beneficial uses by toxics in the Columbia Slough. Most of the available fish tissue data were collected in the summer of 1994 as part of the sediment remediation project undertaken by BES. Different organisms can be expected to bioaccumulate chemicals differently based on age, life cycle patterns, amount of fatty tissue and feeding habits. However, since bioconcentration factors are generally available for specific chemicals rather than for specific species, results for the different species tested have been grouped together. The BCFs used to develop screening values were obtained from the EPA Region VIII Criteria Chart (July 1993).

Fish tissue screening values can be calculated directly from the OAR Table 20 criteria as follows:

Fish Tissue Screening Value (mg/kg) = Table 20 Criteria for protection of human health (ng/L) $*$ BCF (L/kg) * (mg/10^6 ng)

Screening values were exceeded for DDT, dieldrin, and PCBs. Table 17 contains a summary of the monitoring results for these chemicals. In August 1995, the Oregon Health Division issued a fish consumption advisory for PCBs and DDT/DDE.

Table 17: Summary of Fish Tissue Exceedances of OAR Table 20-derived screening values

Chemical	Screening Value	No. of values	No. of detects(% of	No. of exceedances

	(ug/kg)		total samples)	(% of total samples)
4,4' DDT	1.29	65	15 (23.1%)	15 (23.1%)
aroclor 1248 (PCB)	2.46	55	6 (10.9%)	6 (10.9%)
dieldrin	3.5	61	24 (39.3%)	24 (39.3%)

Polychlorinated dibenzodioxins (dioxins) refers to a group of highly toxic compounds that are generally found together in complex mixtures of congeners (Parametrix, July 5, 1995). Congeners are compounds formed of the same elements that have different molecular structures. In the case of the various dioxin congeners, the chlorine substitution occurs in different locations on the base molecule. Table 20 of the water quality standards contains one criterion value for dioxin, and it is for the most toxic congener known as 2,3,7,8-TCDD. The results of fish tissue data for 2,3,7,8 TCDD are shown in Table 18.

Table 18: Summary of Dioxin Results for Fish Tissue

Location	Collected By	Date of Collection	Value (ng/kg)	Detection Limit (ng/kg)
Lower Slough (above N. Slough)	DEQ, National Bioaccumulation Study	July 1987	2.86	not reported
Lower Slough (at SP&S bridge)	DEQ, National Bioaccumulation Study	July 1987	7.66	not reported
Lower Slough (river mile 0-3)	Parametrix, for BES	Summer, 1994	0.97	not reported
Lower Slough (river mile 6-8.6)	Parametrix, for BES	Summer, 1994	ND	1.0
Upper Slough (River mile 0-3)	Parametrix, for BES	Summer, 1994	ND	0.8
Whitaker Slough	Parametrix, for BES	Summer, 1994	ND	2.1
North Slough	Parametrix, for BES	Summer, 1994	ND	0.9

Parametrix samples are composite samples.

The screening value for dioxin is 0.07 ng/kg. As seen in the above table, 3 of the 7 samples collected exceed this screening value.

To summarize, the Columbia Slough is considered water quality limited for PCBs, DDT/DDE and dioxin due to elevated fish tissue levels. Fish tissue data indicates elevated levels of dieldrin, so a preventative TMDL has been calculated for dieldrin as well. An analysis of the sources of the organics is contained in Appendix A.

Loading Capacity Defined

For phase I of the TMDL process the fish consumption criteria to protect human health is used. For a long term exposure, EPA recommends the use of harmonic mean flow for instream flow. Due to the lack of data to calculate harmonic mean flow, the annual average flow is used as an estimate of long term flow. According to the Waterbody Assessment (CH2MHill, 1995), the total annual inflow to the Columbia Slough, not counting tidal inflow from the Willamette, is 1.48×10^8 m^3/yr. The loading capacity is calculated as follows:

total annual inflow (m^3/yr) x Table 20 criteria (ng/L) x (1000 L/m^3) x 1 yr/365 days x 1kg/10^{12} ng = loading capacity (kg/day)

The Table 20 criterion for DDT is used for DDT and DDE. The following table lists the OAR Table 20 criteria for the protection of human health and the corresponding LCs for the 303(d) organics.

Table 19: OAR Table 20 Criteria[11] and LCs for 303(d) Organics

Parameter	Criteria (ng/l)	LC (kg/day)
DDT/DDE	0.024	9.73×10^{-6}
Dieldrin	0.071	2.88×10^{-5}
Dioxin (2,3,7,8-TCDD)	1.3×10^{-5}	5.27×10^{-9}
PCBs	0.079	3.2×10^{-5}

Allocations

The difference between the loading capacity and the WLA for sediment partitioning and diffusive flux (from Table 15 in Appendix A) will be split evenly into WLAs for total urban storm water and the MOS. The total urban storm water allocation is further divided to account for future growth which may expose soils containing the organics, as well as current storm water loads. The storm water allocation also includes the ECSI sites. As ECSI sites or new storm water sources are identified, they will receive an allocation based on unit area.

WLA for MOS = 1/2 x (LC - WLA for sediment partitioning)
WLA for total urban storm water = 1/2 x (LC - WLA for sediment partitioning)
Future growth WLA = 1/3 total urban storm water allocation
Current storm water WLA = 2/3 total urban storm water allocation

The calculations for DDE/DDT are summarized as an example. According to Table 15, Appendix A, sediment partitioning contributes 4.87×10^{-13} mg/L DDT to the water column. This concentration is converted to a mass load as follows:

$(4.87 \times 10^{-13}$ mg/L) x $(1.48 \times 10^{8}$ m^3/yr) x (1000L/m^3) x (1 kg/10^6 mg) x (1 yr/365 days) =1.97×10^{-10} kg/day

The same calculation for DDE yields a mass load of 2.91×10^{-10} kg/day of DDE to the water column. The total mass load for DDT/DDE is 4.88×10^{-10} kg/day.

The WLA for MOS = ½ x (9.73×10^{-6} kg/day – 4.88×10^{-10} kg/day) = 4.86×10^{-6} kg/day
The WLA for total urban storm water = 4.86×10^{-6} kg/day. The WLA for future growth = 1/3 x (4.86×10^{-6} kg/day) = 1.62×10^{-6} kg/day

The WLA for storm water (current) = 2/3 x (4.86×10^{-6} kg/day) = 3.24×10^{-6} kg/day

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[11] criteria for the protection of human health, water and fish ingestion

NuWay Oil Site Storm water runoff allocation:
For PCBs the storm water allocation is 5.3 x 10^{-6} kg/day for the entire Slough drainage basin. The basin is about 40,000 acres or 1.62 x 10^{8} m^2 . The unit area allocation is then 5.3 x 10^{-6} kg/day/1.62 x 10^{8} m^2 = 3.27 x 10^{-14} kg/day/m^2. To determine an allocation for storm water runoff from the NuWay oil site for PCBs, the area of the site is multiplied by the unit area allocation. The calculation is as follows:

NuWay Oil site process and non process area = 60, 000 ft^2 x 1m^2/10.76 ft^2 = 5576 m^2
The allocation for surface runoff from NuWay Oil Site is:
(5576 m^2) x (3.27 x 10^{-14} kg/day/m^2) = 1.82 x 10^{-10} kg/day
No allocations were calculated for the other organics as they have not been found at the site.

No estimates of dioxin loads from sediment partitioning are available, so the loading capacity is divided evenly between the three sources and the margin of safety. The waste load allocations are annual and summarized as follows:

Table 20: **Organic Allocations (kg/day)**[12]

Parameter	**LC**	**LA sediments**	**WLA storm water**	**WLA Future Growth**	**MOS**[13]	**NuWay Oil**
DDT/DDE	9.73 x 10^{-6}	4.88 x 10^{-10}	3.24 x 10^{-6}	1.62 x 10^{-6}	4.87 x 10^{-6}	N/A
dieldrin	2.88 x 10^{-5}	1.08 x 10^{-8}	9.6 x 10^{-6}	4.8 x 10^{-6}	1.43 x 10^{-5}	N/A
dioxin	5.27 x 10^{-9}	1.31 x 10^{-9}	1.31 x 10^{-9}	1.31 x 10^{-9}	1.34 x 10^{-9}	N/A
PCBs	3.2 x 10^{-5}	1.61 x 10^{-7}	5.3 x 10^{-6}	1.06 x 10^{-5}	1.59 x 10^{-5}	1.82 x 10^{-10}

Implementation Strategy

Monitoring as part of the Buffalo Slough sediment remediation project has indicated that the largest contributor of PCBs to the Buffalo Slough is sediment in storm water, while storm water contributes pesticides. The organics present in fish tissue in the Columbia Slough are not the result of continuing use of the chemicals, but previous use and application. The TMDL strategy focuses on implementation of BMPs to control erosion in the Slough basin and monitoring to evaluate their effectiveness. This strategy is based on limited data indicating that control of sediment input to the Columbia Slough will reduce the organic load.

Industrial Storm water permits

The DEQ anticipates requiring implementation of BMPs through storm water permits. A basin specific general storm water permit will be developed by DEQ to address all 303(d) pollutants. Requirements to reduce the organic load from industrial storm water will be as follows:
1. Monitoring for TSS.

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[12] Due to rounding, sum of WLA may not equal LC (but does not exceed LC). For dioxin excess LC was allocated to the MOS.
[13] Excess loading capacity is allocated to the MOS in the allocation table.

2. Implementation of BMPs to control erosion and sedimentation.
3. Monitor effectiveness of BMPs at erosion and sedimentation control.

Environmental Cleanup Sites

DEQ’s Site Response section has conducted a review of the sites in the Environmental Cleanup Site Information (ECSI) database to determine which of those merit increased attention due to the presence of 303(d) chemicals and proximity to the Slough. High priority sites have been moved to the cleanup program. DEQ water quality program will develop a monitoring protocol to be included in the statement of work for site cleanup to estimate the load of 303(d) pollutants from individual sites. The individual project managers will select BMPs for surface runoff control and require BMP implementation.

Designated Management Agencies

1. Conduct pilot monitoring projects to determine the relationship between TSS and organics in storm water.
2. Identify and implement BMPs, as listed in the municipal NPDES permits, for erosion control based on limited data suggesting storm water sediment as a current source of organics.
3. Monitor the effectiveness of BMPs at TSS removal.
4. Estimate the load reduction of TSS achieved for storm water at the end of Phase I.
5. Implement water quality management plans as developed as part of the Lower Willamette Subbasin plan.

The responsibilities of the DMAs, by reach, is summarized below:

Table 21: Organic Control Summary

Reach	Control Strategy	Responsible DMA
1	2,3,4	City of Portland, PDX
2 (Buffalo Slough)	1	City of Portland (as part of sediment remediation project for Buffalo Slough)
2	2,3,4	City of Portland, PDX
3	2,3,4	City of Portland, City of Gresham
4	2	City of Fairview, Multnomah County
5	2	City of Fairview, City of Gresham, Multnomah County, City of Wood Village
1-5	5	Oregon Department of Agriculture
1-5	2,3,4	Oregon Department of Transportation

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Temperature Analysis

Water Quality Criteria

To accomplish the goals identified in OAR 340-41-120(11), unless specifically allowed under a Department approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable surface water temperature increase resulting from anthropogenic activities is allowed:

(i) In a basin for which salmonid fish rearing is a designated beneficial use, and in which surface water temperatures exceed 64.0°F (17.8°C).

This numeric criteria is measured as the seven day moving average of the daily maximum temperatures (OAR 341-41-006(54)). For point sources, the surface water management plan will be part of their NPDES permit. For nonpoint sources, the surface water management plan will be developed by DMAs which will identify the appropriate BMPs or measures.

Monitoring

Analysis of water quality data indicates that the 17.8° C criteria would be violated in most reaches in the Slough in the spring, summer and fall. Temperatures in Reaches 1A, 1B, 1C, 2A and 3 indicate frequent exceedances of the criteria during these seasons. The limited data for Reaches 4 and 5 also indicate frequent exceedances of the temperature criteria in the spring, summer and fall. Temperatures in the winter in the Slough are generally below the criteria. (CH2MHill, 1995, Part 2)

Modeling

Instream temperature may be influenced by loads from industrial point sources, storm water, illicit discharges, and nonpoint sources as well as the hydrology of the Slough. Loads from storm water and illicit discharges are presumed to be insignificant in comparison to the effect of solar radiation on instream temperatures.

Most banks of the Slough are built up as levees and have little vegetation. Shallow water levels in the Slough exacerbate the effect of lack of shading, so solar radiation heats up the water to levels exceeding the temperature criterion. Modeling has been done to assess the impact of additional shading via tree planting on the Middle and Upper Slough (Wells, 1995).

For the Middle and Upper Slough, the average amount of shaded water surface was estimated for the month of August (Biorn-Hansen, personal communication) using field measurements in representative areas by a solar pathfinder. The pathfinder is used to measure the magnitude of the shadow cast by the treeline in a particular area. For each location where the pathfinder was used, data was also collected on stream width, bank geometry and vegetation density. Site-specific shading estimates were then generated based on field measurements combined with information on azimuth, declination angle, latitude, and time of year. These estimates were then applied to the rest of the Slough. The average amount of shaded water surface was estimated to be 20%. These field estimates of shading correlated with estimates developed by Wells (Wells, 1995, memo).

In the shading simulations, approximately 80% of the Upper Slough was assumed to be unshaded for existing conditions and 50% was assumed to be unshaded for future conditions. The effect of flow management alone on instream temperature was simulated; then the effect of flow management and increased shading (to 50%) was simulated. According to the simulations, the Upper Slough would be in compliance with the temperature criteria if 50% is shaded. Shading in upstream reaches is predicted to have little effect on the temperature in the Lower Slough, because the temperature of the Lower Slough is most impacted by the incident solar radiation and relatively long residence times.

Modeling indicated that additional shading in the Lower Slough, under current hydrological conditions, would have negligible effect on instream temperature. This is because of the following conditions:

- Much of the Lower Slough is bordered by levees, and the Army Corps of Engineers prohibits the planting of trees on levees,
- The sections of the Lower Slough that are not bordered by levees are already reasonably well-vegetated, and
- The Lower Slough is generally so wide (up to 400 ft) that most of the water surface is unshaded whether or not there are trees along the banks, thus shade measurements made at various locations along the Lower Slough yielded values ranging from 0% to 5%.

Several refinements are being made to the existing model for the Columbia Slough. Some of these refinements, such as shade calculation based on vegetation height, will influence temperature simulations. The model will be used to predict the influence that management strategies will have on instream temperature. The results of these analyses will form the basis for a temperature/solar radiation TMDL.

Conversion Factors

To convert from:	**to:**	
kg/day or kg/yr	lb/day or lb/yr	divide by 0.454
1 m^3	ft^3	multiply by 35.3

Equation to use flow and concentration to calculate a mass load:

(m^3/sec) x (1000 L/m^3) x (mg/L) x (1 kg/10^6 mg) x (60 sec/min) x (60 min/hr) x (24 hr/day) = kg/day

APPENDIX A
SOURCES DOCUMENT

Sources of Toxics to the Columbia Slough

Overview

The Columbia Slough is on DEQ's 1994/1996 303(d) list of water quality-limited waterbodies for the following chemicals:

- DDT and metabolites
- Dioxins
- Lead
- PCBs

Impairment of beneficial uses by DDT and its metabolites, dioxin and PCBs is demonstrated by occurrence in fish tissue. Review of fish tissue data indicates that dieldrin is also present at elevated levels. Water column data provides evidence of impairment by lead. Because of their presence on the 303(d) list, these chemicals will be referred to as 303(d) chemicals. General information on the sources, fate and transport of each is provided below.

DDT and its metabolites

4,4'-DDT, also known simply as DDT, is a low-cost broad-spectrum insecticide that was banned in the U.S. in 1972 although it is still being used in some tropical countries. Over time DDT breaks down to form DDE and DDD, which are also associated with toxicological effects. All are subject to photodegradation or redeposition by rain or dry deposition, and are widely dispersed by erosion, runoff and volatilization. On land, they preferentially bind to soil and sediment. In water they are subject to sedimentation, volatilization, photodegradation, and uptake into the food chain. Release of these compounds to water is primarily via transport of particulates contained in runoff. Both DDT and DDE bioaccumulate in organisms, particularly in fatty tissues, and levels are subject to increase as they advance up the food chain.

Due to extensive past use of DDT worldwide and the persistence of DDT and its metabolites, these materials are virtually ubiquitous in the environment, and have been detected in virtually all media. They are continually being transformed and redistributed in the environment (EPA 1993, Meyer 1990, U.S. Public Health Service 1988).

Dieldrin

Dieldrin was widely used in the United States from 1950 to 1974 as a broad spectrum pesticide, primarily on termites and other soil-dwelling insects and on cotton, corn, and citrus crops. It is a metabolite of aldrin, thus the environmental concentrations of dieldrin are a cumulative result of the historic use of both aldrin and dieldrin. EPA banned the production and most major uses of dieldrin in 1974, and in 1987 all uses of dieldrin were voluntarily canceled by industry. Dieldrin is extremely persistent in the environment, and by means of bioaccumulation it is concentrated many times as it moves up the food chain. Its persistence is due to its extremely low volatility and low solubility in water resulting in a high affinity for fat (EPA 1993, Meyer 1990).

Dioxins

Dioxins are a family of compounds, the most hazardous of which is 2,3,7,8-TCDD. Dioxins may be produced as a byproduct of incomplete combustion whenever chlorine is contained in the fuel source. Some specific examples of sources include chlorine-bleaching pulp mills, municipal and medical waste incinerators, secondary smelters which recover metal from waste products such as scrap automobiles, and wood treaters using pentachlorophenol. Dioxins are also found in sludges at major municipal wastewater treatment plants. These are most likely from industrial sources discharging to the treatment plants since the temperatures associated with sewage treatment processes are not sufficient to produce dioxins. Dioxins found in treatment plant sludges may also have been conveyed there by storm water.

Dioxins have been a contaminant in a number of compounds formerly manufactured as broad spectrum herbicides, the best known being Agent Orange. The association of dioxins with certain herbicides has provided a route of entry into the environment through the use of those herbicides and by the improper disposal of chemical wastes associated with herbicide production. Because 2,3,7,8-TCDD is an extremely stable substance that begins to thermally decompose only when heated to its boiling point, 930°F, and because it readily dissolves in fatty tissues, it is highly persistent in the food chain (EPA 1991, 1992,1993, 1994, Meyer 1990).

Lead

Historically, lead has had a number of industrial uses. It has been used in paints, in solder and as a gasoline additive. As recently as the mid-1980s, the primary source of lead in the environment was the combustion of gasoline; however, use of lead in U.S. gasoline has fallen sharply in recent years. The maximum amount of lead now allowed in unleaded gasoline is 0.1 g/gal. Because lead has been associated with the combustion of gasoline, it is found in urban runoff. About 75% of houses and apartments built before 1978 in the United States contain lead paint, which may also contribute to the lead found in urban runoff. At present, lead is used primarily in batteries, electric cable coverings, some exterior paints, ammunition, and sound barriers. Currently, the major points of entry of lead into the environment are from mining and smelting operations, and from fly ash resulting from coal combustion (EPA 1993, Meyer 1990, Dennis O’Neill, Metro, pers. comm.).

PCBs

PCBs were once used extensively by industry as insulating fluids in electrical transformers and capacitors, as plasticizers, as lubricants, as fluids in vacuum pumps and compressors, and as heat transfer and hydraulic fluids. They were never intended to be released directly into the environment. Prior to 1979, the disposal of PCBs and PCB-containing equipment was not subject to federal regulation, and approximately 1.25 billion pounds was purchased by U.S. industry. Their production and use in the United States were banned by the EPA in July 1979. PCBs are extremely persistent in the environment and are bioaccumulated throughout the food chain (EPA 1993, Meyer 1990).

DDT (and by extension, its metabolites), dieldrin and PCBs have been banned by the EPA. Their presence in the Slough environment is likely the result of past practices. The same is true to a lesser extent for lead and dioxin. Car emissions contain less lead than they used to owing to the increased use of unleaded gasoline, and dioxin production associated with pulp and paper mills has been reduced in recent years.

The sources analyzed in this document include the following:
- industrial discharges
- combined sewer overflows
- municipal storm water
- industrial storm water
- groundwater
- contaminated sites
- contaminated sediment
- air deposition
- spills
- illicit discharges

Additional sources may include: agriculture activities, sumps, septic tanks and illegal dumping. Data is not currently available to quantify the loads from theses sources. TMDLs include a margin of safety to account for this uncertainty, and monitoring requirements will be established to provide data needed to reduce uncertainty.

Interpretation of Standards

Lead appears on the 303(d) list for the Columbia Slough because it is detected in the water column at levels which exceed the OAR Table 20 chronic criteria for the protection of freshwater aquatic life. The organic chemicals appear on the list because they are detected in fish tissue at levels which exceed screening values developed from the OAR Table 20 criteria. These values were developed for the protection of human health from exposure to contaminated fish.

The specific application of standards for each of the 303(d) parameter and the interpretation of data for evaluating sources is discussed in the following sections.

Lead

When interpreting information on sources of lead to the Columbia Slough, it is important to consider both the dissolved and total lead concentrations. Lead can be present in the water column in both forms, with the solid form being adsorbed onto sediment particles in the water column. The ratio of the sorbed to dissolved concentration is known as the partition coefficient and it varies with the presence of suspended solids according to the following equation (EPA TMDL):

$$K_p = \frac{C_p/SS}{C_d}$$

where K_p = partitioning coefficient
C_p = concentration of solids
C_d = concentration in solution
SS = suspended solids concentration

Because lead in the solid form adsorbs onto sediment particles, total lead levels will generally be higher in a water column characterized by high suspended solids. As settling occurs, or as TSS levels in the water column otherwise become diluted, lead that was formerly adsorbed onto particulate matter in the water column may partition into the dissolved form. Therefore it is important to consider both total lead and dissolved lead concentrations when evaluating sources of lead to the Slough.

When total lead data is available and appropriate partitioning equations are available, dissolved lead concentrations can be calculated. However, to develop the partitioning coefficient for the Columbia Slough lower detection limits for total lead are needed. For this reason, dissolved lead values are evaluated to determine compliance with the chronic criteria for the protection of aquatic life. The City of Portland Bureau of Environmental Services (BES) has collected 296 dissolved Pb and hardness samples from all reaches of the Slough, throughout all seasons.

The chronic criteria is defined as the four day average concentration not to be exceeded once every three years. There is insufficient data with which to calculate 4 day averages directly, so the existing data is compared directly to the criteria. Using the hardness measured with each sample, a total lead criteria is calculated according to the following equation:

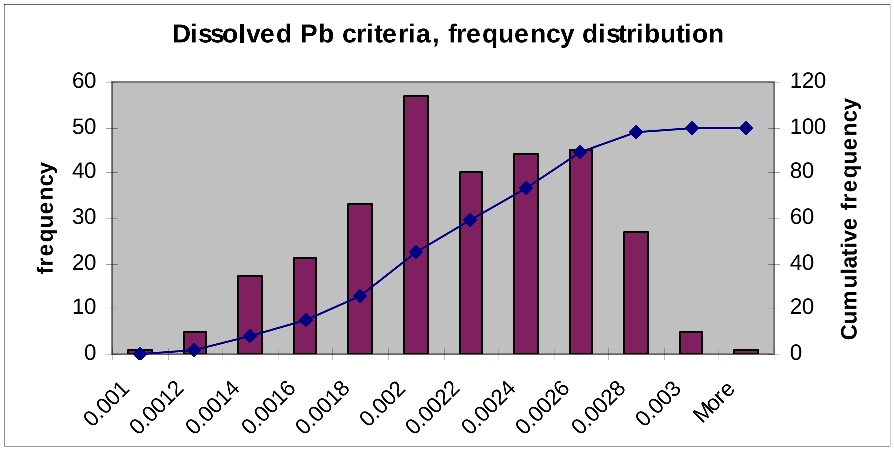
total lead criteria (Table 20) = $e^{(1.273[\ln(\text{hardness})]-4.705)}$
(EPA 1986)

EPA recommends the use of the dissolved metal criteria. Total metal criteria can be converted to a dissolved metal criteria via the use of a conversion factor (CF). The equation for Pb is as follows:

CF = 1.46203 - [ln(hardness)(0.145712) (EPA 1996).

Using these equations, a criteria was calculated for each hardness and dissolved Pb sample. From the frequency distribution of the criteria the 5th percentile criteria was calculated to be 0.0012 mg/L dissolved Pb. The 5th percentile represents a "worst case" assumption (EPA, 1995).

Figure 1: dissolved Pb criteria



Organics

The 303(d) list organic chemicals are detected in fish tissue rather than in the water column. The appearance of these organics in fish tissue is the result of bioconcentration and biomagnification. Bioconcentration is the term used to describe the uptake and retention of pollutants directly from the water mass by organisms, through tissues such as the gills or epithelial tissues. Biomagnification is the process whereby pollutants are passed from one trophic level to another and exhibit increasing concentrations in organisms related to their trophic status (Connell, 1984).

There is insufficient information at present to allow the development of a quantitative relationship between water column concentrations in the Columbia Slough and concentrations of organics in fish tissue. Therefore, for this phase of the TMDL process it will be assumed that if the OAR Table 20 chronic criteria for the protection of aquatic life are not violated, then fish tissue concentrations will also be below levels necessary to demonstrate impairment of beneficial uses.

Source Analysis

Industrial Discharges

Lead is the only 303(d) chemical which is monitored as a requirement under industrial discharge permits issued in the Slough watershed.

There are 27 permitted non storm water industrial discharges to the Columbia Slough. Of these, 22 have general permits and 5 individual permits. General permits apply to industrial categories that can meet the general conditions assumed to cause negligible degradation of water quality.

Table 1 contains a summary of the active industrial in the Columbia Slough watershed. Information on what is monitored under the various types of discharge permits is included for completeness.

Table 1 Summary of General Permits for Industrial Discharges to the Columbia Slough

Permit Type	Expiration Date	Description	Parameters Reported[1]	No. of Active Permits
GEN01	7/31/2001	cooling water/heat pumps	flow, temperature, pH, chlorine	8
GEN02	12/31/1995	filter backwash	settleable solids, pH	2
GEN13	12/31/1999	oily storm water runoff	flow, oil and grease, oxygenated fuel additives (ethanol and/or methyl-t-butyl ether)	2
GEN15	6/30/2000	petroleum hydrocarbons cleanup	flow, pH, total petroleum hydrocarbons, benzene, BETX[2], lead[3]	4
GEN17	12/31/1997	vehicle wash water	pH and oil & grease OR pH, arsenic, chromium VI, copper, lead, zinc[4]	3
			total number of general permits:	22

[1] All metals are measured as total. Requirements to measure the dissolved portion are not currently in place.
[2] BETX stands for benzene, ethylbenzene, toluene and xylene.
[3] Monitoring for lead is not required for all permit holders.
[4] The latter set of parameters applies to cleaning operations using strong acids, caustics, or other metal brighteners. None of the current permit holders fall into this category.

Only the GEN15 (petroleum hydrocarbons cleanup) and GEN17 (vehicle wash water) permits currently require monitoring for lead, and then only under certain circumstances. Under the GEN15 permit, ongoing monitoring for lead is required when detectable levels of lead have been found in the influent to the treatment system. Under the GEN17 permit, monitoring is required for those facilities that have cleaning operations using strong acids, caustics, or other metal brighteners. None of the 3 discharges indicated in Table 2 fall into this category, therefore they are exempt from monitoring for lead.

It should be noted that while monitoring for lead can be required under these permits, the permits do not currently contain actual limits for lead. The intent of the monitoring requirements is simply to collect data for one permit cycle and then the need for an effluent limit will be evaluated as these general permits come up for renewal. At this time, it is anticipated that when the GEN17 permit is renewed it will contain permit limits for lead. Additional detail on the GEN15 permit holders discharging to the Columbia Slough is summarized in Table 2.

Table 2 Summary of GEN15A Permits in the Columbia Slough Watershed

Permit Holder	Location	Comments
Case Corporation	1745 NE Columbia Blvd., Portland	Site is impacted by gasoline and diesel. No lead has been detected at this site, therefore monitoring for lead is not required[1].
General Motors Corporation	9225 NE Airport Way, Portland	This facility discharged about 1 gpm from 10/95 to 10/96. 100 ppb of total lead was detected in one of the on-site wells.
Jubitz Truck Stop	10210 N. Vancouver Way, Portland	This cleanup site involves a diesel fuel discharge only.
Unocal Station #6139	985 E. Burnside Street, Gresham	Involves a diesel fuel discharge only, therefore monitoring for lead is not required.

[1] Don Pettit, DEQ, pers. comm.

Using the Pb concentration associated with the discharge that existed between 10/95 and 10/96, an annual Pb load can be calculated as follows:

100 ug/l x 1 gpm x 3.79 l/gal x 1400 min/day 365 days/yr x 1 kg/10^9 ug = 0.19 kg/yr = 5x 10^{-4} kg/day

All of the 5 individual permits are classified as minor discharges (less than 1 million gallons per day) and none require monitoring for 303(d) parameters. Two are for treated groundwater, and require testing for volatile organic compounds. Both of these permits are currently under review, and monitoring requirements may be expanded. Two more of the 5 discharges go to the City of Portland's municipal storm water system, and they are being rerouted to the City's sanitary system (Michael Pronold, BES, pers. comm.).

Combined Sewer Overflows (CSOs)

There are 13 CSO outfalls located on the Lower Slough. The CSOs are currently regulated under the NPDES program as well as an Amended Stipulation and Final Order (ASFO) which the Department and the City of Portland entered into in 1994. Under the terms of the ASFO, the CSOs are to be effectively removed from the Columbia Slough by December 1, 2000. Because the justification for removing CSOs has been based on the quantities of bacteria they discharge, and because a schedule has been developed for

CSO removal, little monitoring has been done that would help quantify non-bacterial pollutant loads associated with CSOs.

In April of 1991, samples were collected from one CSO outfall to the Columbia Slough. Information on the outfall is summarized below.

Table 3 Monitored Combined Sewer Overflow Data (BES 1992)

Basin	Receiving Stream	Size (acres)	Predominant Land Use	% Impervious Surface	Total Pb
Vancouver	Columbia Slough	255	residential	45	24.4 ug/L

Monitoring did not include hardness or dissolved lead concentrations. The total lead value exceeds the chronic criteria for dissolved lead (=1.2 ug/l,) by a substantial margin.

Although there were no detects of DDT and its metabolites, dieldrin or PCBs in the CSO effluent, the detection limits for all of these chemicals were above the chronic criteria . Since sampling of these chemicals has not been extensive and detection limits have been high, it cannot be concluded that they are not present in any quantities in CSOs No information is available with which to estimate dioxin loads to the Slough.

In addition to sampling results for CSO effluent, modeling of CSO pollutant levels has been done by OTAK as part of the CSO Management Plan. Results of this modeling estimate the annual loading rate of lead to the Slough to be 149 lbs/yr (BES 1993). This is very close to the value of 185 lb provided by CH2MHill in the Waterbody Assessment, Part II (CH2MHill 1995). An average of these values, or 167 lbs/yr (75.7 kg/yr) is used as the estimated annual total lead load from CSOs.

Storm water

Types of Storm water Permits

Two types of permits are issued for the control of storm water: municipal permits and industrial permits. In addition, in a few cases, NPDES permits issued for the control of process wastewater have been modified to contain storm water requirements.

Municipal Separate Storm Sewer System (MS4) permits, also known as municipal permits, are issued to municipalities, drainage districts and other entities with jurisdiction over separate storm sewer systems in metropolitan urban areas. MS4 permits can have several co-applicants, each of whom will be responsible for some portion of the permitted area. Two municipal permits have been issued for the Columbia Slough watershed and will be referred to as either the Portland MS4 permit or the Gresham MS4 permit.

The Portland MS4 permit holders are as follows:

- City of Portland
- Multnomah County
- Port of Portland
- Oregon Department of Transportation
- Multnomah Drainage District #1
- Peninsula Drainage District #1
- Peninsula Drainage District #2

The Gresham MS4 permit holders are as follows:

- City of Gresham
- City of Fairview
- Multnomah County
- Oregon Department of Transportation

Both permits were issued by DEQ on September 7, 1995. The areas covered by the two permits are summarized below.

Table 4 Areas Covered by MS4 Permits in the Columbia Slough Watershed

Permit Holder	Permit Area (acres)	Col. Sl. Area (acres)	% of Col. Sl. Watershed	Source of Information
Portland et al	44,307	16,971	81%	MS4 Permit App., Table 3-37
Gresham et al	38,310	3,860	19%	MS4 Permit App., Tables 5-4
totals:	82,617	20,831	100%	

Monitoring requirements for MS4 permit holders are described in the MS4 permit applications. To summarize, catchments representative of particular land uses (for example, commercial, industrial, or residential) are monitored during 3 winter storm events and one summer storm event. Parameters measured include conventional pollutants as well as metals. The 1996 annual reports for both MS4 permits issued in the Slough watershed contain the results of all monitoring performed since 1991.

Industrial storm water permits, which are also known as general permits, are issued for particular categories of activities or facilities, such as construction sites or metal scrap yards. Whether or not a particular industrial activity needs a permit will depend on its SIC (Standard Industrial Classification) code. Monitoring requirements vary by permit type, but generally include pH, oil and grease, BOD, TSS and metals. Metals include arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Only total metal concentrations are measured.

Storm water Pb data

The following table summarizes the extent of storm water monitoring for lead.

Table 5 Extent of Storm water Monitoring for Lead

	Portland MS4	Gresham MS4	Industrial
No. of Monitoring Stations	10	4	74[1]
No. of Storm Events Monitored	18	3	2/yr
No. samples analyzed for total lead	119	11	466
No. samples analyzed for dissolved lead	119	none	none
No. samples analyzed for hardness	111	none	none

[1] Each permit holder is required to monitor one site.

Monitoring under the Gresham MS4 permit and the industrial permits did not include dissolved lead. These results can be converted to dissolved lead by using the following equation that gives total lead in terms of the percentage of dissolved lead. This equation was developed from data collected under the Portland MS4 permit (DEQ, 1996.):

$$Pb_{diss}/Pb_{tot} = 3.036 \text{ x } TSS\hat{}^{-0.7846} \qquad \text{(eq. 1)}$$

Monitoring results for municipal and industrial storm water are shown below, along with the results of calculations using equation (1).

Table 6 Monitoring Results for Lead

	Portland MS4	Gresham MS4	Industrial
No. Detects (rate, %)			
Total Lead	118 (99%)	11 (100%)	425 (100%)
Dissolved Lead	79 (66%)	not analyzed	not analyzed
Maximum			
Total Lead	0.290	0.031	7.00[1]
Dissolved Lead	0.100	N/A	N/A
Minimum Concentration			
Total Lead	0.001	0.004	0.001
Dissolved Lead	0.001	N/A	N/A
Mean			
Total Lead	0.048	0.023	0.112
Dissolved Lead	0.005	N/A	N/A
Median			
Total Lead	0.029	0.009	0.023
Dissolved Lead	0.003	N/A	N/A

[1] This value may be an outlier. The next highest value is 2.67 mg/l.

Figure 2 shows the frequency distributions for total Pb data collected by the MS4 and industrial permit holders.

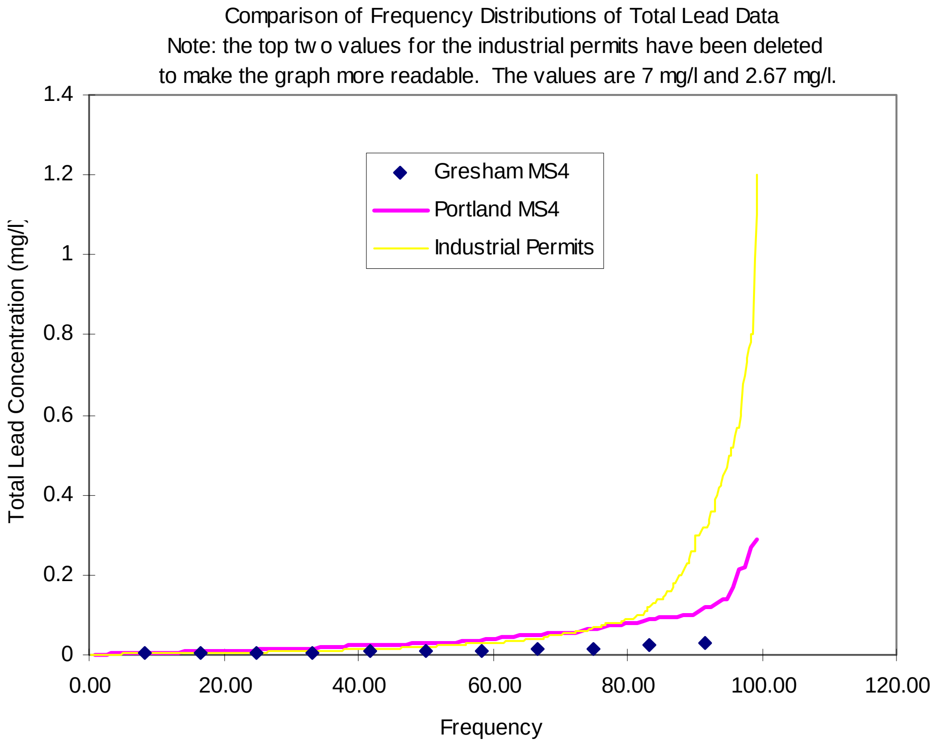


Figure 2 Total Pb frequency distribution

As can be seen from Figure 2, the frequency distributions for the 3 datasets vary markedly. In particular, concentrations associated with industrial permits are significantly higher than concentrations associated with MS4 permits.

Estimate of Annual Lead Load

MS4 Pb load

The MS4 permit applications summarize storm water loading information for a statistically average year. The following table summarizes the estimated annual Pb load to the Columbia Slough.

Table 7 Summary of Total Lead Loads As Estimated in MS4 Annual Reports

Permit Holder	Columbia Slough (lbs/yr)	Entire Permit Area (lbs/yr)	Source of Information
Portland et al	2196 (est.) (996 kg/yr)	4274 (1939 kg/yr)	Annual Compliance Report, Section VIII Monitoring Program, Table 4-7
Gresham et al	298 (135 kg/yr)	1,592 (722 kg/yr)	NPDES MS4 Permit No. 101315 Annual Report, Table 3-8

A specific lead load to the Columbia Slough is not contained in the Annual Report for the Portland MS4 permit, however an estimate was arrived at based on information contained in the permit application. The permit application states that the lead load from the entire permit area is 4,640 lbs/yr, of which 2387 lbs/yr is discharged to the Slough (Table 3-37 of the permit application). In the 1996 Annual Compliance Report, the lead load from the entire permit area was adjusted to 4,274 lbs/yr, a reduction of 8%. This correction yields a total lead load to the Slough from the area covered by the Portland MS4 of 2196 lbs/yr (=92% of 2387 lbs/yr). The lead load is estimated as 298 lb/year in the Gresham permit application. The estimate is based on an event mean concentration of 0.02 mg/l and an annual runoff volume of 5,474 acre-ft per year. Combining the total lead load from both permits, an annual estimate of 2494 lbs/yr (1131 kg/yr) is obtained.

This is very close to the modeled total lead load to the Columbia Slough reported in the Waterbody Assessment, Part II, done by CH2MHill in 1995. The total value obtained from Figures 6-19, 20 and 21 is 2463.5 lbs/yr.

Breakdown by Land Use

The Portland MS4 permit application breaks down the contributions of lead by land use. These results are summarized below. It should be noted that these numbers do not describe the watershed as a whole, since the Portland MS4 only covers about 80% of the total watershed. They also do not reflect the modifications that have been made to the pollutant loading model upon which the MS4 permit application is based. This table is intended to give a general sense of the relative contributions from different land uses.

Table 8 Lead Loads Associated with Various Land Uses for the Portland MS4 Permit Area Draining to the Columbia Slough

Land Use Category	Area (acres)	% of Total	Lead Load (lbs/yr)	% of Total
Residential (light)	1541.5	9	124.1	5
Residential (heavy)	171.8	1	22	1
Industrial	2322.6	14	724.8	30
Commercial	2827.7	17	1370.2	58
Parks & Open Space	2303.5	14	7.6	0
Vacant	7220.3	43	24	1
Traffic Corridor	379.5	3	110.4	5
totals:	16766.9	100	2383.1	100

Source: Portland MS4 permit application, Tables B-1 and C-1.

Industrial Pb Load

The contribution of lead from permitted industrial sites can be calculated using the following equation (EPA 1992):

Area x Annual Rainfall x Runoff Coefficient x Pollutant Concentration = Annual Pollutant Load

The annual rainfall for the watershed is given in Table 3-12 of the Portland MS4 permit application as 34.3 inches per year, and the runoff coefficient for industrial areas is given in Table 3-13 as 0.68.

A search of the files for general storm water permits resulted in areas for 52 of the sites. If the permit area associated with the Port of Portland is excluded because the Port of Portland is a co-applicant of the Portland MS4 permit, the total area associated with industrial permits, not counting those issued for construction projects, is 977 acres. This calculation assumes that the area represents 100% of the facilities that require industrial storm water permits.

The pollutant load associated with the areas that are currently covered by general industrial permits can be estimated using an event mean concentration for industrial areas. The mean pollutant concentration reported in Table 3-14 of the Portland MS4 permit application is 0.059 mg/l. The Gresham MS4 permit application contains monitoring results from a residential area and an area that is half industrial and half residential, and these suggest that the concentration associated with industrial areas is

0.06 mg/l. For this phase of the TMDL process, a value of 0.06 mg/l will be used to approximate the concentration of lead found in runoff from industrial areas.

Using the above estimates, the annual lead load associated with the permitted industrial area can be calculated as follows:

977 acres x 34.3 inches/yr x 0.68 x 0.06 mg/l total Pb

x 43560 sq. ft/acre x 1 ft/12 in x 28.317 l/cu ft x 1 kg/10^6 mg = 141 kg/yr

Storm water Organics Data

Monitoring for the 303(d) organics has been conducted primarily by the DMAs for the MS4 permits and the St. John's landfill closure. There are currently no non storm water discharges of 303(d) organics from industrial sources to the Slough. Monitoring under industrial storm water permits focuses primarily on metals, so no data are available from these permittees for organic pollutants. Monitoring under the municipal permits is more extensive.

Under the Gresham MS4 permit, testing for DDD, DDE, DDT, dieldrin and PCBs is limited to one storm event during which samples were collected at 4 different locations. Dioxin was not monitored. There were no detects of these pollutants[1] (City of Gresham, May 1993). Monitoring for the Portland MS4 permit includes 28 samples, with 5 samples above the detection limit. All analyses had detection limits above the OAR Table 20 criteria. Results are presented below:

Table 9: Detects of 303(d) Organics in Storm water

Parameter	Land Use	Concentration (det. limit) mg/l
4,4'-DDT	Residential	0.09 (0.07)
4,4'-DDT	Mixed	0.7 (0.4)
4,4'-DDE	Residential	0.04 (0.04)
4,4'-DDE	Mixed	0.15 (0.1)
dieldrin	Mixed	0.1 (0.1)

There have so far been no detects of PCBs in storm water monitored under the Portland MS4 permit. The detection limits for PCBs ranged from 0.3 to 3.0 ug/L.

As part of the Columbia Slough Sediment Remediation Project, additional monitoring has been conducted in storm water pipes draining to Buffalo Slough. Sampling occurred during dry event and storm event. The dry event sediment samples were collected in mid summer when no storm water flows were present. Sediment

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[1] detection limits were: DDD = 1.0 ug/L, DDE = 0.5 ug/L, DDT = 0.5 ug/L, dieldrin = 0.5 ug/L, Aroclor 1221 = 3.0 ug/L, all other aroclor = 1.0 ug/L

sample SW-3 was collected and composited from the two storm water catch basins that discharge into the storm water pipe. These results are summarized in Table 10.

Table 10: **Dry Weather Sediment Sampling Results (ug/kg)[2] (BES, May 1997)**

Parameter	SW-3
dieldrin	2.92 (.10)
DDE	14.20 (.08)
DDD	ND (.07)
DDT	ND (.11)
PCBs	35.40 (6.84)

The storm water samples were collected in October when conditions met the requirements of a representative storm (BES, May 1997). These samples were collected in manholes (SW-1, SW-2 and SW-6) or a catch basin (SW-3) above the outfalls. There was no receiving water inflow in these samples (Chris Prescott, BES, personal communication, 1998). Detection limits for storm water were on the order of 1 ng/l. Typical detection limits for storm water are 1000 to 10,000 ng/l. These results are summarized below.

Table 11: **Storm Water Sampling Results (ng/L) (BES, May 1997)[3]**

Parameter	SW-1	SW-2	SW-3	SW-6
dieldrin	ND (.51)	ND (.54)	2.32 (.5)	ND
DDE	ND (.44)	1.17 (.46)	5.60 (.42)	ND
DDD	1.93 (1.23)	ND (1.3)	3.62 (1.19)	ND
DDT	1.28 (.94)	12.89 (.99)	24.05 (.91)	ND
PCBs	ND (1.96-3.92)	ND (.82-4.13)	ND (.79-3.79)	ND

The storm water data indicates that storm water is a source of pesticides. Results from the dry weather sediment sample at SW-3 indicate that sediment associated with storm water is contributing PCBs to the Buffalo Slough as well as dieldrin and DDE. Additional monitoring will be conducted by the City of Portland to verify this conclusion. Fugacity modeling has been conducted using the results of the Buffalo Slough monitoring. The fugacity model is a compartment model and contaminants are assumed to be in compartments that represent areas of the environment, such as surface water, algae or fish tissue. The results of this modeling indicate that storm water sediment is the likely source of contamination of fish tissue. Without storm water control any remediation may not be effective. However, this modeling was based on one sample result and additional modeling will be conducted when additional storm water samples are collected.

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[2] Detection limit in parentheses

[3] PCB data has a range of detection limits depending on Aroclor analyzed, SW-6 detection limits not recorded.

Industrial Storm Water Permits - Organics Monitoring

Storm water monitoring for industrial permits focuses primarily on metals, and does not include 303(d) organics.

Summary of Storm water Information

Based on information obtained under the general storm water permits and the MS4 permits issued in the Columbia Slough watershed, the following observations can be made:

- The total lead load to the Columbia Slough is estimated in the MS4 permits to be 1131 kg/yr. Of this, 141 kg/yr is estimated to come from areas covered by industrial permits.

- Sampling for the other parameters found to impair beneficial uses in the Columbia Slough has been infrequent, and so far, only the pesticides have been detected. Current information is insufficient for developing pollutant loads associated with any of the 303(d) organics. With lower detection limits, it may be possible to develop pollutant loads.

Groundwater

Several of the 303(d) parameters are hydrophobic, which means they tend to adsorb strongly to soil particles and are comparatively less likely to be found in groundwater. DDT, PCBs and dioxin are all considered to be hydrophobic. This characteristic is expressed quantitatively in terms of the retardation factor. In a report “Characterization of Subsoil Properties Affecting the Transport of Toxic Metals, Ammonia, and Hydrophobic Organic Compounds at the St. Johns Landfill Site” (Fish, 1994), Dr. William Fish states:

> “Calculated retardation factors for selected priority-pollutant organic compounds range from less than 20 for the more soluble compounds such as toluene or chlorobenzene, to hundreds or even thousands for hydrophobic compounds such as PAHs, PCBs, and dioxins...”

In the same report, Dr. Fish points out that lead will have retardation factors much larger than those observed for nickel and copper, which are typically in the range of 10 to 30.

It should be noted that a high retardation factor does not preclude the possibility of contamination by a hydrophobic substance, it simply reduces the rate at which it will move through soil.

General Characterization

Groundwater to the Slough has been monitored less frequently than storm water, however groundwater quality is also less dynamic than storm water. Information on groundwater quality in the vicinity of the Columbia Slough is available from the city of Portland Water Bureau. Monitoring has also been performed by DEQ and USGS on a more limited basis. Information on groundwater in the vicinity of contaminated sites is also available, and is available through DEQ's Environmental Cleanup Site Information (ECSI) database. This information is summarized in the following sections.

Monitoring Well Results

The City of Portland Water Bureau maintains 8 monitoring wells in the vicinity of the Columbia Slough. These wells are located in the Troutdale Sand and Gravel Aquifer (TSA) which is the source of groundwater to the Columbia Slough. Of the 303(d) parameters, only total lead is currently monitored.

A total of 57 total lead samples were collected in these wells from 1984 through 1996, with between 2 and 11 samples collected at each site. The detection limit was 0.001 mg/l, and lead was detected in 8 of the 57 samples. Of these 8 values, 5 were at the detection limit, 1 value was equal to 0.002 mg/l and 2 values were equal to 0.003 mg/l. According to Cathy Casson of the Water Bureau, lead is generally only detected when the pumps are first started and may be the result of leaching from the pumps

In 1991, DEQ collected data from 14 wells located in East Multnomah County in the vicinity of Fairview Lake. The detection limits ranged from 5 ug/l to 7 ug/l. The results are summarized below.

Table 12 Summary of DEQ Well Monitoring Data

Parameter	No. of Samples	No. of Detects
Total Lead	5	1 (=5 ug/l)
Dissolved Lead	20	0
Dieldrin	27	0
DDT	27	0
DDE	27	0
DDD	27	0

The lack of detects may reflect the relatively high detection limits associated with this sampling effort.

On 7/27/95, the USGS collected samples from five wells in parks along N. Columbia Blvd. from about N. Portland Rd. to NE 33rd Drive (Nancy Hendrickson, BES, pers. comm.). The results for dissolved lead, DDE and Dieldrin showed no detects. The detection limits were 1 ug/l, 6 ng/l and 1 ng/l respectively. These detection limits are unusually low, and are well below the chronic criteria for these chemicals. No tests were done for dioxin or PCBs.

Pollutant Loading Estimates

Loading estimates for total lead can be developed from the data collected by the USGS. Using values set at ½ the detection limit, the dissolved lead concentration is 0.5 ug/L.

In Part II of the Waterbody Assessment, the annual flow of groundwater to the Columbia Slough is estimated to be 1.86x 10^9 cu ft/yr. The annual rate of dissolved lead loading is calculated as follows:

$$(0.5\text{ug/l}) \times (1.86\text{x } 10^9 \text{ cu ft/yr}) \times (28.317 \text{ l/cu ft}) \times (1 \text{ kg}/10^6 \text{ mg}) \times (1\text{mg}/10^3\text{ug}) = 26 \text{ kg/yr or } 0.07 \text{ kg/day.}$$

Contaminated Sites

As of August 28, 1996, there were 106 sites listed in DEQ's Environmental Cleanup Site Information System (ECSI) for the Columbia Slough study area. In addition to sites from which a release of hazardous materials has been confirmed, this list also contains sites that have since been found to not pose a risk to groundwater or surface water, as well as sites that have been cleaned up. It also contains sites that upon closer examination turn out to not drain to the Columbia Slough. In other words, not all 106 sites in ECSI are likely to impact water quality in the Columbia Slough.

The following tables contain the sites listed in the database that have indications of the presence of a 303(d) parameter. The status line describes the present status of the site, i.e. the site actually drains to the Columbia River, or data review indicated insufficient information to develop a load estimate at this time, etc.

PCBs					
COMMON NAME	**ADDRESS**	**NAME**	**MEDIUM**	**Possible Data**	**STATUS**
Oregon Waste Systems - Proposed Transfer Station	11535 N Force ST	PCB 1221	GW	10.8 ppm	drains to Columbia River
Portland (City of) - Columbia BLVD POTW	5001 N Columbia BLVD	PCB 1254	OT	50.27 ppm	does not drain to Slough
Columbia Slough	31.5 miles of waterway	PCBs	SE	520 ppb (LS)	load developed and sediment
					partitioning allocation in TMDL
Columbia Slough Consolidation Conduit		PCBs	SL		this site is not an active cleanup site, DEQ has been workin
					with the City of Portland to characterize any areas of
					contamination along the alignment so that the media can b
					properly managed during construction.
Lamm Property - Site 2	4065 N Suttle RD	PCBs	SL	10 ppm and less	drains to Columbia River
Malarkey Roofing Co.	3131 N Columbia BLVD	PCB 1242	SL	7.2 ppm	site remediated in 1989 and 1990
Morrison Oil Co.	3747 N Suttle RD	PCBs	SL	7 ppm	drains to Oregon Slough
General Electric Industrial Co.	2410 N Columbia BLVD	PCB 1221	SL	1 to 5 ppm	PCB levels lower than cleanup action level of 0.7 mg/kg
					(OARS 340-122-045) (average PCB 1254 =.28 mg/kg,
					PCB 1260 0.19 mg/kg data from 7/19/96)
Schnitzer Property - N Kerby AVE	8520 N Kerby AVE	PCB 1221	SL	0.8 ppm	PCB from soil sample taken from 2 feet below surface,
					below asphalt so no surface runoff contamination possible,
					no groundwater samples were taken, no load calculated
NW Cast/Universal Silver	9233 N Calvert Ave.	PCB	SL		
Nu-Way Oil Co.	7039 NE 46th AVE	PCB 1242	SL	0.7 ppm	load and allocation in TMDL
Nu-Way Oil Co.	7039 NE 46th AVE	PCB 1260	SL	1.5 ppm	load and allocation in TMDL
N Marine DR Extension - North Portland	N Marine DR	PCBs	SL		drains to Columbia River
Pacific Meat Co.	2701 N Newark St	PCB	SE/SL		
medium codes:					
GW = groundwater					
OT = other (sludge)					
SE= instream sediment					
SL = soil					

DDT, p,p'-

COMMON NAME	ADDRESS	MEDIUM	Possible Data	STATUS
Rhone-Poulenc - N Marine DR	4429 N Suttle RD	GW	up to 88 ppb	does not drain to Columbia Slough
Rhone-Poulenc - N Marine DR	4429 N Suttle RD	SE	up to 1,200 ppb	does not drain to Columbia Slough
Rhone-Poulenc - N Marine DR	4429 N Suttle RD	SL	up to 3,100,000 ppb	does not drain to Columbia Slough

Dieldrin

COMMON NAME	ADDRESS	MEDIUM	Possible Data	STATUS
Rhone-Poulenc - N Marine DR	4429 N Suttle RD	SL	up to 100,000 ppb	does not drain to Columbia Slough
Rhone-Poulenc - N Marine DR	4429 N Suttle RD	GW	up to 1.9 ppb	does not drain to Columbia Slough

medium codes:
GW = groundwater
OT = other (sludge)
SE= instream sediment
SL = soil

Lead				
COMMON NAME	**ADDRESS**	**MEDIUM**	**Possible Data**	**STATUS**
Oregon Waste Systems - Proposed Transfer Station	11535 N Force ST	GW	1.2 - 41 ug/L	drains to Columbia River
St. John's Landfill	9363 N Columbia BLVD	GW	4.4 ppm	load developed and allocation in TMDL
Oregon National Guard - PDX Airport #1	Southwest portion of airport	GW	2.175 ppm	in 1989 no metals were detected at levels
				above regulatory thresholds, site under review by DEQ
DeWitt Construction	10910 NE Holman ST	GW	1.08 PPM	data from an unfiltered, turbid groundwater sample.
				Filtered sample was a non detect
				with a detection limit of 0.002 mg/L
Nu-Way Oil Co.	7039 NE 46th AVE	GW	0.033 ppm	load developed and allocation in TMDL
Schnitzer Property - N Kerby AVE	8520 N Kerby AVE	GW	.006 ppm	groundwater Pb level lower than drinking
				water standard, no load calculated
St. John's Landfill	9363 N Columbia BLVD	OT	10.2 ppm	landfill leachate
Nu-Way Oil Co.	7039 NE 46th AVE	SE	up to 20,500 ppm (est)	this data from lagoon, which has since been remediated
				load developed and allocation in TMDL
				using data from 8/12/97 for other sections of site
				with exposed soil
JB's Quality Metal Inc.	7715 NE 21st AVE	SE	54-1500 ppm	1500 ppm sample from soils removed
				in 1992/1993, currently has no further
				action status in cleanup program
Columbia Slough	31.5 miles of waterway	SE	510 ppm (LS)	load developed and sediment
				partitioning allocation in TMDL
DeWitt Construction	10910 NE Holman ST	SL	188 ppm	Pb present at background levels, no load calculated
Fernley Tire Fire	5411 NE Portland Hwy	SL	240 ppm	Pb present at background soil levels, no load calculated
Flightcraft	7505 NE Airport WAY	SL	1.6 mg/l	5/94 data showed no groundwater contamination
Holman Redevelopment Area - Parcel 249	10835 NE Holman ST	SL	3,140 ppm	site remediated in 1992, no further
				action recommended by clean up staff
Lamm 1	4101 N Suttle RD	SL	414 ppm	drains to Columbia River
Lamm Property - Site 2	4065 N Suttle RD	SL	93 ppm (in a composite	drains to Columbia River
			of 4 surface samples)	
Malarkey Roofing Co.	3131 N Columbia BLVD	SL	1500 ppm	site remediated in 1989 and 1990
Mt. Hood Metals	9645 N Columbia Blvd	GW/OT		active voluntary clean up project
Morrison Oil Co.	3747 N Suttle RD	SL	30 ppm	drains to Oregon Slough
Oregon National Guard - PDX Airport #1	Southwest portion of airport	SL	46 ppm	Pb present at background soil levels, no load calculated,
				site under review by DEQ
Oregon Waste Systems - Proposed Transfer Station	11535 N Force ST	SL	3.5 - 235 mg/kg	drains to Columbia River
Pacific Meat Co.	2701 N Newark St	SE		
Redi-Strip of Oregon	9940 N Vancouver WAY	SL	25 ppm EP Tox.	data to date has been EP toxicity, so no load developed
				in site response program, sampling will
				occur by Spring 1998, including sampling
				of drainage ditches and groundwater
Schnitzer Property - N Kerby AVE	8520 N Kerby AVE	SL	290 ppm	Pb present at background soil levels, no load calculated
medium codes:				
GW = groundwater				
OT = other				
SE= instream sediment				
SL = soil				

Where sufficient data was available to develop a load and allocation, such estimates were completed. The calculations for these sites follow.

The NuWay Oil site has been found to have the highest concentration of both lead and PCBs reported for any site in the Slough watershed. The maximum detected PCB soil concentration is 29 mg/kg (data from Bill Dana, DEQ, 9/8/97). The average concentration of Pb in the process area of the site is 1532 mg/kg (data from Bill Dana, DEQ, 9/8/97).

NuWay Oil Site

NuWay Oil Groundwater Load

The NuWay Oil site is located immediately adjacent to the Whitaker Slough immediately upstream of the confluence with the mainstem. In order to estimate pollutant loading associated with groundwater from this site, it is first necessary to establish groundwater velocity. This can be calculated from Darcy's Law (Todd, 1980), which is as follows:

$$v = K * (dh/dL)$$

where v = velocity
K = hydraulic conductivity
dh/dL = hydraulic gradient

The hydraulic gradient was calculated from on-site well information (NuWay) to be 3×10^{-4} ft/ft. The hydraulic conductivity is a function of soil type. The site was found to have soils that were a mixture of sand, silt and clay. The hydraulic conductivity of such soils is typically 10^{-2} to 10^{-3} m/day (Mavis Kent, DEQ, pers. comm.). If the higher value is used in order to be conservative, the result is:

$$\begin{aligned} v &= (10^{-2} \text{ m/day}) * (1\text{ft} / 0.3048\text{m}) * (3 \times 10^{-4} \text{ ft/ft}) \\ &= 9.84 \times 10^{-6} \text{ ft/day} \end{aligned}$$

The rate of groundwater flow from the site can be calculated as follows:

$$Q = v * \text{length of site along the Slough} * \text{depth}$$

The length of the NuWay site along the Whitaker Slough is about 400 ft. If the contamination is assumed to run the entire length of the site and to extend to a depth of 20 ft., then the rate of groundwater flow from this volume of soil will be:

$$\begin{aligned} Q &= (9.84 \times 10^{-6} \text{ ft/day}) \times (400 \text{ ft.}) \times (20 \text{ ft.}) \\ &= 0.08 \text{ cu ft/day} \end{aligned}$$

Groundwater data from April/May 1997, July 1997 and November 1997 was used to obtain an estimate of the groundwater load of Pb and PCBs to the Slough. Five Pb samples were taken during this time and had two non detects (at detection limits of 0.1 mg/L and 0.005 mg/L, respectively) and three detects at 12.2 ug/L, 15 ug/L and 18.6 ug/L. With the non detects set at ½ the detection limit, the average Pb concentration is 0.02 mg/L.

Using the average groundwater concentration, the loading rate is calculated as follows:

Lead loading rate = (0.08 cu ft/day) x (0.02 mg/l) x (28.317 l/cu ft) x (1 kg/10^6 mg)= 4.53 x 10^{-8} kg/day or 1.65 x 10^{-5} kg/yr total Pb

PCB data from the same time period were non detects at a detection limit of 0.0001-0.0003 mg/L. Using ½ the detection limit of 0.00015 mg/L, the annual loading rate is 3.4x 10^{-10} kg/day or 1.24 x 10^{-7} kg/year. Retardation factors have not been included in either of these calculations.

From this analysis, it appears that the loading rate of lead and PCBs from NuWay Oil to the Columbia Slough via groundwater is not large, even if retardation factors are not taken into account. Yet contamination levels at this site, particularly with respect to lead; are very high.

NuWay Oil Storm water Load

The NuWay Oil Site can be divided into two sections; the lagoon area and the process area. The lagoon area has been excavated and capped. The process area is scheduled for remediation, which may include soil excavation. There is also an area around the lagoon, which has been sampled and is covered with gravel. Annual Pb loads from surface erosion from both the process area and the area around the capped lagoon (non process areas) can be estimated with the Universal Soil Loss Equation (USLE) and the measured Pb soil levels.

Using the Universal Soil Loss Equation, the soil loss from the site is calculated as follows (EPA, 1985):
$X = 1.29\, E(K)(1s)C(P)$
where:
X = average annual soil loss by sheet and rill erosion in t/ha
E = rainfall/runoff erosivity index (102 m-tonne-cm/ha-hr), from map of average annual erosivity indices (pg.163)
K = soil erodibility (t/ha per unit of E), table of erodibility per soil type (pg. 165)
1s = topographic factor
C = cover management factor, table of C factors for a construction site (pg.168)
P = supporting practice factor, table (pg. 172)
The topographic factor, 1s, is calculated as follows (EPA, 1985):
$1s = (0.045x)^b(65.41\sin^2\theta + 4.56\sin\theta + 0.065)$
The slope angle is obtained from percent slope, s by:
$\theta = \tan^{-1}(s/100)$
(percent slope estimates from Ken Cameron, DEQ, personal communication)

The annual watershed solid phase chemical load in rural runoff (kg/yr) is then calculated by:
Ls = .001(Sd)(Cs)(X)(A)
where:
Sd is the sediment delivery ratio and is a function of the drainage area = 0.35 (pg. 178)
Cs is the solid phase chemical concentration in sediment = average of 1073 mg/kg for non process area and 1532 mg/kg for process area (Bill Dana, DEQ, personal communication)
X is the soil loss from the eroded area, calculated using the USLE
A is the acreage of the eroded area = 30,000 ft^2 $=^{=}$ 0.28 ha (Ken Cameron, DEQ, personal communication)

The following table summarizes the input parameters and the annual Pb load from the process and non process areas:

Table 13	**E**	**K**	**s**	**1s**	**C**	**P**	**X**	**Cs**	**A**	**Sd**	**Ls**
process	86.75	.16	2%	0.1628	1	1	2.916	1532	0.28	.35	.438
non-process	86.75	.16	0%	0.058	0.05	1	0.519	1073	0.28	.35	.005

The USLE predicts soil loss from sheet and rill erosion, but does not predict erosion from gullies, streambanks or landslides. (Vesilind, 1982).

An estimate of the PCB load from the NuWay Oil Site can also be calculated using the USLE. Using average Aroclor 1260 concentrations for the process area of 3.74 mg/kg and non process area of 1.65 mg/kg (Bill Dana, DEQ, personal communication), an estimate of the PCB load can be made. Only Aroclor 1260 data was used as the other PCBs were present at detection levels. The Aroclor 1260 loads are then 8.4 x 10^{-6} kg/yr and 1.1 x 10^{-3} kg/yr, for the non process and process areas, respectively.

Nu Way Oil Sediment Partitioning

Current erosion estimates may not reflect previous loads, as much of the site has been excavated, regraded and covered with gravel. Instream sediment Pb levels are high (BES memo to DEQ, 9/11/97) and may continue to contribute to violations of the Pb criteria due to sediment partitioning. In the SLRA (Parametrix, 1995), sediment flux from contaminated sediment was estimated. The maximum estimated sediment flux value for Pb (5.5 x 10^{-4} mg/L, Parametrix 1995) was obtained for a sample from Whitaker Slough. Using this value, an estimate of the annual load to Whitaker Slough is possible.
The SLRA (Parametrix, 1995) estimates the average flow of Whitaker Slough to be 55 ft^3/sec or 1.74 x 10^9 ft^3/yr.

(5.5 x 10^{-4} mg/l) x (1.74 x 10^9 cu ft/yr) x (28.317 l/cu ft) x (1 kg/10^6 mg) = 27.1 kg/yr

St. Johns Landfill

Priority pollutants are monitored yearly at 9 wells around the St. Johns Landfill. Some of the nine wells sampled may change year to year. Results of this monitoring, since October 1993, are summarized below (Paul Vandenburg, METRO, pers. comm.):

- Lead - the average concentration of total lead found in monitoring wells is 0.0183 mg/l (Metro 1995 and Dennis O'Neill, pers. comm.):
- PCBs - have not been detected in any of 36 samples that have been tested for each of the seven Aroclor (PCB) classes (detection limit was 0.5 ug/L for Aroclors other than 1221, Aroclor 1221 had a detection limit of 2 ug/L, Table 20 PCB criteria = 0.079 ng/L)).[4]
- DDT, DDE and DDD - none of these compounds have been detected in any of the 36 samples tested since October 1993 (detection limit for DDT was 0.1 ug/L, DDE detection limit was 0.04 ug/L, DDD detection limit was 0.05 ug/L, Table 20 DDT criteria = 0.024 ng/L).
- Dieldrin -no dieldrin has been detected in any of 36 samples tested since October 1993 (detection limit was 0.04 ug/L, Table 20 criteria = 0.071 ng/L).
- Dioxin - No well samples have been taken for dioxin. Fish samples taken from the reach of the Slough near the landfill showed levels of dioxin comparable to levels in fish taken from other parts of the Slough and the Columbia and Willamette Rivers. This indicates that there is no local source of dioxin in the area of the landfill. (Parametrix, July 1995) (Table 20 dioxin criteria = 1.3 x 10^{-5} ng/L).

The lack of detects with respect to PCBs, DDT and dieldrin in the St. Johns Landfill monitoring wells should not be taken as evidence that they are not present at the site. The low detection frequency is more likely to be reflective of the tendency of these parameters to adsorb onto sediment particles. This reduces the rate at which they are likely to leave the site. Initial results of modeling conducted as part of landfill closure indicate that with the cap installed, pollutant loads from St. Johns Landfill are negligible. Additional work is currently being conducted by the DEQ solid waste program to verify the assumptions of the model and the accuracy of the predictions.

Annual Pb load:
The lateral flow rate is estimated to be 0.05 to 0.08 cfs.

0.08 ft^3/sec X 0.0183 mg/L Pb X 28.317 L/ft^3 X (1kg/10^6 mg) X (60 sec/1 min) X (60 min/hr) X (24 hr/day) = 3.6 x 10^{-3} kg/day = 1.31 kg/yr of lead to the Slough from the St. Johns Landfill.

Riedel Site

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[4] Aroclor 1221 detection limit changed to 0.4 ug/L in August 1995, for all other Aroclors the detection limit changed to 0.1 ug/L in August 1995.

DEQ performed limited monitoring from 1989 to 1993 at 7 different locations on the Nashpit landfill. This landfill was closed in 1991, and is now known as the Riedel site. Results of monitoring are shown below.

Table 14 Summary of Monitoring at Nashpit Landfill (Riedel)

Parameter	No. of Samples	No. of Detects	Concentrations (mg/l)
Total Lead	10	3	0.011 to 0.018
Dissolved Lead	33	0	NA
DDT, DDE, DDD	4	0	NA
Dieldrin	4	1	0.006

As indicated in the table, lead (total) and dieldrin have all been detected at the Riedel site. The sample found to contain these pollutants was collected in the landfill leachate sump. Leachate from this sump is directed to the Columbia Blvd. treatment plant and is highly unlikely to impact the Slough. The source of the dieldrin may not be the landfill itself, but rather the site located next to the landfill which was formerly a pesticide storing or manufacturing facility (Tim Spencer, DEQ, pers. comm.).

Lead levels appear to be higher than those associated with groundwater samples collected from the city groundwater monitoring wells but it is not clear at this time whether or not levels seen are due to contamination at the landfill.

To summarize the information available on the Riedel site, at this time it appears that the landfill is associated with higher than usual levels of lead and that dieldrin may be associated with this site. There is insufficient information with which to estimate pollutant loads to the Slough.

Sediment Partitioning

Sediments within the Columbia Slough can also be a source of pollutants because some of the pollutants can enter the water column via partitioning. Predictions of water column concentrations of various pollutants have been developed (SLRA 2/95, Chris Prescott, BES, pers. comm.). Interstitial water concentrations of the organic chemicals were predicted based on the theory that organic chemicals tend to preferentially bind to the organic carbon fraction of sediment, where an assumed equilibrium concentration is achieved between the sediment organic carbon and interstitial water concentration over time. The organic carbon normalized partition coefficient (Koc) was used to estimate the organic constituent concentration in the sediment interstitial water. Surface water concentrations were calculated based on the flux of organic constituents from the interstitial water to the surface water. (SLRA, 2/95, Appendix D). By multiplying the surface water concentrations by the annual flow through the Columbia Slough, overall mass loads can be developed.

The Waterbody Assessment (CH2MHill, 1995) gives the total annual flow to the Columbia Slough, not counting tidal inflow from the Willamette, as 1.48 x 10^8 m^3/yr. Water column concentrations are calculated as follows:

> total annual inflow (m^3 /yr) x predicted median water column concentrations (mg/L) x (1000 L/1 m^3) x (1 kg/10^6 mg)) = pollutant load (kg/yr)

Predicted median water column concentrations and associated pollutant loads are listed below.

Table 15 Predicted Median Water Column Concentrations and Pollutant Loads

Parameter	Predicted Median Water Column Conc. (mg/l)	Pollutant Load kg/yr
DDT	4.87 x 10^{-13}	
DDE	7.17 x 10^{-13}	
DDD	1.2 x 10^{-12}	
total value:	2.4 x 10^{-12}	3.55 x 10^{-7}
Dieldrin	2.67 x 10^{-11}	3.95 x 10^{-6}
Dioxin	no value available[1]	
PCB Aroclors		
Aroclor 1016	9.1 x 10^{-11}	
Aroclor 1221	1.14 x 10^{-10}	
Aroclor 1232	5.14 x 10^{-11}	
Aroclor 1248	4.08 x 10^{-11}	
Aroclor 1254	4.76 x 10^{-12}	
Aroclor 1260	9.59 x 10^{-11}	
Aroclor total :	3.98 x 10^{-10}	1 x 10^{-4}
Lead	2.056 X 10^{-7}	0.030

[1] Sediments have not been tested for dioxin.

Due to the toxicity and bioaccumulation of these chemicals, a low instream concentration causes fish tissue concentrations to exceed consumption advisory levels.

Air Deposition

Of the toxic parameters for which the Slough is listed, only lead and dioxins are associated with current as well as past air emissions. Other parameters were associated to some extent with past emissions. Specifically, DDT and dieldrin were manufactured by Rhone-Poulenc on North Marine Drive until the early 1970s. PCB releases were likely associated with the burning of PCB-contaminated waste oil, prior to the phasing out of this method of disposal in the 1970s.

Dioxin Sources:
Of the activities and industries that could result in air emissions of dioxin, the EPA currently only requires monitoring of pulp and paper industries. Though there are pulp and paper plants located on the Columbia River, there are no such industries located along the Columbia Slough. The nearest facility to the Columbia Slough would be the James River facility in Camas, Washington. It would be difficult to translate an air emission in Camas to a loading rates to the Columbia Slough because of the multiple transport mechanisms.

Lead Sources:
Though the airshed for the Columbia Slough is not as well -defined as the watershed, for the purposes of this discussion it will be assumed that the industries and activities most likely to impact the Slough are those located within Multnomah County. The industries covered by the Department's ACPD (Air Contaminant Discharge Permit) that are likely to emit lead include the following:

- metal casting (foundry operations)
- battery manufacturing
- battery recycling
- metals recycling

The current Source List maintained by DEQ's Air Quality Division lists 16 companies located in Multnomah County as falling into one of these categories. A search of the Air Quality Division permit files revealed that most of these companies either no longer exist or no longer engage in an activity associated with lead emissions. The companies that are currently discharging are all metal casting/foundry operations, and they are listed in Table 23. Only Columbia Steel Casting and Oregon Steel Mills are actually located within the Columbia Slough watershed. The ESCO plants are included because of the possibility that air emissions from these plants may migrate into the Columbia Slough watershed.

Table 16 List of Companies with Lead Air Emissions

AQ File No.	Name	Address	Process Type	Est. Lead Emissions [1]
26-1869	Columbia Steel Casting	10425 N. Bloss	Steel Foundry	<1200
26-2067	ESCO, Plant 3	2211 NW Brewer	Steel Foundry	<1200
26-2068	ESCO, Plant 1	2141 NW 25th Avenue	Steel Foundry	<1200
26-1865	Oregon Steel Mills	14400 N Rivergate Blvd.	Steel Foundry	<2200

[1] Units are lbs/yr. Values were reported as tons per year, but have been converted.

Of the four companies listed, only Oregon Steel has provided an actual estimate of lead emissions to DEQ. The values provided for the other discharges are based on the significant emission rate for lead from foundries, which has been estimated by EPA to be less than 1200 lbs/yr.

The reason there is comparatively little information on lead emissions associated with these facilities is that lead is not considered by the EPA to be a pollutant of significance for metal casting operations and so it has not provided an emission factor for lead for metal casting operations. Since DEQ only requires monitoring for parameters for which EPA provides emission factors, no monitoring data is available for most of the foundries listed above.

Oregon Steel:

DEQ has information on lead emissions from Oregon Steel because it is large enough to be required to apply for a permit under Title V. Title V came into effect under the Clean Air Act Amendments enacted in 1990. Title V sources are those that discharge more than 100 tons/yr of the criteria pollutants, or more than 10 tons/yr of a particular criteria pollutant, or more than 25 tons/yr total of more than one criteria pollutant. Lead is a criteria pollutant. Title V sources are required to quantify all emissions of criteria pollutants in excess of 0.6 tons/yr.

Oregon Steel applied for a permit in 1995. Their permit application states that they currently emit 2200 lbs/yr of lead. They have asked to be permitted to discharge 4600 lbs/year.

The plant is located on the Willamette River approximately 1.5 miles from the mouth of the Columbia Slough. An estimate of the annual Pb load to the Columbia Slough watershed can be made by calculating the load due to dry and wet deposition of emitted particulates. Particulates, if sufficiently large, will be removed from the air by simple settling due to gravity (dry deposition). The settling velocity can be calculated using Stoke's law. Due to turbulence in the atmosphere, particles less than 20 *u*m will seldom settle out by gravity (Vesilind et al, 1982). Pollutants may also be removed from the air by precipitation (wet deposition); rain falls through the air and the air pollutants dissolve in the rain droplets.

Wet deposition may be estimated by the following equation: (EPA 1985)

L = 10 C*P*A
where:
L = load of the pollutant delivered to the receptor area as wet deposition (mass/sec)
C = concentration of pollutant in precipitation (mass/liter)
P = precipitation rate (cm/sec)
A = projected receptor area (m^2)
10 = conversion factor

Quarterly emission reports provided by Oregon Steel were reviewed for input data (1993-1996). The report contained the emission rate of Pb in lb/hr. The outlet flowrate from the stack was reported as cubic foot/minute (standard, dry). The concentration (g/L) of Pb in the emission was calculated as emission rate divided by flow rate:
(lb/hr)(1hr/60 min)(min/ft^3)(35.3 ft^3/m^3)(454 gr/lb)(1m^3/1000L) = g/L

The precipitation was calculated as the annual average precipitation for the period of 1987-1997. The projected receptor area was the Columbia Slough drainage basin, 40, 000 acres. Using the EPA equation, the annual Pb load from wet deposition was calculated as:
90% = 10.6 kg/yr
50% = 4.4 kg/yr
10% = 0.99 kg/yr
The percentile range was calculated with the varying flow rates and Pb emission concentrations as reported in the quarterly emissions reports.

Using the 50% annual estimate, an estimate of the quantity of Pb that would land on the Columbia Slough water surface may be calculated. This calculation assumes that Pb that is not deposited on the Slough surface water is deposited on land and accounted for in the storm water load. As stated above, the Slough drainage basin is 40,000 acres. An estimate of the Columbia Slough surface area is contained in a memo from Scott Wells to the City of Portland (September 27, 1995). At approximately 6 feet water level, the surface area is estimated as 0.51×10^6 m^2.
The relative area of surface water to drainage basin is calculated as follows:
Surface water: 0.51×10^6 m^2
Drainage basin: 40,000 acres X 43560 ft^2/acre X 1 m^2/10.76 ft^2 = 1.62×10^8 m^2
Ratio = 0.51×10^6 m^2/ 1.62×10^8 m^2 = 0.0031

The annual wet deposition to the surface of the Columbia Slough is 4.4 kg/yr x 0.0031= 0.014 kg/yr

The wet deposition equation was used with the following assumptions:
1. The concentration of Pb emitted from the stack is the concentration of Pb in the precipitation, i.e. 100% of the Pb emitted goes to the precipitation.
2. No gradient in the precipitation concentration is assumed.
3. The airshed actually covered by the plume was not calculated, therefore all the Pb emitted may not fall within the Columbia Slough watershed.
4. The emission of the Pb is constant.
5. The average annual precipitation was used, there may be peak loading periods.

Dry deposition may also be calculated for this source using the following equation (EPA 1985):
$L = V_d * C_p * A * f$
where:
L = load of the pollutant delivered to the receptor surface as dry deposition (mass/sec)
V_d = settling velocity (m/sec)
C_p = concentration of atmospheric particulates (mass/m3)
A = projected receptor area (m2)
f = fraction (by mass) of the pollutant in the particulates

Settling velocity, V_d, is calculated using Stoke's law:
$V_d = g(ad)^2(\rho - \rho_a) /18 u$
where:
V_d = settling velocity (cm/sec)
g =acceleration of gravity, 981.46 (cm/sec^2)
d = particle diameter (micro meters)
ρ = particle density (~ 2 g/cm^2)
ρ_a = density of air (0.001243 g/cm^3 at 10C)
u = viscosity of air (0.000177 g/cm-sec at 10C)

The particle diameters are <10 *u*m, likely 2 *u*m (Greg Grunow, DEQ, personal communication). Using these diameters, the settling velocity varied from 1.93 E -12 m/sec (10 *u*m) to 7.71 E-14 m/sec (2 *u*m). Using these settling velocities, the concentration of particulates in the emissions and the fraction of Pb in the particulates, the dry deposition of Pb to the Columbia Slough drainage basin was calculated. The results are summarized below:

Table 17: **Air Deposition of Pb**

percentile	**2 um**	**10 um**
10 %	3.82×10^{-6} kg/yr	9.55×10^{-5} kg/yr
50%	1.16×10^{-5} kg/yr	2.9×10^{-4} kg/yr
90%	1.64×10^{-5} kg/yr	4.1×10^{-4} kg/yr

Using the ratio of relative area of Columbia Slough surface water to the drainage area, the annual dry deposition Pb load to the surface water can be calculated.
2.9×10^{-4} kg/yr X 0.0031 = 8.99×10^{-7} kg/yr

The dry deposition equation was used with the following assumptions:
1. The particle density was not known, and assumed to be 2 g/cm^3.
2. The viscosity of air and the density of air were not temperature corrected.
3. The Pb emitted with the particulates was accounted for in the wet deposition calculation, so double counting of Pb load from the source may occur.

Past Lead Sources:
Information on past sources is contained in the following table. Lead emissions again reflect the Best Professional Judgment of DEQ Air Quality staff. The sites associated with these closed plants may release airborne dust contaminated with lead. Only Zusman Metals Co. is actually located within the Columbia Slough watershed. The others are included because air emissions from these plants may have migrated into the Columbia Slough watershed.

Table 18: List of Companies with Past Lead Emissions

AQ File No.	Name	Address	Process Type	Est. Lead Emissions
26-1866	Gould’s Metals	5909 NW 61st	Lead Oxide Closed 1984	<0.6 tpy
26-1864	Pacific Steel Foundry	1979 NW Vaughn	Foundry-closed in 1972	<0.1 tpy
26-2072	Zusman Metals Co. (Incinerator)	1525 NE Columbia Blvd.	Wire Recycler closed 1984	<0.2 tpy

Spills

DEQ has been maintaining records on reported spill events since 1987. A computerized database has been developed and it contains records of all spill events that have occurred since 1994, with some events from 1994 as well. Since 1994, 38 spill events have been reported in the Columbia Slough watershed. The substance released is only listed for 5 of these, and none are on the 303(d) list for the Slough. The substances released are described variously as food waste, oil (gasoline and diesel), sewage and process water.

No pollutant loads for 303(d) toxics can be associated with spills based on this information.

Illicit Discharges

The cities of Portland, Fairview and Gresham are required to monitor for illicit discharges under the terms of the MS4 (Municipal Separate Storm Sewer System) permit. Though these programs have been effective in reducing pollutant loads to the Slough, the parameters measured under them do not include 303(d) parameters.

Summary of Pb Loads

Lead loads associated with various sources in the Columbia Slough are summarized below.

Table 19: Summary of Total Metal Loads to the Columbia Slough (kg/yr)

Source	**Lead**
Industrial Discharges	0.19
Combined Sewer Overflows	75.7
Storm water (total)	1131
MS4 area only	990[5]
Industrial permitted area only	141
Groundwater[6] Overall loading	26
NuWay Oil Site (to Whitaker Slough)	
groundwater	1.65 x 10^{-5}
sediment partitioning	27.1
soil erosion- process area	0.438
soil erosion - non process area	0.005
St. John's Landfill	1.31
Miscellaneous	
Sediment Partitioning	0.030
Air Deposition[7]	
Oregon Steel wet deposition	0.014
Oregon Steel dry deposition	8.99 x 10^{-7}
Spills	estimate not available
Illicit Discharges	estimate not available
Total of Estimates:	1262

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[5] The calculated total Pb load minus the load associated with industrial areas.

[6] Dissolved Pb concentration

[7] Using the 50th percentile mass load.

Table 20 Summary of PCBs Loads to the Columbia Slough (kg/yr)	
Source	**PCBs**
NuWay Oil Site	
groundwater	1.24×10^{-7}
soil erosion - process area (Aroclor 1260)	1.1×10^{-3}
soil erosion - non process area (Aroclor 1260)	8.4×10^{-6}
Sediment Partitioning[8]	
DDD, DDE, DDT (total value)	3.55×10^{-7}
Dieldrin	3.95×10^{-6}
Aroclor total	1×10^{-4}

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[8] Calculated by multiplying the daily load (Table 15) by 365 days/year.

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APPENDIX B
BOD CALCULATIONS

State of Oregon

Department of Environmental Quality Memorandum

Date: 4/16/98

To: **File**

From: **Bob Baumgartner**

Subject: Columbia Slough Winter Dissolved Oxygen Analysis

Background: The Columbia Slough is water quality limited (WQL) for dissolved oxygen. Pulses of low dissolved oxygen concentrations are associated with deicing events at the Port of Portland international airport (PDX).

The federal Clean Water Act requires that pollution control plans defined as Total Maximum Daily Loads (TMDLs) be established for WQL limited streams. The federal Clean Water Act requires TMDLs to be established with existing data, include a reasonable margin of safety to cover uncertainty with existing knowledge, establish a load for background where possible, and allow for future growth and development.

The TMDL for dissolved oxygen defines separate loading capacities (LC) which varies with stream flow and the dissolved oxygen criteria applied. In order to establish allocations that reflect the pulses of storm driven events the LC also varies by the duration of the low dissolved oxygen events. The State dissolved oxygen criteria varies in relationship to the duration of the low oxygen event. The instantaneous instream DO should not fall below 4 mg/l, the seven (7) day average of the daily minimums should not fall below 5 mg/l, and the lowest thirty (30) day average of the daily means should not fall below 6.5 mg/l.

The loading capacity (LC) and margin of safety (MOS) are estimated using both existing field data and available literature. This memorandum summarizes the available information that was used to identify the loading capacity and subsequent allocations. The approach used, as are all models, is a simplification of reality. The discharges are assumed to be plug flows. The available data and literature were used to select reasonable model inputs. Field conditions were selected to represent likely worst case scenarios.

The TMDL distributes allocations to the three (3) defined sources; de-icing loads, storm water loads, and background. The storm water load is further subdivided between loads regulated by the designated management agencies and permitted industrial storm water.

AMBIENT DATA:

The Columbia Slough is listed as being WQL based on observation of substandard dissolved oxygen. The instream dissolved oxygen is influenced in part by the instream BOD_5 concentrations. Temperature directly influences the dissolved oxygen concentration by establishing the level of saturation and indirectly by controlling the rate of reactions that influence dissolved oxygen levels. Much of the ambient data is available in a series of documents and memoranda published by Portland State University (PSU) and supported by the City of Portland (Wells(1992), Wells and Berger (1995) Wells et al (1996)). Much of this information is also reviewed and presented in the Columbia Slough Water Body Assessment (CH2MHill 1995) conducted for the City of Portland. Ambient data is available from the City of Portland and from DEQ.

Ambient Dissolved Oxygen Data:

Substantial review of historical dissolved oxygen data is contained in the Water Body Assessment (CH2MHill 1995).

Field data for dissolved oxygen can be reviewed to determine the magnitude of the DO problems. Comparison of the ambient conditions associated with depressed oxygen can be used to define the conditions that result in the low oxygen.

Critical conditions for low dissolved oxygen appear to occur following freezing weather, followed by warm rain with increasing temperature in the receiving stream. In the Lower Columbia Slough increasing stage from the Willamette appears to be associated with depressed oxygen. This is likely due to increased residence time and reduced aeration.

Table 1, Dissolved Oxygen Data

Lower Columbia Slough				
Date	DO	Location of DO	Load Estimate	High BOD
1/10-25/95	1	SJB		
2/4-9/95	<5	SJB		
2/19-24/95	0	SJB		
2/21/95	0	Landfill		
12/10/95	0	N. Denver		
1/28/96	>4	N. Denver	1/18/96	
2/10/96	0	N. Denver	2/4-5/96	
2/15/96	4	SJB	2/4 -5/96	
12/30/96	>1	N. Denver		78
Upper Columbia Slough				
1/15-25/95	>4-2	MCDD1		
2/5-19,95	>5>4	MCDD1		75
11/16/95	>5	MCDD1		
1/28/96	>2	MCDD1	1/18-30/96	
2/3-4/96	>1	MCDD1	2/4-5/96	

Several periods of low dissolved oxygen have been observed in both the Lower and Upper Columbia Slough. Continuous monitoring data collected by the City of Portland is the most robust record of the low DO occurrences. Some ancillary data may also be recorded, however, coincident instream BOD data is sparse. Low dissolved oxygen data have been observed and associated with de-icing events for several years. This data is summarized in Table 1.

The February 1995 low DO event in the Lower Slough occurred following a cold period when instream temperatures increased and river stage increased due to high water in the Willamette River. Increasing stream temperatures also occurred at MCDD1 during the event.

Wells and Berger (1996) discuss the two (2) significant low dissolved oxygen events observed during late 1995, early 1996. The events occurred following cold periods followed by rain. Figure 1 shows the decreasing instream DO levels as the instream temperature began to rise. Instream conditions are characterized by warming stream temperatures and stagnation in the

Lower Slough due to increased stage because of high water in the Willamette. The low DO events lasted from 5 to 10 days in the Lower Slough. No oxygen sag was observed at stations upstream of the airport discharge. Similar physical conditions and low dissolved oxygen were observed in December 1996-January 1997. Continuous data recorded in December 1996-January 1997 shows the dissolved oxygen sag becoming apparent at RM 6.9 as early as 12/27-28. At N. Denver Bridge the minimum dissolved oxygen of 0.99 mg/L occurred at 2100 hours at 12/30/96 and recovery began by the end of the day, 12/31. Near RM 2.9 the minimum DO occurred near 0500 on 1/4/97, several days later than when peak BOD$_5$ measures were recorded. However, BOD$_5$ concentrations would also be reduced by degradation rates. The plug of low DO occurred about 4.3125 days later at RM 2.9. The average velocity was estimated as the difference in time from minimum DO divided by distance (3.8 miles/4.3 days) as 0.054 f/s, similar to the velocities estimated using observed BOD$_5$ data. Observed stream temperature near 5.2 C had begun to increase by the time the minimum DO was recorded at RM 6.7 Stream temperatures had increased substantially to near 7.1 C by the time the minimum DO was recorded near RM 2.9. Willamette River stage was near 10.3 feet during this period.

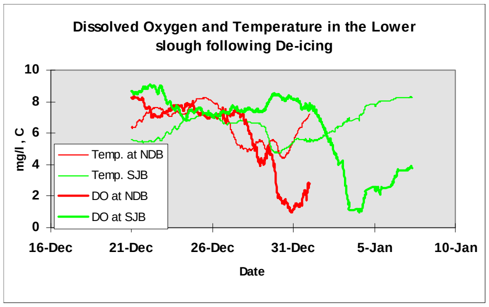

Figure 1, Dissolved Oxygen and Temperature in the Lower Slough

Previous storm monitoring in the Slough did not suggest reduced dissolved oxygen associated with storm water discharge (City of Portland BES, 1989). There were three storm event monitoring efforts conducted by the City of Portland on May 22, April 21 and May 2, 1988. The dissolved oxygen during these events was not reduced to near water quality standards during these surveys.

Occasional periods of reduced oxygen are apparent in the field data that are not known to be associated with de-icing events. This field data would suggest conditions other than de-icing influence ambient dissolved oxygen levels. Simulations presented by Wells and Berger (1995) indicate oxygen reduction during storm events to near the dissolved oxygen standard after the estimated de-icing load was eliminated. The simulations suggests that storm water and CSOs may reduce dissolved oxygen in the Slough, however, the storm water induced reduction of dissolved oxygen is not well defined with existing data.

Ambient BOD measures:

Ambient BOD concentration is the result of natural background contribution, source loading of BOD, and decay. Where information of source loads and background are known or can be reasonably approximated, ambient measures of BOD can be compared to estimates of loading and dilution to determine if such estimates appear to reasonably explain the observed conditions. Where associated with hydraulics data, observed changes in ambient BOD concentration may be used to estimate instream decay rates.

Instream BOD_5 concentrations reported by the City Portland vary from greater than detection to below detection (Nancy Hendricksen, BES, personnel communication) (Figure 2). Maximum recorded concentrations are 75 mg/l BOD_5. Well defined spatial trends are not apparent in the data provided by the City of Portland. Using the existing information the estimated mean BOD_5 concentration in the Columbia Slough is 2.5 mg/l BOD_5

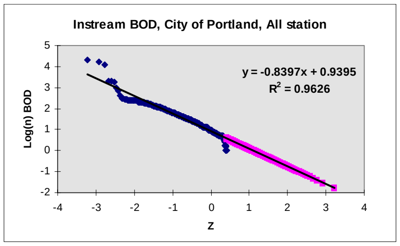

Figure 2, BOD Distribution

A maximum instream BOD of 150 mg/l is presented graphically as BOD_u by Wells and Berger (1995) for the Columbia Slough near Alderwood. Measured BOD_5 of > 70 mg/l is illustrated for near MCDD4, and > 60 mg/l near NE Alderwood in February 1995. During deicing events in 1995-1996 the observed oxygen demand concentrations reported by the City of Portland frequently exceed the maximum reporting level of 20 mg/l BOD_5 (Nancy Hendricksen, personnel communication).

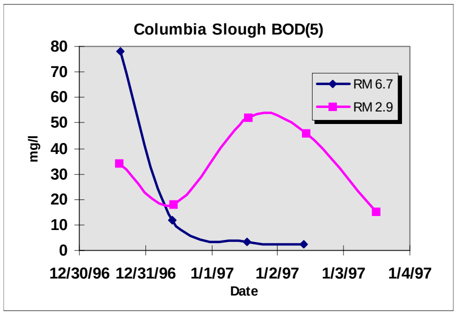

Figure 3, BOD by date and location

Similar elevated levels of BOD_5 ($\approx$ 80 mg/L) are reported by the City of Portland during a December 1996/January 1997 event. Instream data were collected by the City of Portland to evaluate the pulses of low DO from de-icing events. This data demonstrates that pulses of high BOD periodically move through the Columbia Slough. The timing and concentrations of the peak BOD_5 at different locations may be used to calculate deoxygenation rates and travel times. The peak BOD_5 concentration data drops from >78 to 52 mg/l between river miles 6.7 and 1.2 (Figure 3). The peak BOD_5 concentration occurred several (1.9-2.8) days later at river mile 1.2 than at river mile 6.7. The difference in peak concentrations suggest relatively slow velocities (0.08 - 0.12 f/s). Relatively high (0.14-0.20 /day) BOD_5 loss rates (K_r) may be estimated by solving for K_r using: $BOD_{rm1.2} = BOD_{RM6.7} e^{\frac{K_r X}{v}}$. However the peak BOD_5 data near river mile 1.2 is potentially influenced by dilution from the Willamette and dispersion. Instream BOD_5 data suggest that peak concentrations near RM 6.7 were missed by the ambient monitoring. Similarly the peak BOD_5 concentrations near RM 1.2 are not known. The BOD_5 concentrations near river mile 2.9 suggest a plug of BOD_5 on the order of four (4) days passed through the Lower Slough. This observation is consistent with the general length of the DO sag observed near Denver Bridge.

Ambient Temperature:

Cursory observation of available data indicates stream temperatures were near 5C as measured at St. Johns Bridge at the initiation of the February 1995 de-icing event (Wells et al 1996). Over the next several days the dissolved oxygen dropped to anoxic conditions and the temperature increased to approximately 10C. A similar increase in temperature through the low dissolved oxygen event was observed during January 1997. Similarly, at MCDD1 the dissolved oxygen generally drops as temperature increases. Minimum temperatures were near 4C. Reduced dissolved oxygen conditions occurred at temperatures in the range of 7.5C to 12C. Continuous monitoring data was collected by the City of Portland between Julian Day 27 and 70 (figure 25 Wells and Berger) in the Upper and Lower Slough. This data shows that the dissolved oxygen depressions observed occurred during periods where temperature was near 9C in the Lower Slough (St. Johns Bridge) and near 8C in the Upper Slough (MCDD1)

Willamette River stage:

The stage of the Willamette river can substantially influence how fast water moves through the Lower Columbia Slough. As stage increases, water backs up into the Columbia Slough, resulting in reduced velocity, longer residence time (stagnation) and reduced calculated aeration rates (Wells and Berger 1995). The Willamette river stage frequently exceeded 15 feet MSL and occasionally exceeded 20 feet MSL during the winter 1996/97. The 12-day averages, estimated to be the residence time of water in the Slough at high stage and low flow, frequently approached or exceeded a stage of 15 feet MSL (see Figure 4). The City of Portland (1989) reports that stage levels in the Columbia Slough of 14 to 17 feet are routinely reached.

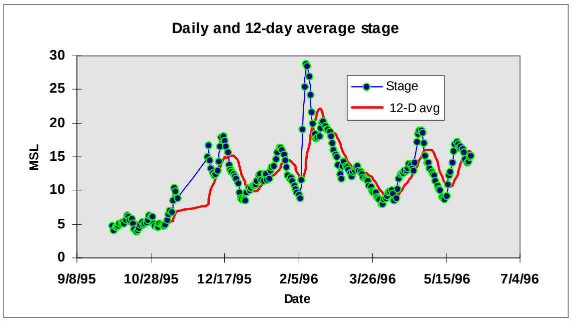

Figure 4, Daily and 12 day average stage

RATES:

Estimates of the loading capacity of the Columbia Slough are dependent upon estimates of the rates of reaction. The principle rates that influence dissolved oxygen in this analysis are the rate at which deoxygenation (K_d) occurs from BOD and the rate of oxygen brought back into the Slough from aeration (K_a). Temperature influences both of these rates and so is important in estimating the loading capacity. The dispersion rate (E_x) can also significantly influence the loading capacity for the short term pulse loads of oxygen demand.

Calculation of Biochemical Deoxygenation (decay) Rate (k_d)

Estimates of K_d were derived from UBOD/BOD_5 information presented in the Final Evaluation of Alternatives for controlling the Environmental Impacts of De-icing, LTI CH2M-Hill, 4/29/1996 (deicing study) and from percent theoretical oxygen demand at five days information provided by Union Carbide Corporation as part of information provided during public hearings. The Union Carbide data showed that most of the theoretical oxygen demand was consumed within 20-days. The theoretical oxygen demand therefore provides a reasonable estimate of the UBOD. K_d was calculated by two methods; a simple method based on the mathematical relationship between BOD_u and BOD_5, and a least squared regression analysis of the data. The following section discusses both methods.

In table 2.4 of the de-icing study, values from five day ($CBOD_5$) and Ultimate ($CBOD_u$) were provided for both propylene and ethylene glycol and from Type 1 and Type 2 aircraft de-icing fluids. Knowing the $CBOD_5$ and BOD_u the K_d rate was calculated as:

$$K_d = -\frac{Log_n(1-\frac{BOD_5}{BOD_U})}{T}.$$

The K_d values calculated from the various data reported varied from 0.05/day to 0.24/day with a median of 0.143/day and a standard deviation of 0.06. The rates were presumed to be measured at 20C. The calculated deoxygenation rates are similar to the range of 0.1/day - 0.2/day at 20 C used by Wells and Berger (1995) in their modeling efforts, and are similar to and slightly less than estimated from limited instream data collected during December 1996, January 1997.

Biochemical deoxygenation rates expressed as a percentage of the theoretical oxygen demand were presented by Union Carbide for three (3) temperature ranges of 4, 10, and 20C for both ethylene and propylene glycol. The K_d was calculated by empirical regression of $Log_n(1-\frac{BOD_t}{BOD_u}).vs.T$ The slope of the regression provides a measure of the K_d. As seen in Figure 5, for propylene glycol, K_d was calculated to be 0.127 for data presented at 20 C.

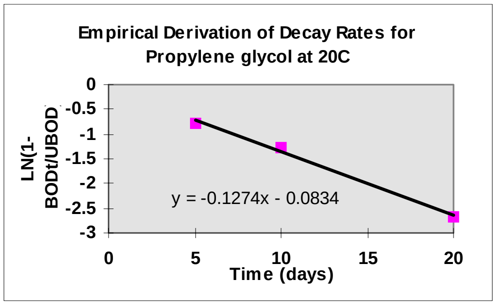

Figure 5, regression analysis for propylene glycol

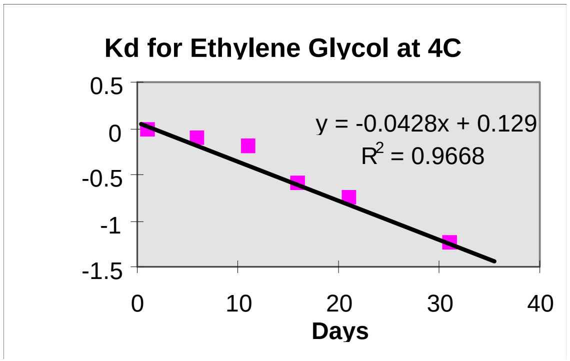

Figure 6, regression analysis for ethylene glycol

Cursory observation of the raw data indicates that there is a considerable lag phase in the deoxygenation tests, especially at the 4C temperature test. Derivation of k_d using the regression equation appears to be less influenced by the lag than would similar derivation using the simple calculations. The observed lag phase could result in an underestimation of the decay rate once the bacterial population was established. For ethylene glycol the observed K_d was 0.043/day using all data (Figure 6). Presuming that any lag phase was complete within 10-days a higher K_d of 0.049/day was derived. Partially acclimated bacteria were used in the original tests.

To model the loading capacity of BOD, the median K_d of 0.143 at 20C was used.

Influence of Temperature on K_d

Reports provided by Union Carbide contained deoxygenation data for three temperature ranges. Observed K_d was derived for each of the three temperatures (4, 10, 20C) included in the study. The influence of temperature on K_d was expressed as theta where: $K_{d_t} = K_{d_{20}}\theta^{(t-20)}$ and calculated directly as: ${\frac{K_t}{K_{20}}}^{\frac{1}{t-20}} = \theta$ for each temperature (10, 4 C).

Table 2, Calculated decay rates and theta

	Propylene		Ethylene	
T	Reg	Simple	Reg	Simple
20	0.127	0.138	0.188	0.151
10	0.066	0.067	0.066	0.055
4	0.053	0.026	0.042	0.028
	Theta			
10	1.07	1.07	1.11	1.11
4	1.06	1.11	1.09	1.11

The decay rates were calculated as a percentage of the theoretical oxygen demand. The decay rates appear consistent with those reported earlier. The regression (Reg) rates were described above, the simple rates are the median values of the K_d determined independently for each temperature. The influence of temperature expressed as theta has a median value of 1.102 and a standard deviation of 0.027. These results are summarized in Table 2.

The calculated theta is within the upper range of values typically used for carbonaceous BOD originating from municipal wastewater treatment plants (Thomann and Mueller 1991 = 1.04, Tchoboanogolous and Schroeder (1985) (1.135 in Wells and Berger 1995). The influence on temperature is similar to that used by Wells and Berger in their modeling efforts. The formulation used by Wells and Berger would reduce deoxygenation rates more severely below 6 C, and less severely above 6 C than the calculated theta of 1.1.

A theta value of 1.10 is used in the loading capacity modeling.

Calculation of Aeration Rate (K_a):

A variety of aeration rates have been suggested for use in the Columbia Slough model. PDX presented K_a in the range of 3.1-4.0/day from field data collected in April 1996. The field data was interpreted to suggest that the aeration rates used by Wells and Berger of less than 1/day may underestimate aeration. The wide discrepancy may reflect the variability that could be observed in the Columbia Slough system. Aeration rates are often expressed as a mathematical function of stream depth and velocity. Both velocity and depth vary independent of flow in the Columbia Slough.

Lower Slough aeration rates:

In the Lower Slough, during the winter, the stream depth is often controlled by the river stage of the Willamette and Columbia Rivers. When the Willamette river stage is high, water backs up into the Columbia Slough resulting in reduced advective flow out of the Slough. Cursory observation of available continuous monitoring data suggest that critically low dissolved oxygen levels (anoxic) are associated with high river stage. During the 1995 oxygen depletion event the river stage increased from near 6 ft MSL to 13 feet MSL. Aeration rates have not been measured during the periods of critically low dissolved oxygen.

Aeration rates were initially estimated using an O'Connor-Dobbins equation ($K_a = \frac{12.9u^{\frac{1}{2}}}{h^{\frac{3}{2}}}$).

Stream velocity (u) was estimated using generalized stream cross section data and discharge. Results were compared to detention time nomographs presented by Wells and Berger (1995). Velocity estimates using generalized stream physical conditions are similar to the velocities estimated using continuous monitoring data collected in December 1996-January 1997 of 0.05 to 0.12 f/s at relatively high stage (5-15 MSL) and discharges of less than 250 cfs (Figure 7).

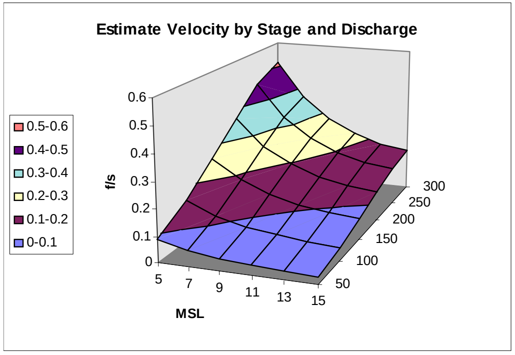

Figure 7, Stage, Discharge, Velocity

Depth (h) was estimated as the difference between bottom elevations reported by Wells and Berger (1995) and stage. As seen in Figure 8 and Table 3, the resulting estimates of aeration suggest that at the annual high stream stages typically observed of > 15ft MSL, the aeration rates would be substantially lower than at a more typical summer low flow range of 6 feet MSL.

cfs/MSL	***5***	***10***	***15***	***20***
100	0.65	0.13	0.06	0.03
200	0.98	0.199	0.08	0.05
300	1.16	0.23	0.10	0.06

Table 3: Lower Slough Est. Ka

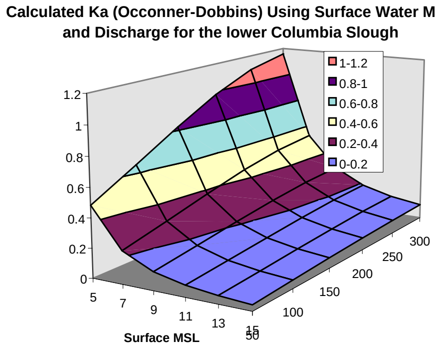

Figure 8, Ka, Discharge, Stage

Wind induced aeration may become an important contributor to the oxygen balance under conditions of high stage and low velocity.

Upper Slough aeration rates:

Stream stage in the Upper Slough is regulated for flood control and stream depth is not necessarily a function of discharge. In the Upper Slough the stage is not directly related to the Willamette River stage. Aeration rates were estimated using generalized stream geometry data and discharge (Figure 9). Results were compared to detention time data presented by Wells and Berger (1995). The generalized aeration rates may approximate averaged conditions, they will not represent specific locations. The Upper Slough is deeper and wider near MCDD1 resulting in reduced aeration rates compared to the estimated aeration rates for the rest of the Upper

Slough (Table 4). The observed dissolved oxygen sags near MCDD1 may be a function of the lower aeration rates.

The estimated aeration rates for the Upper Slough can exceed those estimated for the Lower Slough. Similar to the Lower Slough the aeration rates are much lower at a relatively high stage MSL of 8 feet as compared to a MSL of 6 feet. Estimated K_a is much lower at MCDD1.

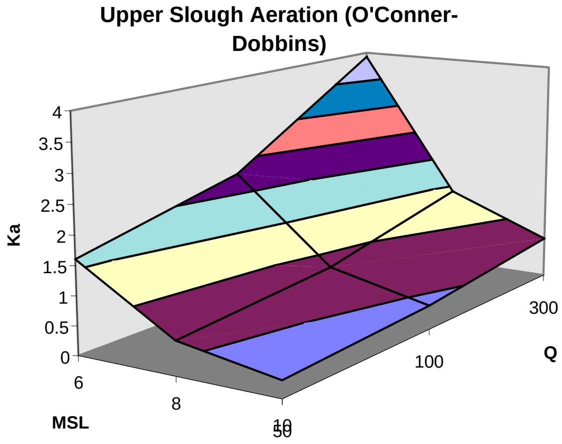

Figure 9, Ka, Stage, Discharge

	Upper Slough			*At MCDD 1*		
cfs/MSL	**6**	**8**	**10**	**6**	**8**	**10**
50	1.6	0.6	0.3	0.09	0.06	0.04
100	2.3	0.8	0.4	0.12	0.08	0.06
300	3.9	1.4	0.7	0.21	0.15	0.10

Table 4: K_a generalized for the upper Slough and for MCDD1

Effect of wind on aeration rates:

The equation used to calculate aeration is appropriate for moderately deep to deep channels (1ft < H < 30 ft) with velocities in the range of 0.5 fps < U < 1.6 fps (EPA Technical Guidance Manual for Performing Waste Load Allocations, 1992). Velocities for the Columbia Slough, during critical time periods, range from 0.05 fps to 0.12 fps. Using the O'Connor Dobbins formula may underestimate the aeration rate, as K_a approaches zero as the depth increases. For these two reasons, the O'Connor - Dobbins formula may be inappropriate for the Columbia Slough.

Due to low velocities, with deep and stagnant waters, the Columbia Slough system is similar to a lake. DEQ evaluated equations for calculating gas transfer rates (K_L) and K_a for lakes and reservoirs. In such waterbodies the effect of wind on reaertion may be significant. Banks and Herrera (Thomann and Mueller,1987) suggest the following equation to estimate K_L.

$$K_L = 0.728 U_w^{1/2} - 0.317 U_w + 0.0372 U^2_w$$

where U is wind speed in m/s and K_L is the wind driven oxygen transfer coefficient in m/day.

To determine an appropriate K_L for the aeration calculations, wind data, Willamette River stage data and Columbia Slough DO data were evaluated for time periods when DO levels dropped to anoxic conditions. Using hourly average wind speed for the period of February 15-22, 1995, values for K_L were calculated using the Banks and Herrera equation. A minimum daily average K_L which represented the critical conditions was estimated. A minimum daily average K_a (reaeration coefficient) was calculated using the following equation:

$K_a = K_L / H$ where H is depth of the waterbody.

Effect of temperature on K_a:

The reaeration coefficient was adjusted for temperature (at 8°C) using the following equation:
$K_{a_t} = K_{a_{20}} \theta^{(t-20)}$

No specific information is available for estimating the influence of temperature on aeration rates. The standard default theta of 1.024 (USEPA) is recommended. The minimum daily average K_L was estimated as 0.577 m/day and the minimum daily average K_a was estimated as 0.107 at 8°C.

Effect of dispersion on instream BOD:
In any river, there is mixing that occurs along the river due to horizontal and vertical gradients in velocity. This phenomenon is known as longitudinal dispersion, and preliminary calculations indicate that peak downstream BOD concentrations will be reduced if dispersion is considered in the dissolved oxygen analysis. The Port of Portland calculated dispersion coefficients (E_x) from reaeration studies conducted during April, 1996. E_x was estimated to be 2.3 ft^2/sec and 26.8 ft^2/sec, at flow rates in the Upper Slough of 50 cfs and 75 cfs, respectively. The pumping rates at MCDD1 were assumed to be 75 cfs and 300 cfs, respectively. DEQ estimated E_x using the following equation (Thomann, 1987):
$E_x = 3.4(10^{-5})\frac{U^2B^2}{HU^*}$ where U is the mean velocity in fps, B is the mean width in feet, H is the mean depth in feet, and U^* is the shear velocity in fps.

Estimates of E_x obtained by this method were of the same order of magnitude for each selected flow as those calculated by the Port of Portland. DEQ used E_x values of 2.0 ft^2/sec for 100 cfs and 20 ft^2/sec for both 200 cfs and 300 cfs.

Results of sensitivity analyses demonstrate that dispersion affects the peak instream BOD values for short term discharges (< 1.5 days). During short discharge periods, the BOD load acts as a plug moving through the Slough. Increasing the discharge period results in the Port's discharge acting as a continuous discharge, with dispersion becoming insignificant. To simplify the analysis, the time of the Port's discharge is limited to one day.

Time to critical deficit :
The dissolved oxygen reaches a maximum deficit at a "critical time" when the uptake of oxygen by the BOD is balanced by input of oxygen from the air: $t_c^* = \frac{1}{K_a - K_d} Log_n(\frac{K_a}{K_d}\{1 - \frac{D_0(K_a - K_d)}{K_d L_0}\}$, where D_0 is the initial oxygen deficit and L_o is the initial BOD_u. Under current conditions the Columbia Slough becomes so heavily loaded with organic material that oxygen will approach depletion, and anaerobic conditions will result. The start of the anaerobic condition occurs prior to the point where critical oxygen deficit would occur. Assuming no other sources, the point of recovery from anaerobic conditions will be dependent upon the aeration rates. Under the anaerobic conditions the rate of BOD decay will be satisfied by the aeration rate.

The expectation of the TMDL will be to eliminate the anaerobic conditions. Once the TMDL is successful dissolved oxygen will not fall below water quality standards. If the residence time of water in the Columbia Slough is longer than the time to critical deficit then the loading capacity is established by the critical oxygen deficit. If the residence time of water in the Slough is less than the time to critical oxygen deficit the loading capacity is defined by the dissolved oxygen deficit that occurs at the time water leaves the Columbia Slough and is diluted by water from the Columbia and Willamette Rivers.

The potential range for time to critical dissolved oxygen deficit was calculated for a range of K_d and θ_d as defined above, and for a range of the estimated K_a and θ_a with an assumed standard error of 0.03 (USEPA). An initial oxygen deficit of zero was assumed. A total of 1000 calculations representing the potential ranges of K_a and K_d as adjusted by temperature were made for defined conditions of temperature and flow. The median calculated Tc for a flow of 100 cfs and stage of 15 MSL was >22 days (Figure 10).

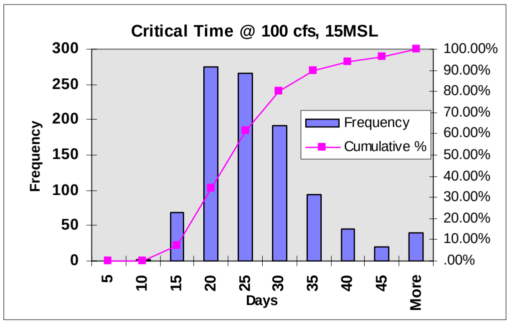

Figure 10, Time to critical DO deficit

Residence time is dependent upon the stage and discharge (Table 5). The time to critical deficit is dependent substantially on the aeration and deoxygenation rates, which in turn are dependent upon temperature, stage, and discharge. However, under the assumed reasonable worst case conditions it appears the time to critical deficit is likely to be greater than the residence time of water in the Columbia Slough. The LC is determined by the residence time of water in the Slough.

Q/MSL	***10***	***15***	***20***
100	7.6	11.2	11.7
200	3.3	4.9	5.1
300	2.8	3.5	3.7

Table 5: Estimated Residence Time, Lower Slough only

OXYGEN DEMAND LOADS:

The instream dissolved oxygen is in part dependent upon the loads of oxygen demanding material discharged to the Slough. The relative contribution of sources varies depending upon whether rainfall runoff or deicing is occurring. The substantive loads that are estimated with existing data include the de-icing loads, storm water loads, and the net background loads.

Combined Sewer Overflows:
A substantial oxygen demand loads is contributed by CSOs. Current efforts will largely eliminate the CSOs. With elimination the WLA for CSOs will be zero and are therefore not further evaluated as part of the TMDL.

Sediment Oxygen Demand:
Sediment oxygen demand (SOD) can substantively influence dissolved oxygen. A single measure of SOD in the Columbia Slough of 2g $0_2/m^2$/day is similar to the sediments of other Western Oregon rivers. Sediment oxygen demand is influenced by ambient temperature with a default theta (θ) of 1.072 (USEPA). The SOD was presumed not significant compared to other sinks of oxygen for this analysis.

De-icing Loads:
De-icing loads to the Columbia Slough were estimated using COD measures and presumed flow by Fish (1996). Wells and Berger (1995) estimated contributions from de-icing by using field data and estimates for rates of aeration and deoxygenation. No direct instream information is available to demonstrate the influence that the de-icing loads have on instream BOD_5 concentrations. Estimates of the influence of de-icing loads were compared to instream concentrations using simple dilution calculations and the results may be compared to instream BOD_5 measures. Unfortunately, available instream measures occurred during different periods than the measured de-icing loads. The instream concentrations would also be influenced by several processes such as dispersion and decay. Comparisons may only provide an approximation of whether the observed instream concentrations are within a reasonable order of magnitude of what would be expected by de-icing loads.

De-icing loads of BOD were estimated by Fish (1996) for events in January and February of 1996. The BOD_5 concentrations were estimated from COD data using empirical correlations developed for the airport. The loads were estimated using presumed “worst case” pumping discharge rates. Peak loads calculated for the February event were on the order of 3.1 lb./second at 6,470 mg/l BOD_5. During the January event peak loads were on the order of 2 lb./second at 1784 mg/l BOD_5. The resulting instream concentrations are not available. Estimates of loads using presumed flow ranges are similar to observed peak instream BOD_5.

The instream BOD_5 concentrations resulting from the estimated de-icing loads can be estimated by a simple mass balance using presumed stream flow (Figure 11). This exercise demonstrates that loads would be periodic pulses moving through the Columbia Slough. Subsequent dispersion would reduce maximum concentrations and act to spread out the period of the pulse.

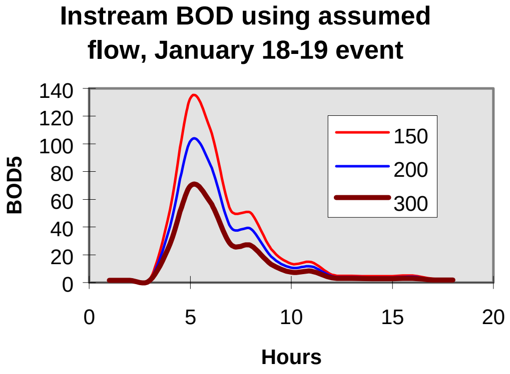

Figure 11, Instream BOD

During the January event the loads were derived principally from subbasin six (6) of the Port. Since flow data was not readily available the instream concentrations was calculated for three (3) assumed discharge rates (150, 200, 300 cfs) and an ambient concentration of 1 mg/l BOD_5 (Figure 11). On other occasions instream measures of > 80 mg/l have been reported. The reported instream BOD_5 levels of > 80 mg/l do not appear unreasonable for peak ambient concentrations for an event of this magnitude.

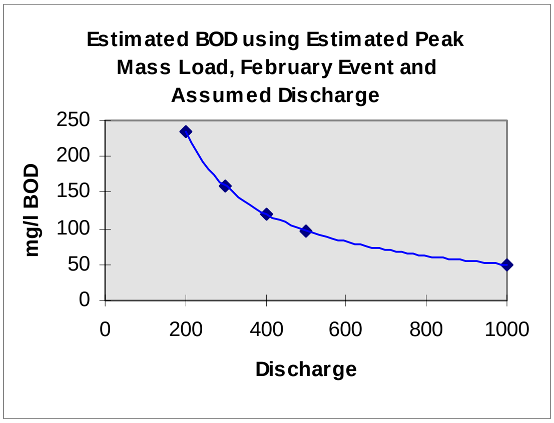

Figure 12, Estimated BOD

Maximum instream concentrations were estimated for the February 1996 event for presumed ambient flows of between 200 and 1,000 cfs and background BOD_5 of 1 mg/l (Figure 12). Instream flow and BOD_5 measures are not available. Significant deicing load contributions occurred for both subbasin six (6) and seven (7). The peak loads for both were assumed to occur simultaneously.

The Willamette river was near or above flood stage during this period. However, the actual flow rate in the Slough is not known. Peak BOD_5 loads in the range of observed peak concentrations of 80 mg/l or greater would not be unreasonable.

Storm water BOD_5 loads:

Numerous efforts have been made to estimate the BOD contribution of storm water to the Slough system. Storm water BOD_5 loading have been estimated for the City of Portland as part of earlier CSO studies. Wells and Berger (1995) estimated storm water loads through calibration of receiving water quality models. Municipal storm water permits predicted storm water loads using runoff equations and assigned concentrations using field data. Each of these efforts is discussed below.

Urban runoff modeling (SIMPTM) conducted by OTAK estimated an overall storm water BOD_5 of ≈ 5 mg/l for the City of Portland. The SIMPTM model used local rainfall data, and Bellevue NURP data supplemented with data collected in Portland. The SIMPTM program simulates pollutant loading from land use and incorporates the influence of local drainage conveyance systems on the total loading of particulate and associated parameters, such as BOD.

In the MS4 permit applications the overall average BOD_5 load is dependent upon the mix of land use, runoff coefficients used for each land use and assigned BOD_5 concentration. The simulations do not account for any losses of BOD_5 through the storm water system. This information was used to develop storm water loading estimates for the Columbia Slough as part of the Columbia Slough Water Body Assessment (CH2MHill 1995).

Wells and Berger (1995) cite calibration with field BOD_5 and dissolved oxygen data as demonstrating that the estimates made by OTAK better fit observed conditions than the more simple models used to develop storm water permit estimates. As part of the calibration efforts to better represent observed instream DO and BOD_5 Wells and Berger reduced storm water concentrations as estimated in the Water Body Assessment (CH2Mhill, 1995) by 50% and 75 %. Although this calibration improved model comparison to field conditions Wells believed additional reduction may be warranted.

Table 6 summarizes these storm water BOD estimates.

Source	mg/L
BES- SIMPTM (mean)	5.2
Gresham MS4 (mean)	5
Portland MS4 (mean)	19
WBA CH2MHill (mean)	21
Wells and Berger calibration (mean)	11 (50% reduction of initial calibration)

Table 6: Summary of estimates of storm water BOD concentration

DEQ initially used 11 mg/L as the concentration of BOD_5 from storm water in the estimation of the BOD loading capacity. The City of Portland commented that the representative storm water BOD_5 concentrations should be reduced from 11 mg/L to near 5 mg/L. To respond to this comment, DEQ estimated the storm water BOD concentration by two methods: calculation of a flow weighted mean urban runoff concentration and solution of a simple mass balance. These two methods are discussed in detail below.

Flow weighted mean method:
A flow weighted mean urban runoff BOD_5 concentration for the Columbia Slough was derived using land use distributions and associated event mean concentrations. The results of this calculation are summarized in Table 7.

LAND USE	EMC	RUN OFF	AREA
Residential	9.35	0.39	0.105
Industrial	54.05	0.68	0.14
Commercial	10.78	0.82	0.164
Open	3.84	0.14	0.132
Vacant	3.84	0.41	0.438
Traffic	13.65	0.91	0.023
(average)	15		
Sum (BOD*Runoff*area) = Sum (Runoff*area)			20.39

Table 7: Flow weighted man

The calculated weighted mean concentration of 20.39 mg/l BOD_5 is greater than the recommended 5 mg/l to represent urban runoff. The BOD associated with land use classification for vacant and open spaces were below the proposed 5 mg/l BOD_5. The land use classifications for residential, industrial, commercial, and traffic corridor had event mean concentrations exceeding the proposed 5 mg/l.

Available data suggest that industrial storm water provides a significant contribution to the overall storm water BOD_5 loads to the Columbia Slough. Industrial storm water has higher BOD_5 concentrations than other land uses.

Mass balance:

A simple comparison of dilution rates and instream concentrations can be used to estimate storm water concentrations. This approach is similar to the calibration efforts used by Wells and Berger for a single event. A calibrated SWMM model was used to estimate urban storm water flows and transport these flows through the Slough. Backwater and tidal effects were ignored. Dilution was estimated by assuming a constant background flow of 75 cfs in the Slough. The BOD concentration uninfluenced by storm water was assumed to consistent with the median BOD of 2.5 mg/l BOD_5. The dilution was calculated for each day and specific location where BOD was monitored in the Slough. The storm water concentration was then directly calculated as: $C_{storm} = \frac{Q_{background}}{Q_{simulate} - Q_{background}} \left\{ C_{observed} - C_{background} \right\} + C_{observed} d$. The simple mass balance provides an indication of how close calibrated storm water concentrations from multiple sampling efforts rather than a single effort would compare to the simulated storm water runoff concentrations.

The results of this calculation are summarized in Table 8.

	MCDD1	LOWER RM 6.9	LOWER RM 4.9
25%	2.0	2.0	2.0
Mean	28	8.6	11.4
Median	6.0	8.8	7.7
Geomean	7.0	5.3	8.3
75%	15.6	11.7	7.4

Table 8, storm water BOD5 concentrations

This analysis suggest that the City of Portland's calibration estimate that storm water typically contributes 5 mg/l BOD_5 to the Slough is reasonable. The interquartile range for estimated BOD from storm water varies from 2 to > 15 mg/l. Mean, median, and geometric mean estimates varied between 5.3 to 28 mg/l, but were typically less than 11 mg/l. The highest estimates may reflect the influence of de-icing materials on instream BOD_5 concentrations used to calculate storm water loads. The reason for the discrepancy between the estimates based on instream calibration and the storm water model estimated are not known. Substantial errors could occur because of uncertain estimates for dilution, hydrologic transport, loss mechanisms, and uncertain load/land use/runoff estimates.

It appears reasonable to conclude that the instream BOD_5 concentrations are less than would be expected from simple dilution models using storm water concentrations estimated using simple runoff models (i.e. the flow weighted mean method). The reduction is on the order of 50% of the load, and may be greater. However, further decrease beyond the proposed 50% reduction may imply precision that does not exist. The storm water BOD_5 contribution is therefore estimated as 10 mg/L.

Background BOD_5 -BOD_u:

The background BOD_5 as applied represents the concentration of BOD_5 originating from natural anthropogenic sources other than storm water and de-icing loads. The mean (log-normalized) of 2.5 mg/l BOD_5 may provide a site specific estimate of background BOD_5 that is consistent with the relatively high range of BOD observed in the Slough compared to other western Oregon streams.

A background flow of 70 CFS is consistent with the volume of water reported in the Columbia Slough Water Body Assessment for groundwater and upstream sources of water.

No direct measure of the background ultimate oxygen demand have been made. The background BOD deoxygenation rate was presumed to be the same as the rate for glycols. This rate may be greater than occurs for background BOD and provides a conservative estimate of $BOD_{u.}$

($BOD_u = \frac{BOD_5}{1 - e^{-K_d * 5}}$.) The estimated BOD_u is ≈ 4.9 mg/l.

<u>DERIVATION OF THE TMDL (LC WLA LA MOS):</u>

A dissolved oxygen TMDL is derived for the Columbia Slough using a very simple analytical solution to a dissolved oxygen balance. A much more complex model is available. However, the lack of robust synoptic data sets providing coincident loading and ambient information results in substantial uncertainty for describing the observed oxygen depletion in the Slough. Additionally, the uncertainty on the decay rates of glycols and the influence of temperature on decay rates increases the opportunity for discussion and debate about model calibration and application for the development of TMDLs. The lack of coincident ambient data and uncertainty about decay rates results in a large number of degrees of freedom and a more complex evaluation may not be more precise than a simple approach.

The federal Clean Water Act clearly states two (2) conditions that influence the TMDL. The TMDLs need to be established with existing data. The TMDL needs to contain an appropriate margin of safety to account for existing lack of knowledge.

The phased TMDL approach allows the refinement of the initial TMDL if more or better information becomes available. The implementation plan can include efforts to obtain information needed to modify the TMDL. The phased TMDL approach allows the TMDL to be modified using information developed during previous phases.

Initial TMDL

A simple oxygen balance was developed to identify the initial TMDL and to test the sensitivity of the various rates and coefficients on the potential TMDLs. Estimates of the stream loading capacity were determined using the best available information on deoxygenation and aeration rates, and the influence of temperature on these rates. A reasonable critical condition for dissolved oxygen concentration was used to define the loading capacity.

The simple oxygen balance provides a means to discuss and evaluate alternative allocation strategies and is presented in terms of the oxygen deficit at a time (t):

$\{DO_s - DO_t\} = \frac{K_d}{K_a - K_d}\{e^{-K_d t} - e^{-K_d t}\}BOD_{u_0} + \{DO_s - DO_0\}e^{K_a t}$, where S = saturation.

The initial TMDL, including a margin of safety can be described using the simple oxygen balance. The simple oxygen balance was modified to include the influence of dispersion on pulse loads of BOD. As a result of this modification, the de-icing events are restricted to a single day.

This information can be used to determine whether further model refinement is needed to reduce the existing uncertainty. Reducing uncertainty will in effect allow a shift of the margin of safety to specific waste loads. This information may be used to focus discussion on what data and information is needed to refine the understanding of the oxygen depletion in the Columbia Slough.

Because of the magnitude of the observed DO problems it is reasonably assumed that further model refinement will occur. To date the information needed has not been collected. A phased TMDL will assure that the information needed will be collected in a timely manner and that controls will be implemented with an appropriate margin of safety.

From the information reviewed above the reasonable design conditions for determining the loading capacity (LC) are:

$K_{d(20)}$ = 0.143/day (at 20C)
$K_{d(8)}$ = 0.045/day (at 8C)
Theta K_d = 1.10
Theta K_a = 1.024
K_a = 0.107/day (at 8C)
Temperature = 8 C
Background BOD_5 = 2.5 mg/l, Background BOD_u = 4.9 mg/l
Storm water BOD_5 = 10 mg/L
De-icing Bod_5 = range of 100 to 2000 mg/L to meet dissolved oxygen criteria
time of discharge = 1 day
E_{xx} (dispersion) = 2 for Q < 100 CFS
E_{xx} (dispersion) = 20 for Q>200 CFS

Q (total flow) = 2.83 m/s (100 CFS), 5.66 m/s (200 CFS), 8.5 m/s (300 CFS)

The residence time of water for calculating minimum dissolved oxygen condition includes the travel time from the airport to MCDD1 in the Upper Slough, and for the travel time through the Lower Columbia Slough. At a stage of 15 MSL in the Lower Slough the residence time varies from a < 5 days to near 12 days depending on discharge (Table 9).

Q	*Lower*	*Upper*	*Residence*
100	11.2	2	13.2
200	4.9	1	5.9
300	3.5	1	4.5

Table 9, residence time (days)

The design conditions represent the best estimate of model input values and a reasonable set of hydraulic and temperature conditions that have been observed to generate critical dissolved oxygen depletion in the Columbia Slough.

Hydraulic conditions are different between the Upper and Lower Slough. The preliminary analysis suggest that the Lower Slough is more likely than the Upper Slough to have reduced oxygen levels due to elevated BOD. Allocations are established to achieve the DO criteria in the Lower Slough.

The simple oxygen balance was solved to determine the loading capacity of instream BOD. The objective of the LC is to achieve dissolved oxygen criteria of 6.5 mg/l as a long term average, 5.0 as an event minimum average, and 4.0 as an absolute minimum. The criteria are used to define the LC for an event hourly maximum, event mean, and long duration discharge. This approach allows the LC and subsequent WLAs to vary dynamically with pulse events of the storm water driven loads.

Allocation Strategy:

Several allocation strategies are available. The three (3) principle allocations are for background, storm water, and de-icing loads. The TMDL is described as the instream target BOD_5 concentration and varies with flow (TMDL (kg/d) = BOD_5(mg/l) *Q(m/s) *conversion factor).

Several alternatives were evaluated for distributing loads between storm water and de-icing loads. From this review there appears to be two (2) reasonable strategies.

1) Allocate the storm water loads at their current estimated concentration and loads. The reduction in loads needed to achieve the LC would be taken from the de-icing load.

2) Equal relative efforts: Under the equal relative effort alternative the reduction of both storm water and de-icing loads is proportional to the calculated increase in BOD_5 in the Columbia Slough. There are two (2) alternative methods used to define what is equal equivalent effort. Information presented by Wells and Berger (1995) was used as the reference condition for deriving equal relative efforts. The WLA would be determined as the reduction from the existing reference condition. The initial allocation reduced 4.5 pounds of de-icing load for each

pound of storm water. Alternatively, if the mass ratio is perceived to be the equitable representation of equivalent effort there would be 3.8 pounds BOD reduced in de-icing load for each pound of storm water (Table 10).

	C	**Q**	**Mass**
Storm	**10**	345.0	18596
de-ice	**2000**	6.5	70070
BKG	**2.5**	70.0	943
8.7 BKG + Storm			
39 BKG + Storm + de-ice			
39/8.7 = 4.5			
Mass de-ice /Mass Storm :			
70070/18596 = 3.8			

Table 10, equal mass reduction calculation

The relative influence of storm water loads would be unique for each set of streamflow, runoff, and de-icing event conditions. The relative load is also dependent upon the uncertain estimates of both storm water and de-icing quality and loads. The relative reduction is unique for each condition. It would not be possible to derive unique reductions for each condition.

Reasonable Margin of Safety:

A TMDL must be established with a reasonable margin of safety to account for uncertainty in existing information on loads and receiving water response. The margin of safety also needs to account for the uncertainty in achieving the assigned load allocations. A substantial amount of uncertainty exists in the current estimates of the loading capacity. A margin of safety of 20% was assigned to the estimates of LC for the three (3) flow regimes and three (3) oxygen criteria.

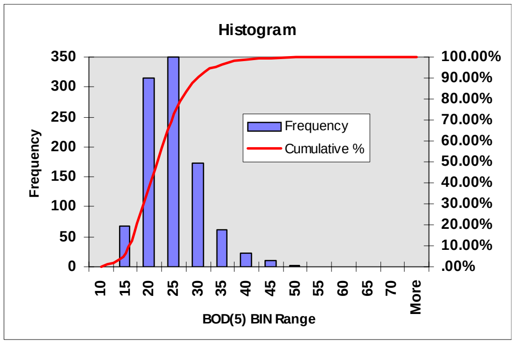

Figure 13, distribution of estimated LC

The amount of uncertainty associated with the selection of K_d, θ_{kd}, K_a, and θ_{ka} was determined by defining probability density functions. The mean and defined standard deviation for K_d, and θ_{kd} are described above. The calculated K_a, and θ_{ka} were assigned a coefficient of variation of 0.03 from USEPA guidelines for conducting uncertainty analysis (QUAL2EU). All distributions were presumed to be normal. The loading capacity was determined as the L_o that would create a deficit equal to the difference between saturation and the state water quality standard (dispersion was not included in this analysis): $\dfrac{DO_s - DO_{stnd}}{\dfrac{K_d}{K_d - K_a}(e^{-K_d t} - e^{-K_a t})}$. The dissolved oxygen was assumed to be initially at saturation. The residence time of water in the Slough was derived above and estimated to be less than the critical time for achieving minimum dissolved oxygen. The distribution of calculated loading capacities is presented in Figure 13.

The calculation of LC depends on both the selection of a reference residence time and the physical-hydraulic conditions used. The approach used presumed reasonable worst case physical hydraulic conditions of a 15 ft MSL stage, and a temperature of 8C. The loading capacity was determined for a criteria of 4.0 mg/l DO. A greater loading capacity would be expected under less severe hydraulic conditions. A greater range for loading capacity would be estimated if the stage, temperature, and residence time were allowed to vary, however the LC is described for specific discharge levels. A discharge of 200 cfs was used in the uncertainty analysis.

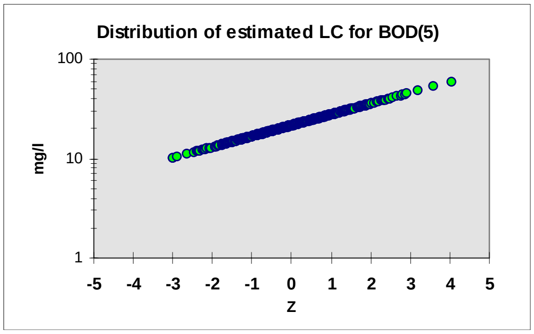

Figure 14: Estimated LC vs Normal Variate (Z)

An appropriate margin of safety needs to provide reasonable assurance that achievement of the WLAs will result in achievement of water quality standards. The margin of safety should also provide an objective measure of the uncertainty with existing knowledge. The allocation to the margin of safety may be redistributed if additional information is developed which improves the precision of the estimated loading capacity.

The margin of safety was defined as a function of the normal variate (z) for the range of LC (Figure 14). Over 68% of the values fall between +/- 1z, and over 95% of the values fall between +/- 2z. A range of 1z indicates the most likely range and 2z represents the reasonably potential range (Table 11).

Table 11, range of LC

z		***LC (mg/l) BOD$_5$***				***% difference***
Low	High	Low	Avg.	High	Range	(avg.-low)/avg.
1.95	1.98	13.3	21.5	35.6	22.3	38.0%
1.00	1.00	16.8	21.5	27.9	11.1	21.8%

The MOS is calculated as: $\frac{21.5 - 16.8}{21.5}$, = 21.8%, ≈ 20%. This value represents one standard deviation around the average LC calculated. A MOS of 20% is applied to all flow rates and DO criteria. Allocating a margin of safety reduces the amount of BOD that may be distributed to other sources. Additional data could act to reduce the MOS and allow some of the mass to be reallocated.

TMDL LC, WLAs, LA s:

Allocations are expressed as a loading capacity that varies with flow as determined for a reasonable design condition.

The allocations are distributed to three (3) classes of sources; background, storm water and de-icing. The storm water loads are divided between permitted industrial storm water and urban runoff from areas managed by the designated management agencies. The storm water and de-icing loads are for those loads that reach the Columbia Slough, rather than those loads that are generated. Both storm water and de-icing loads may be treated between where they are generated and the Slough. A 20% margin of safety is taken from the LC and reserved.

The allocation for the airport is divided between the Port of Portland (PDX) and the Oregon Air National Guard (ANG).

Storm water runoff allocations have been split between industrial and urban runoff. The storm water target loads may also be expressed as an event mean target concentration. The storm water BOD_5 reaching the Columbia Slough is allocated to 46% originating from permitted industrial storm water and 54% from other urban runoff.

Future Growth and Development

From application of the SIMPTM model the City of Portland predicted a 150% increase in storm water pollutant loading over current loads to the Columbia Slough (City of Portland 1989). Future growth therefore receives 1/3 of the storm water allocation.

The allocation of mass loads is summarized in Table 12.

Table 12, BOD allocations

Flow (m3/sec)	BKG	Future Growth	DMA	Industrial SW	PDX	ANG	MOS	TMDL
WLA to achieve 4.0 mg/L DO criteria, BOD5,kg/day								
2.83	428	188	201	175	3342	413	1200	5947
5.66	428	869	931	809	8752	1082	3237	16108
8.50	428	1585	1702	1479	11641	1439	4568	22842
11.33	428	2435	2608	2267	17679	2185	6981	34583
WLA to achieve 5.0 mg/L DO criteria, BOD5, kg/day								
2.83	428	187	200	174	2801	346	1034	5170
5.66	428	854	914	795	7225	893	2784	13893
8.50	428	1553	1664	1446	9645	1192	3992	19920
11.33	428	2361	2529	2198	14825	1832	6089	30262
WLA to achieve 6.5 mg/L, DO criteria, BOD5, kg/day								
2.83	428	183	198	172	1978	244	801	4004
5.66	428	822	889	773	4935	610	2114	10571
8.50	428	1500	1607	1396	6652	822	3132	15537
11.33	428	2251	2411	2095	10504	1298	4795	23782

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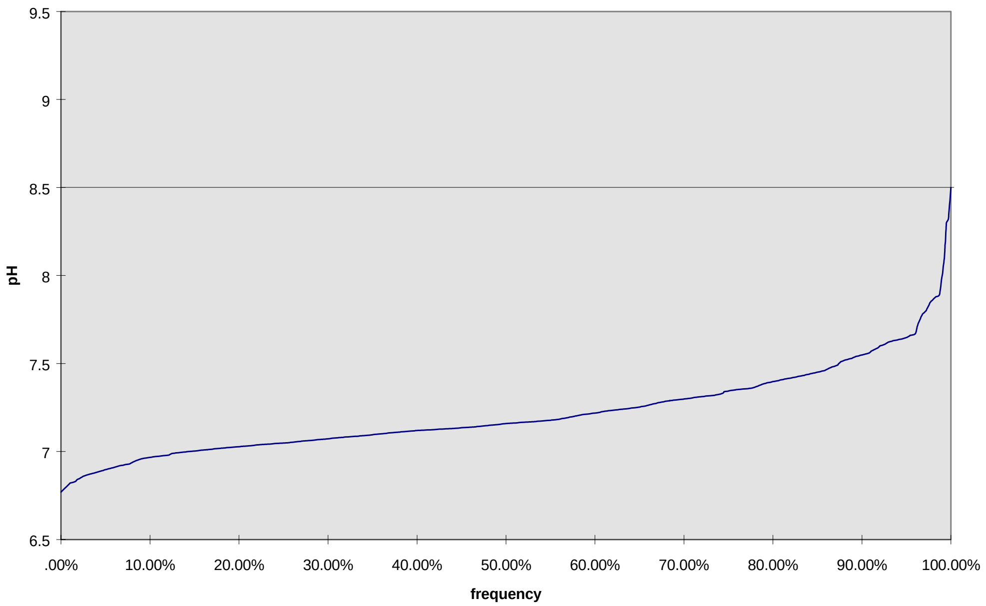
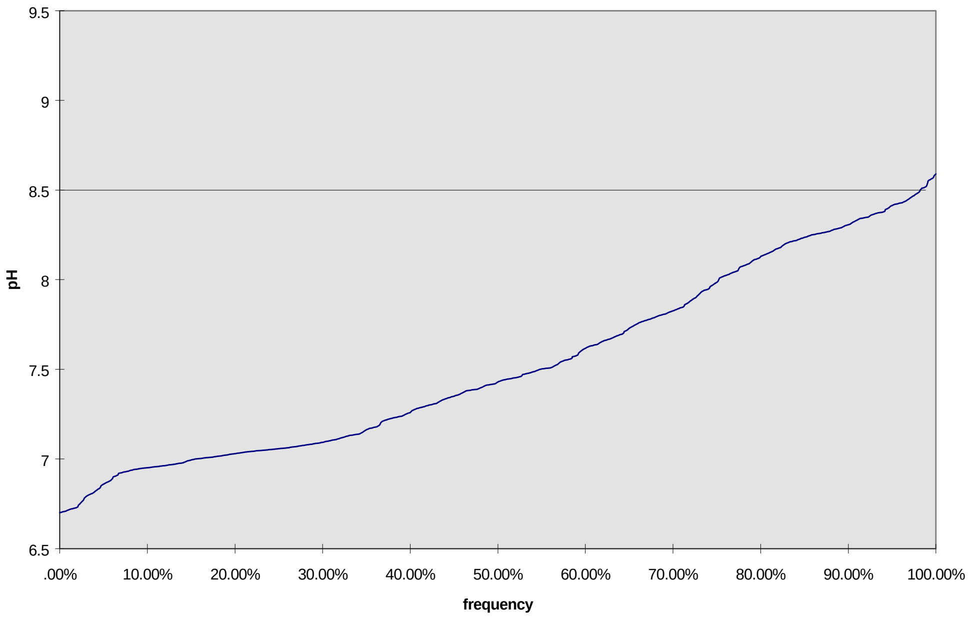
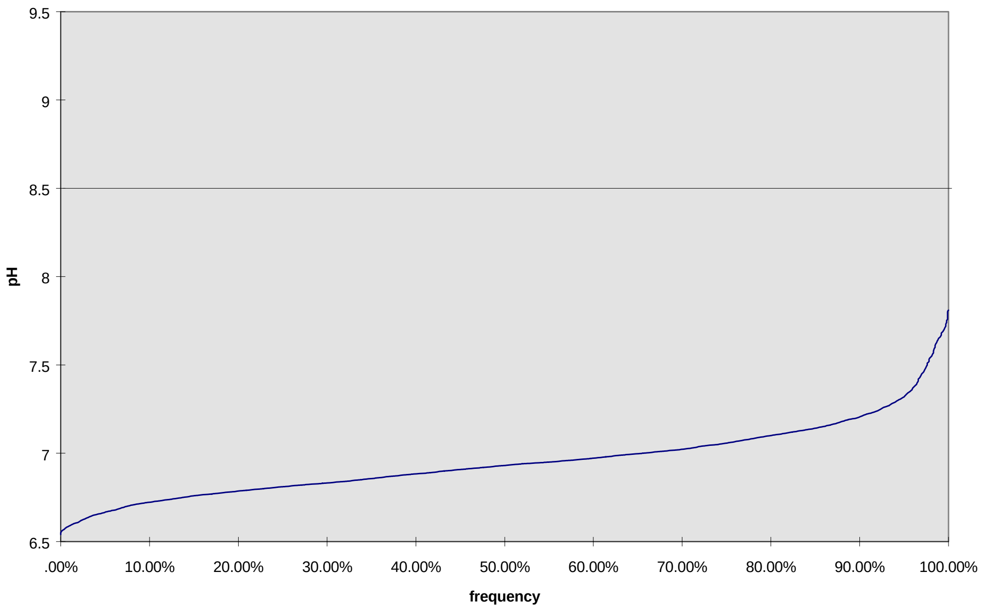
APPENDIX C
ADDITIONAL DATA SUMMARIES

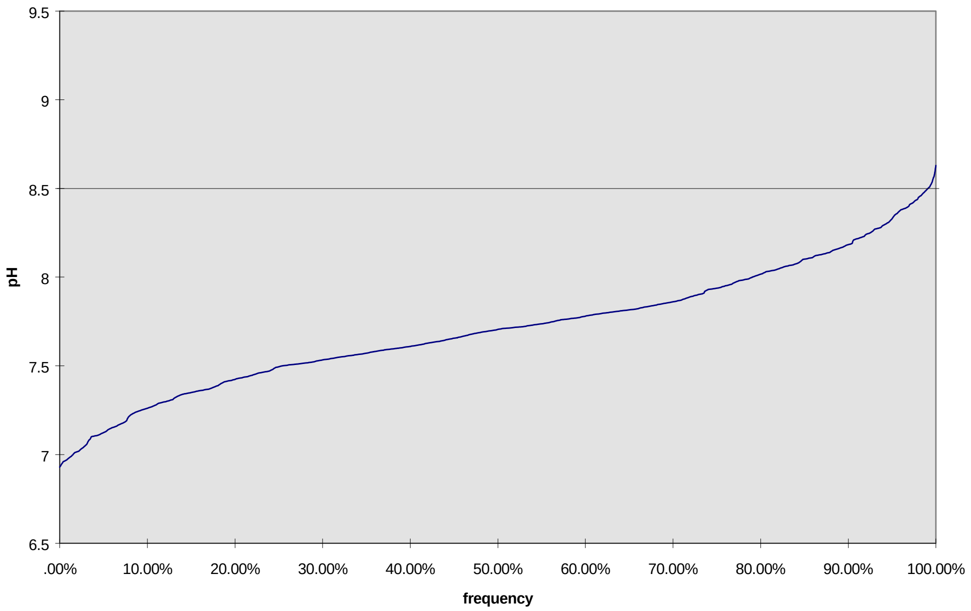

Site MCDD1, August - Sept. 93, pH frequency


Site MCDD1, July 94 pH frequency

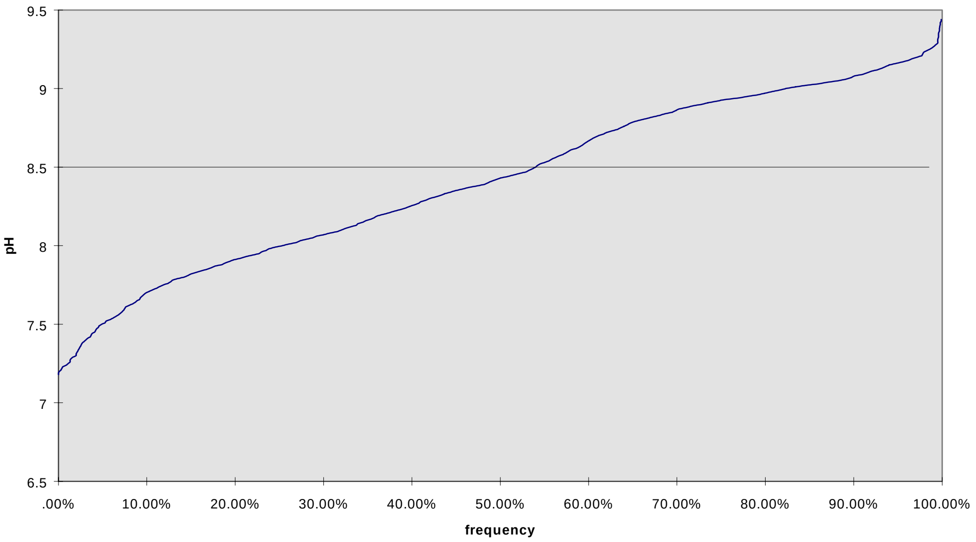
Site MCDD1, July- Sept. 95 pH frequency



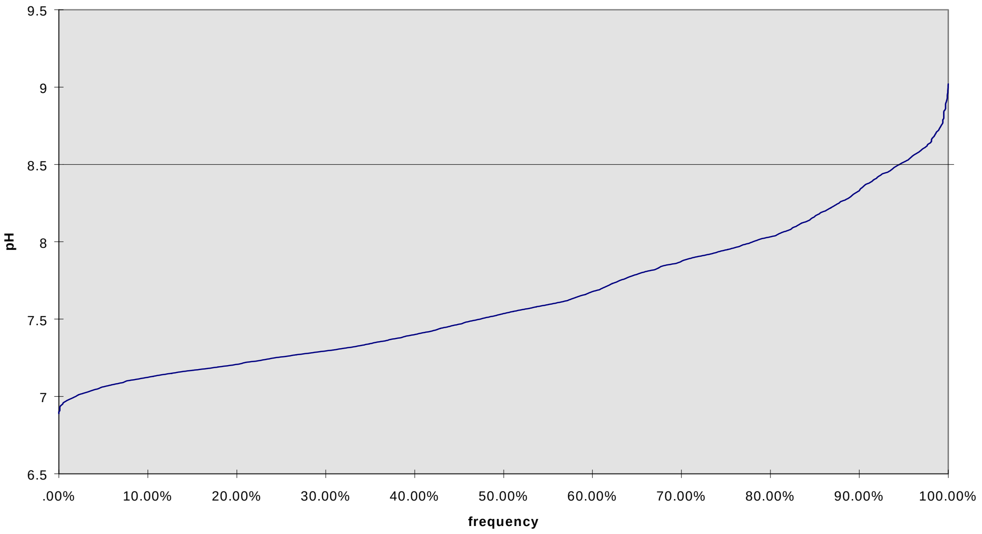
Site SJB, August - Sept. 93 pH frequency

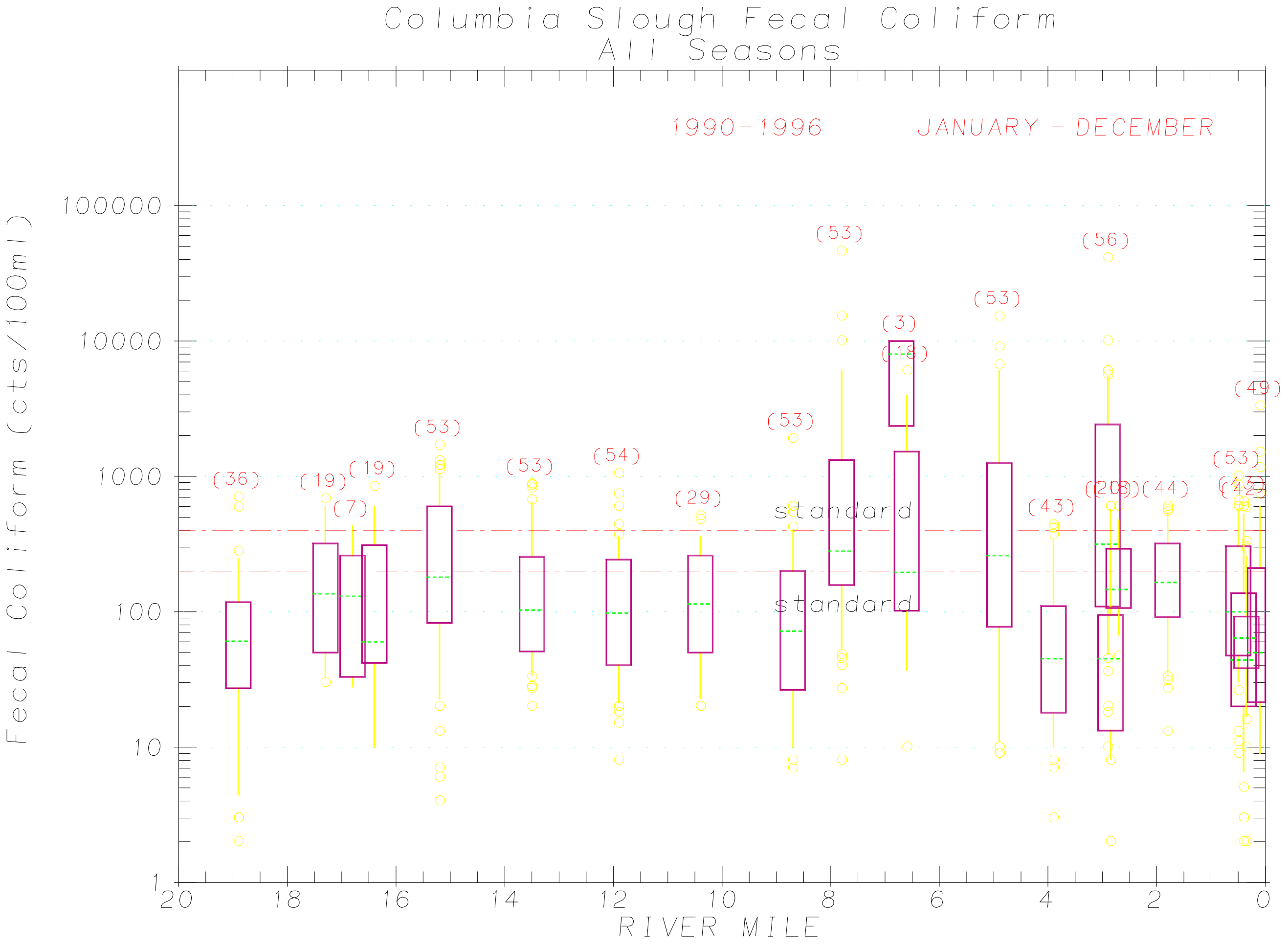


SIte SJB, June- July 94 pH frequency



SIte SJB, July - August 95 pH frequency




Columbia Slough Fecal Coliform
All Seasons
1990-1996
JANUARY - DECEMBER
Fecal Coliform (cts/100ml)
RIVER MILE
100000
10000
1000
100
10
1
20
18
16
14
12
10
8
6
4
2
0
standard
standard
(36)
(19)
(7)
(19)
(53)
(53)
(54)
(29)
(53)
(53)
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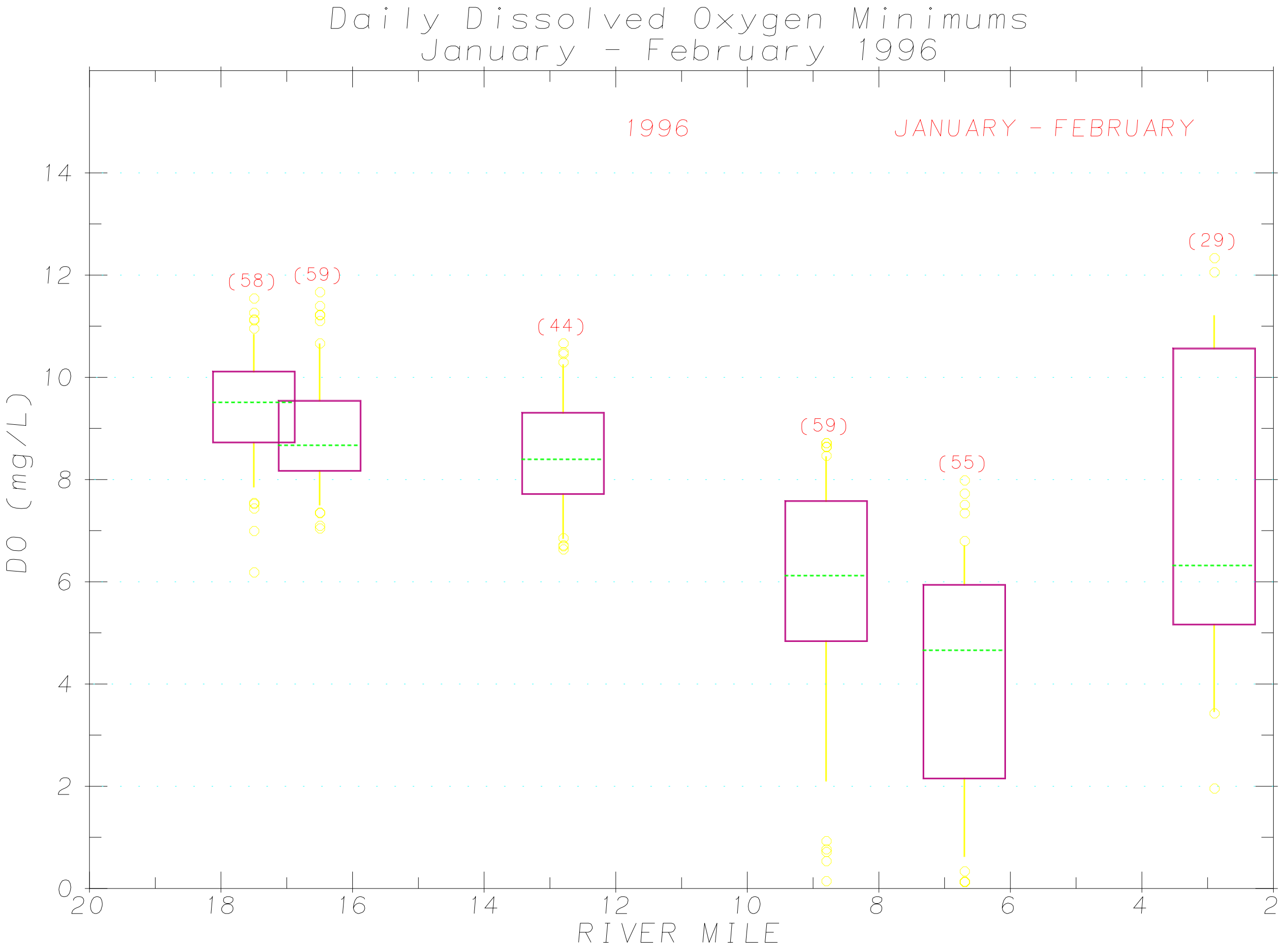
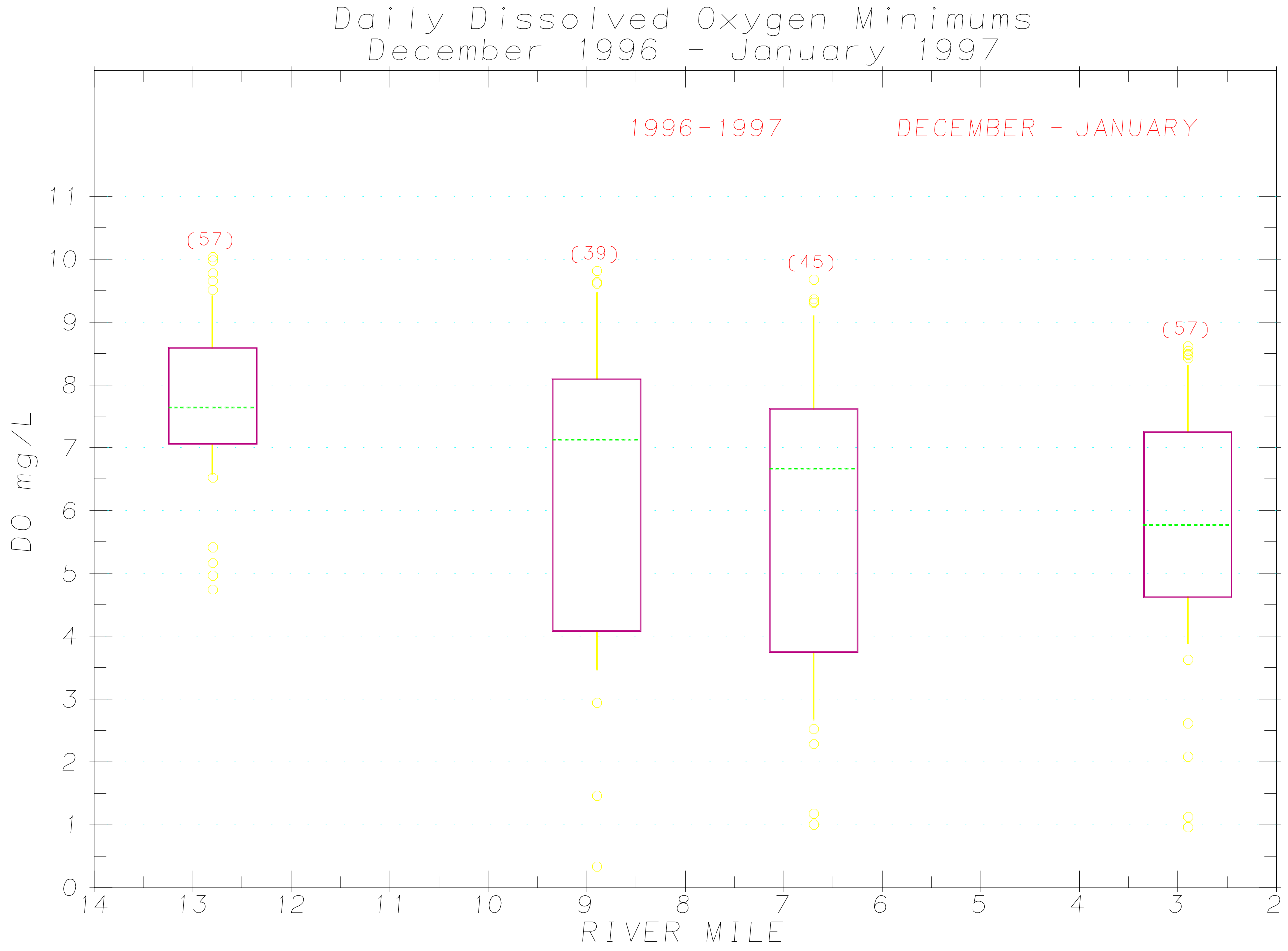
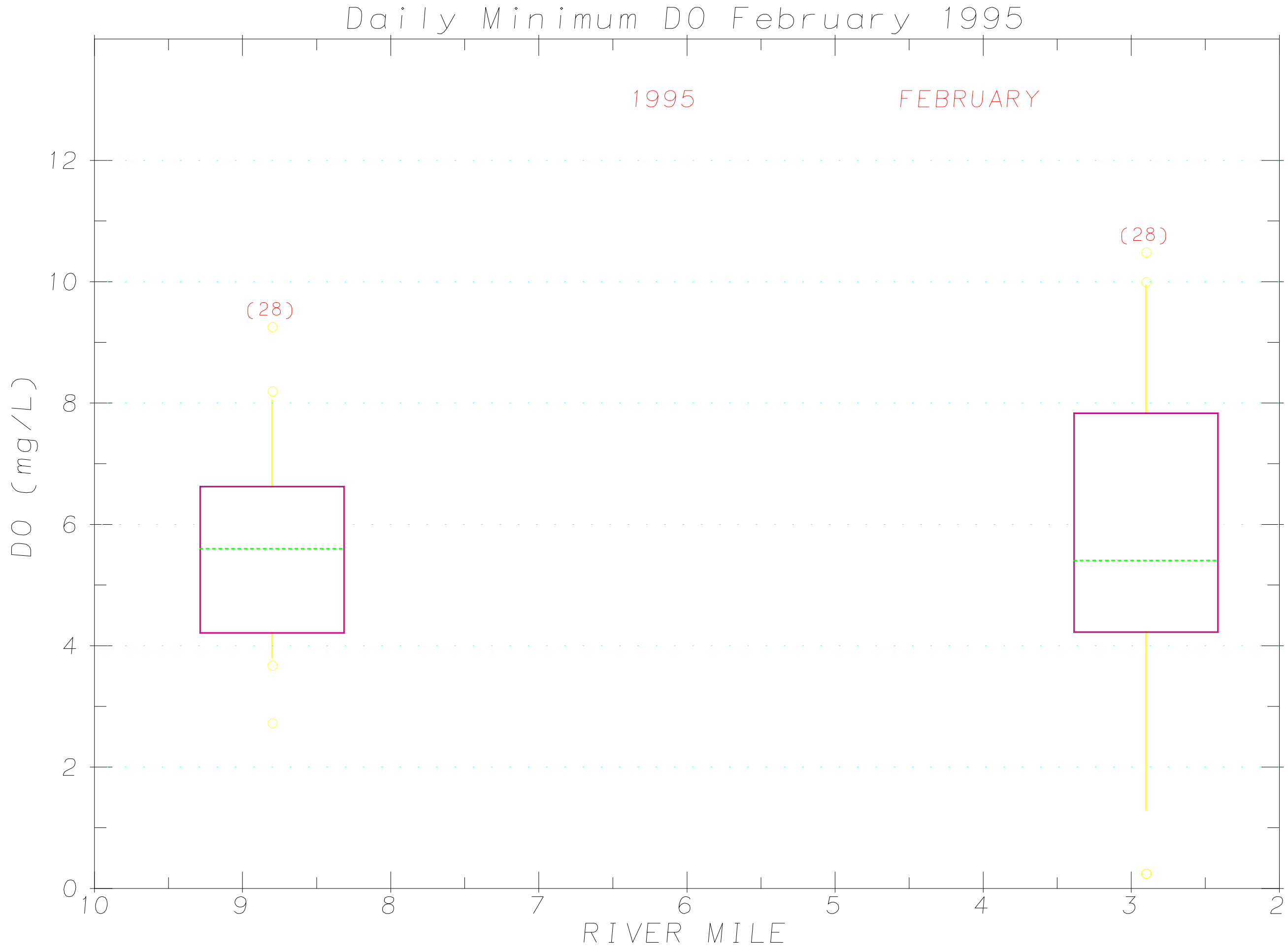
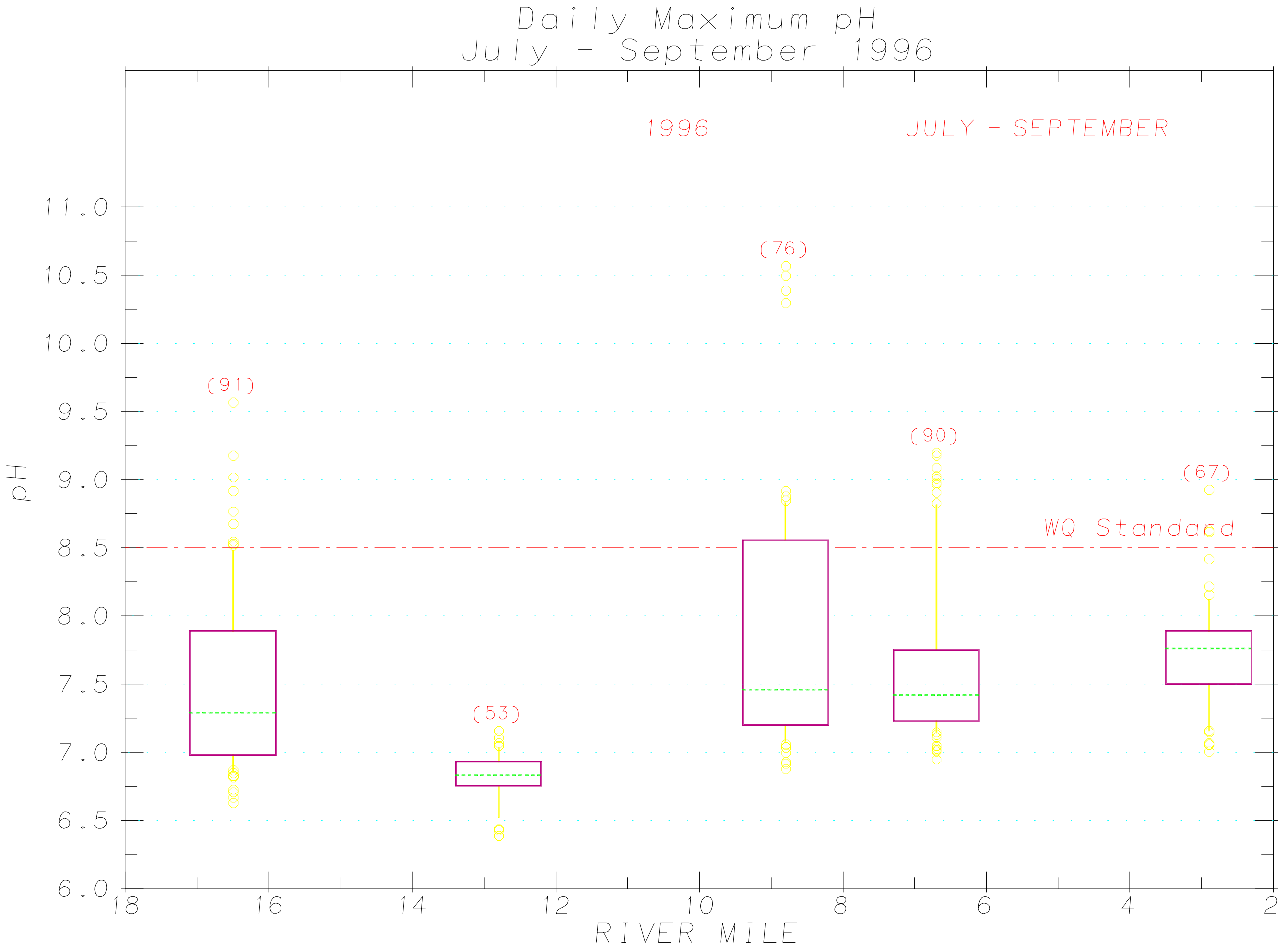
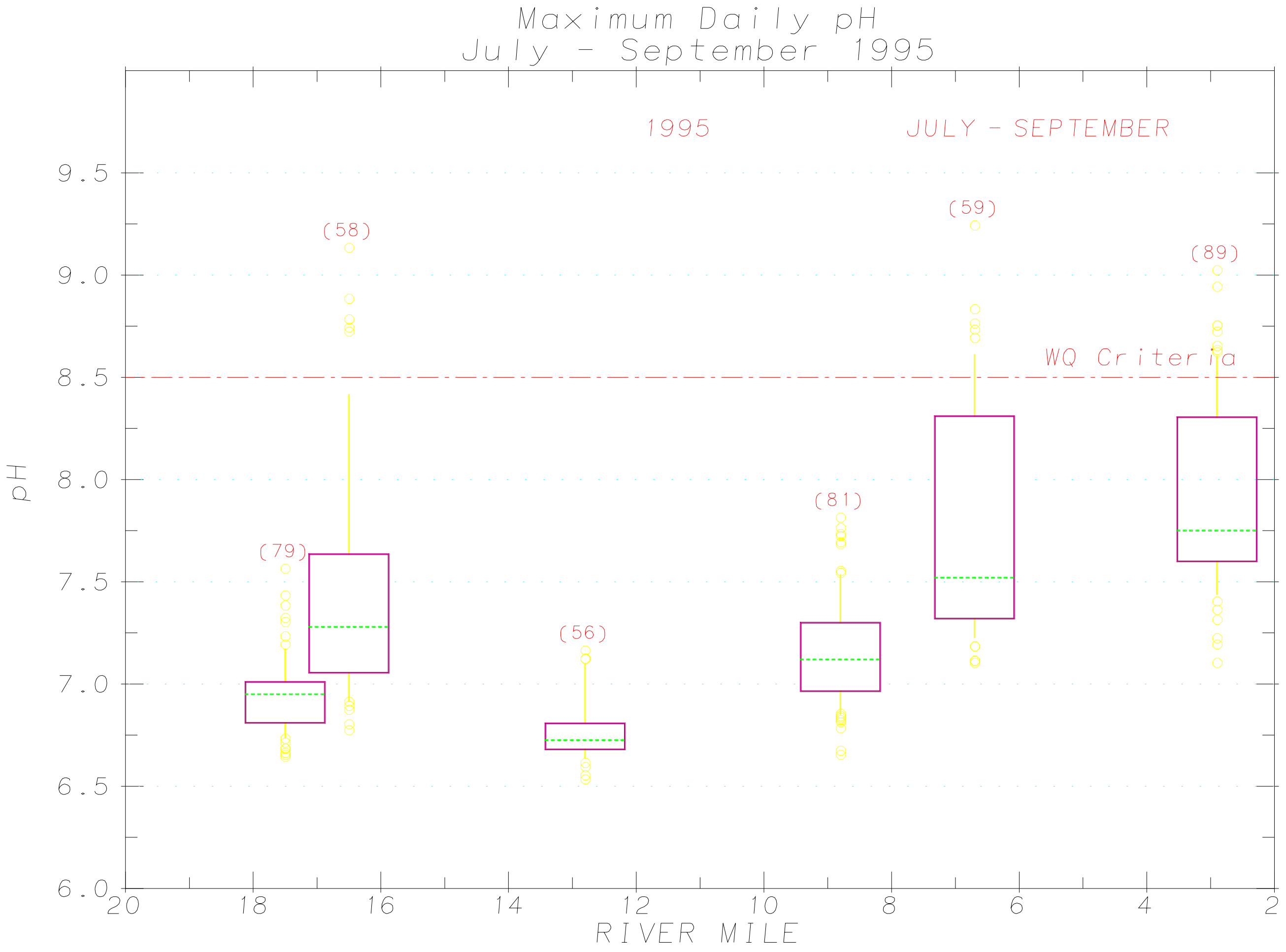
(53)
(47)
(42)
(49)

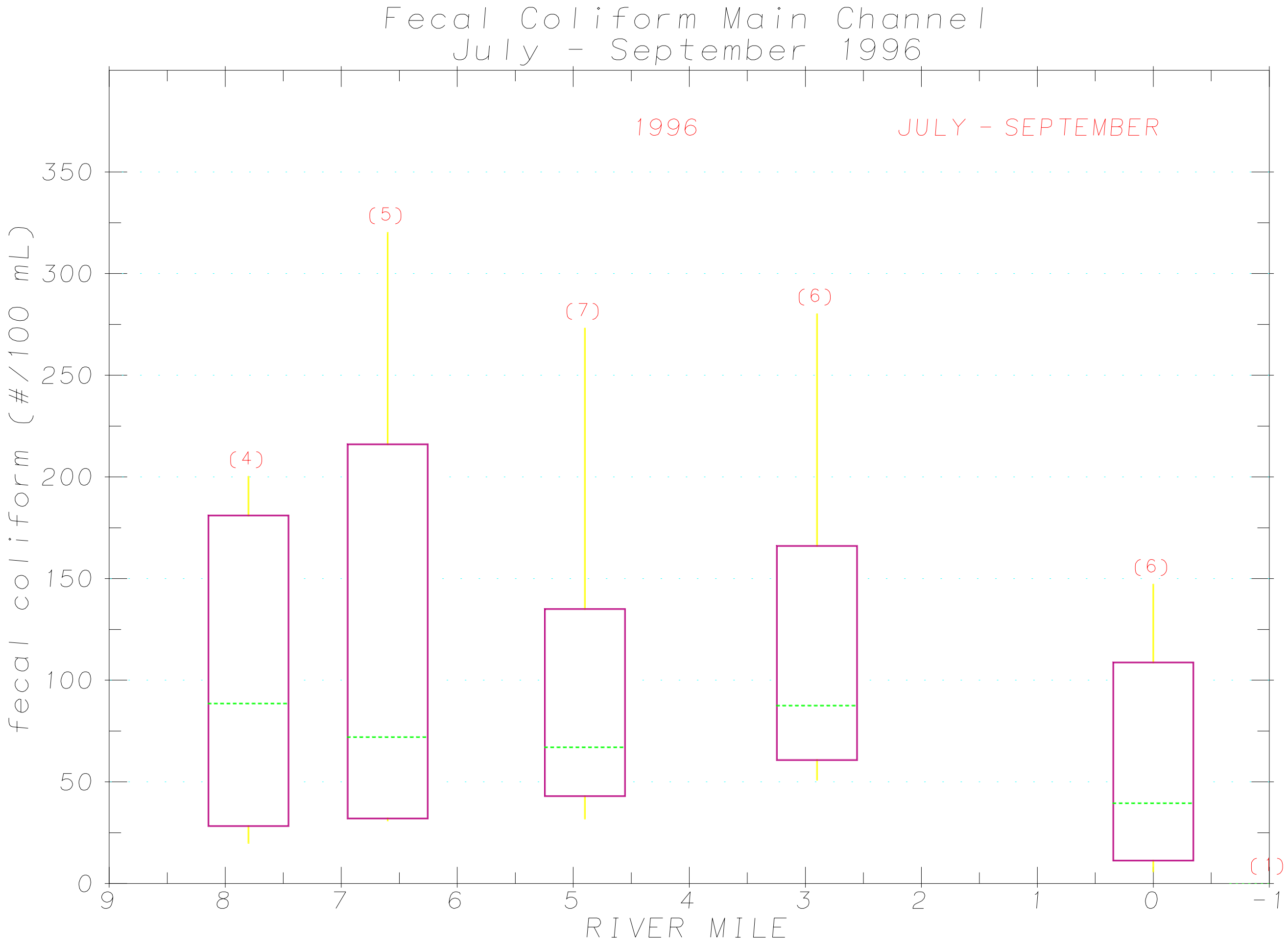

Daily Dissolved Oxygen Minimums
January - February 1996
1996
JANUARY - FEBRUARY
DO (mg/L)
0
2
4
6
8
10
12
14
(58)
(59)
(44)
(59)
(55)
(29)
20
18
16
14
12
10
8
6
4
2
RIVER MILE

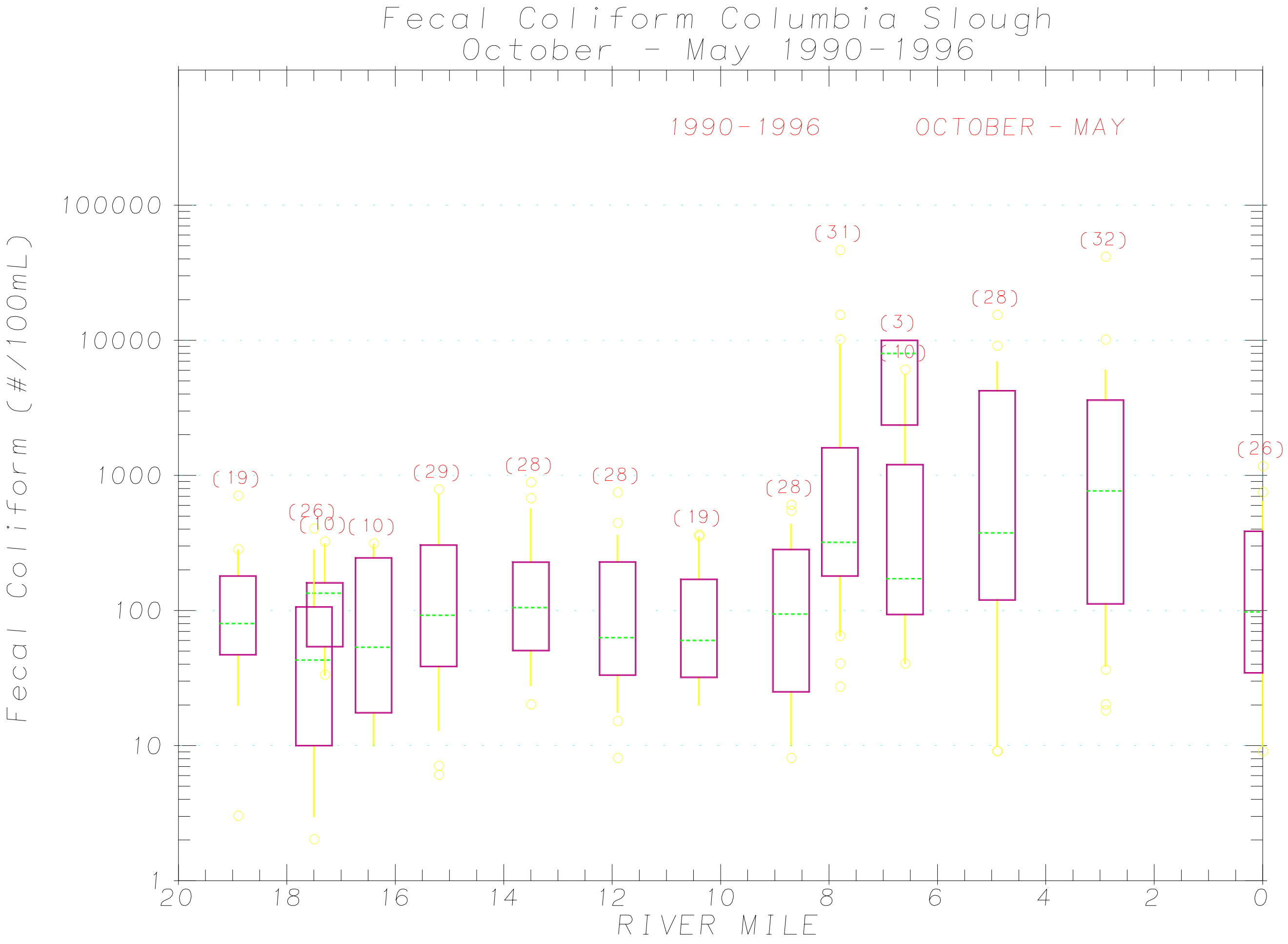

Daily Dissolved Oxygen Minimums
December 1996 - January 1997
1996-1997
DECEMBER - JANUARY
(57)
(39)
(45)
(57)
DO mg/L
0
1
2
3
4
5
6
7
8
9
10
11
14
13
12
11
10
9
8
7
6
5
4
3
2
RIVER MILE

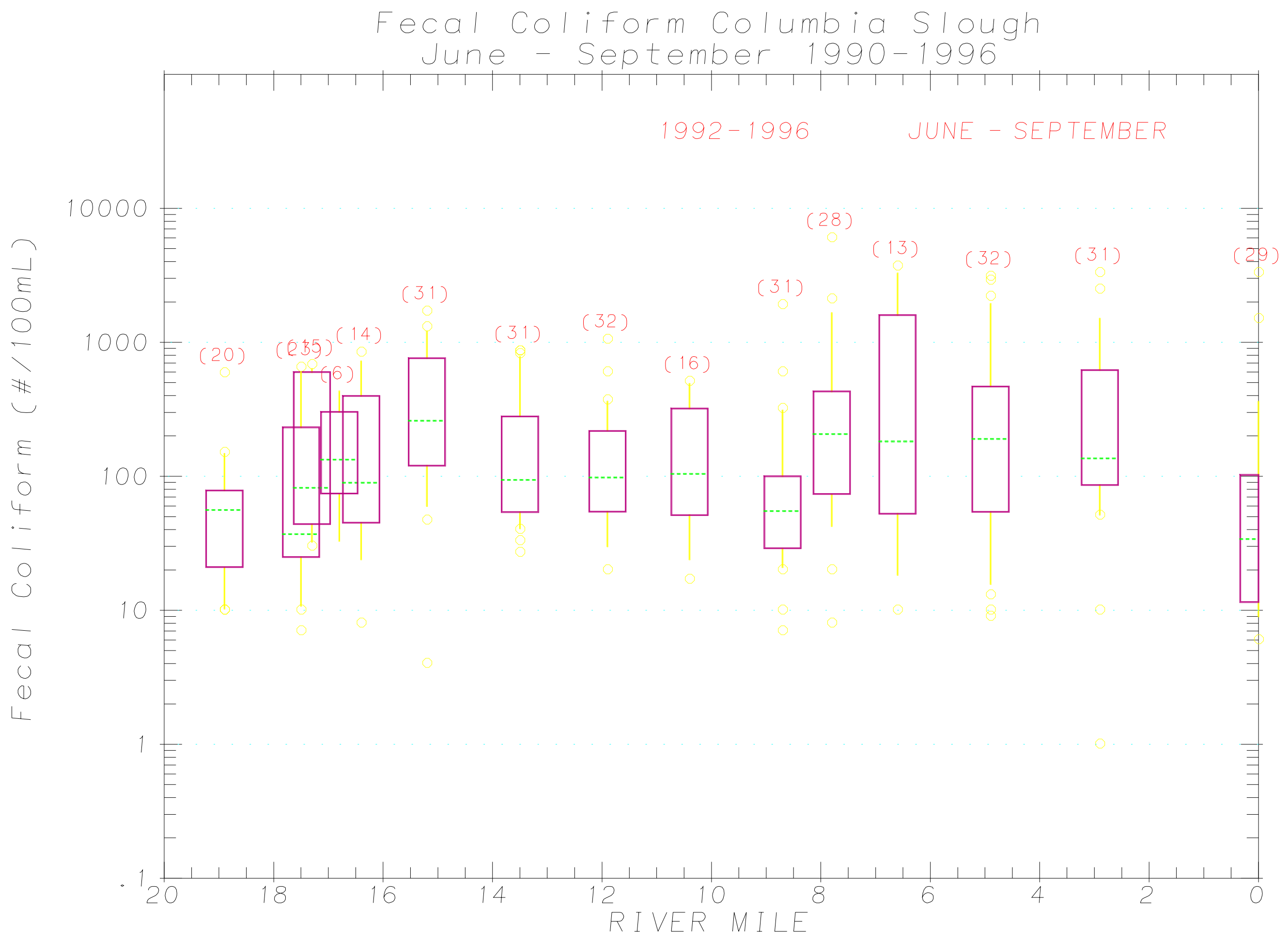

Daily Minimum DO February 1995
1995
FEBRUARY
(28)
(28)
DO (mg/L)
0
2
4
6
8
10
12
10
9
8
7
6
5
4
3
2
RIVER MILE

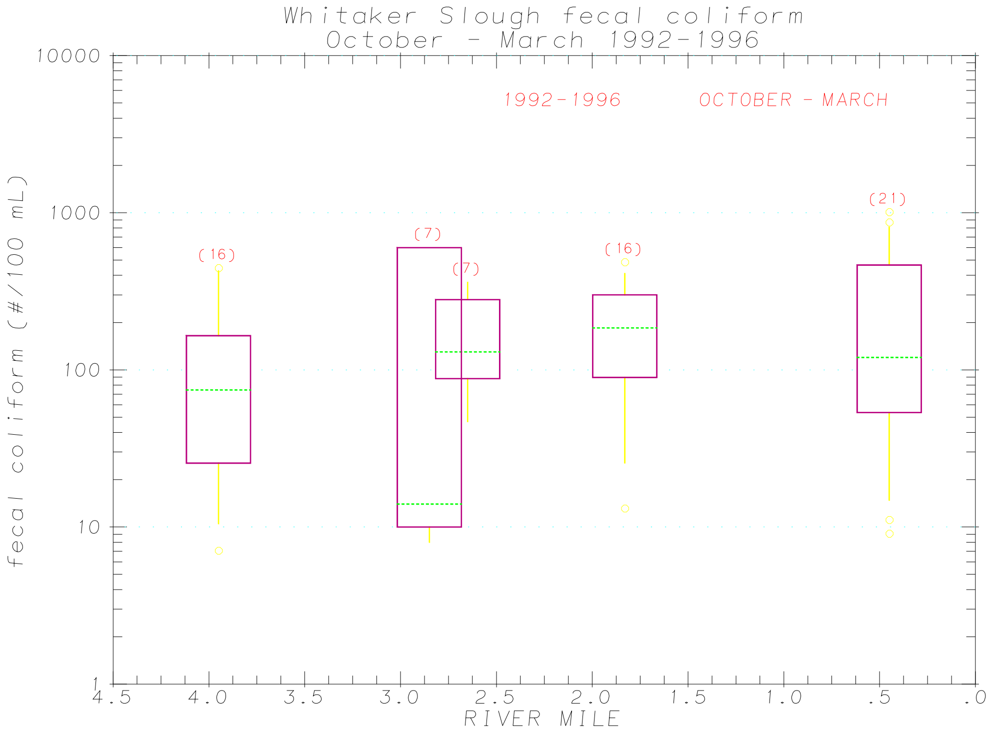

Daily Maximum pH
July - September 1996
1996
JULY - SEPTEMBER
pH
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
(91)
(53)
(76)
(90)
(67)
WQ Standard
18
16
14
12
10
8
6
4
2
RIVER MILE


Maximum Daily pH
July - September 1995
1995
JULY - SEPTEMBER
WQ Criteria
(58)
(79)
(56)
(81)
(59)
(89)
pH
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
20
18
16
14
12
10
8
6
4
2
RIVER MILE

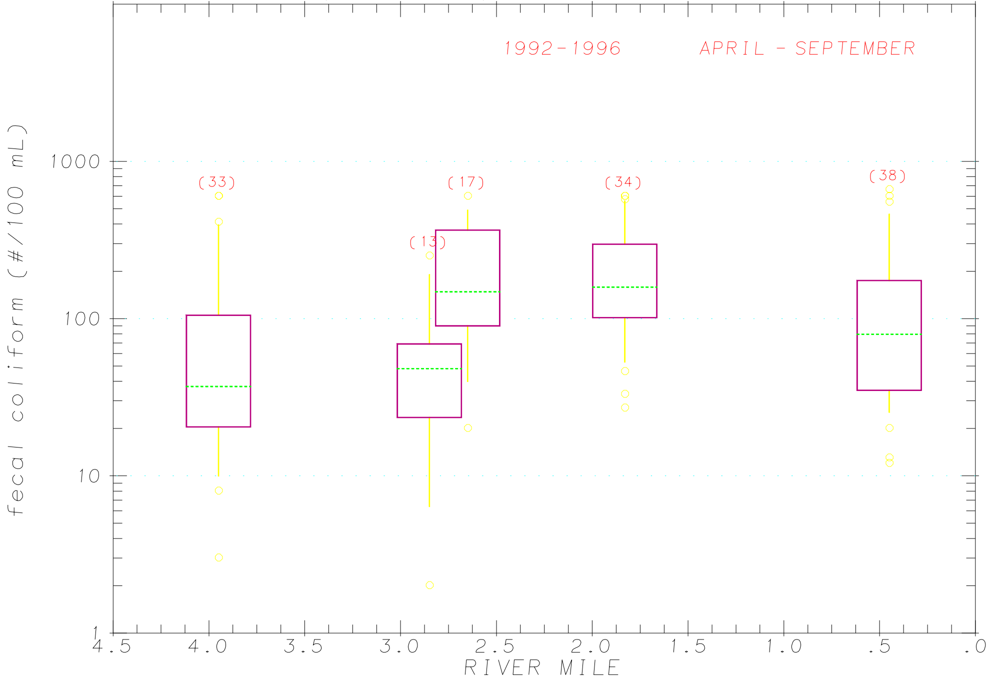
Fecal Coliform Main Channel
July - September 1996
1996
JULY - SEPTEMBER
fecal coliform (#/100 mL)
0
50
100
150
200
250
300
350
RIVER MILE
9
8
7
6
5
4
3
2
1
0
-1
(4)
(5)
(7)
(6)
(6)
(1)

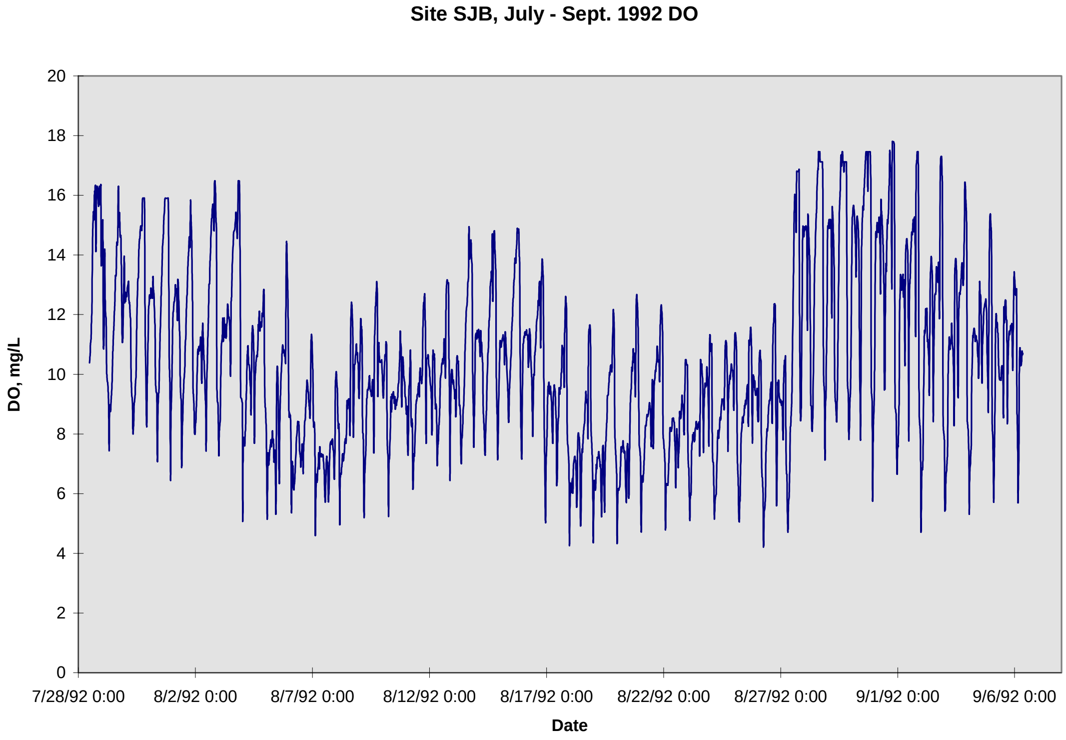

Fecal Coliform Columbia Slough
October - May 1990-1996
1990-1996
OCTOBER - MAY
Fecal Coliform (#/100mL)
100000
10000
1000
100
10
1
20
18
16
14
12
10
8
6
4
2
0
RIVER MILE
(19)
(26)
(10)
(10)
(29)
(28)
(28)
(19)
(28)
(31)
(3)
(10)
(28)
(32)
(26)


Fecal Coliform Columbia Slough
June - September 1990-1996
1992-1996
JUNE - SEPTEMBER
Fecal Coliform (#/100mL)
10000
1000
100
10
1
.1
RIVER MILE
20
18
16
14
12
10
8
6
4
2
0
(20)
(23)
(15)
(6)
(14)
(31)
(31)
(32)
(16)
(31)
(28)
(13)
(32)
(31)
(29)

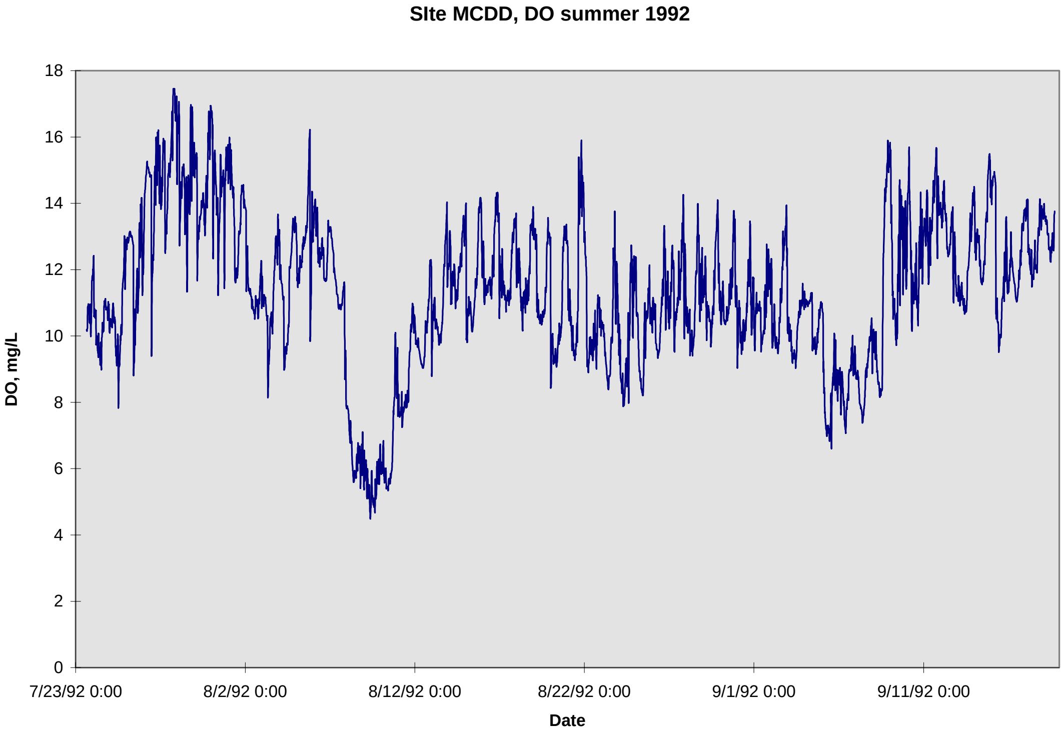

Whitaker Slough fecal coliform
October - March 1992-1996
1992-1996
OCTOBER - MARCH
fecal coliform (#/100 mL)
10000
1000
100
10
1
(16)
(7)
(7)
(16)
(21)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
RIVER MILE

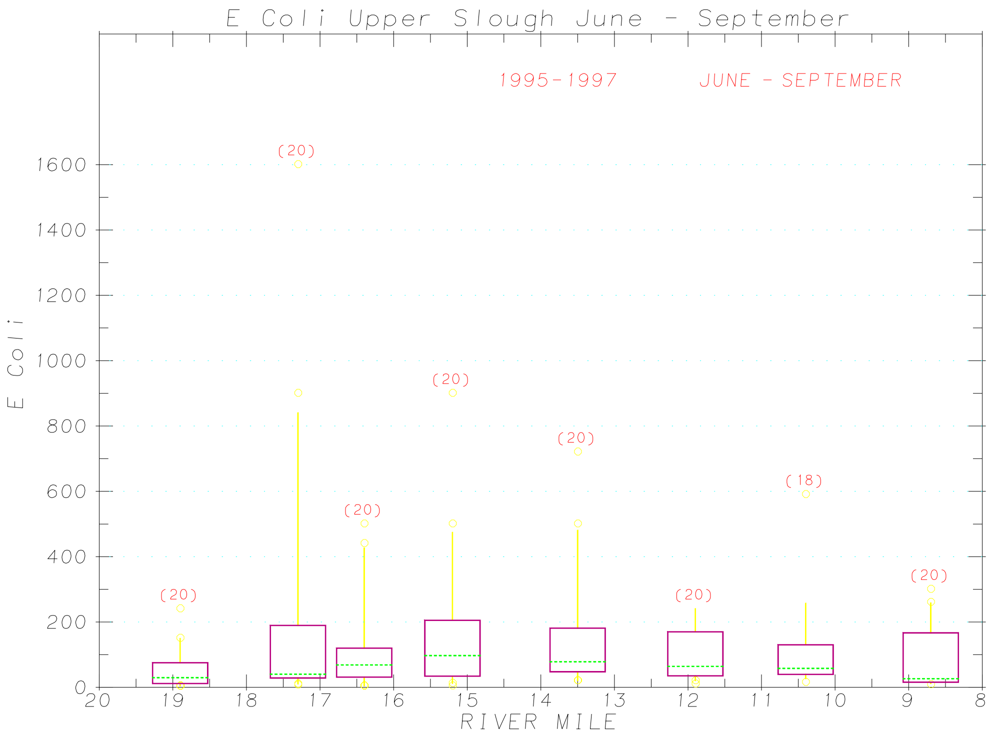
Whitaker Slough Fecal Coliform
April - September 1992-1996

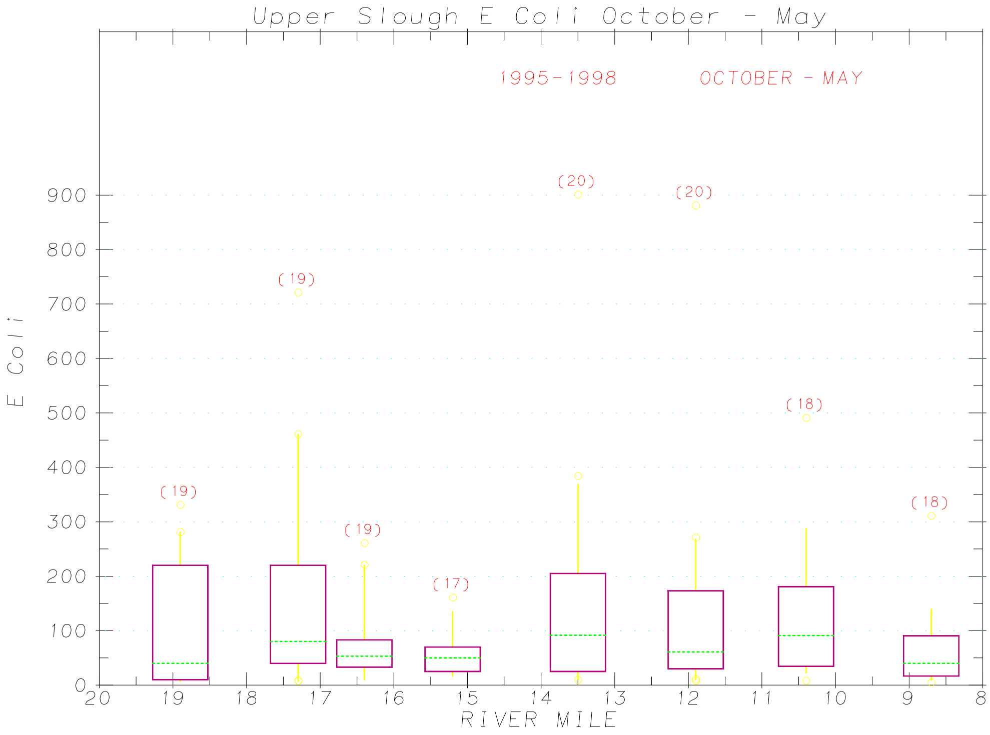




Site SJB, July - Sept. 1992 DO


SIte MCDD, DO summer 1992
DO, mg/L
18
16
14
12
10
8
6
4
2
0
7/23/92 0:00
8/2/92 0:00
8/12/92 0:00
8/22/92 0:00
9/1/92 0:00
9/11/92 0:00
Date


E Coli Upper Slough June - September
1995-1997
JUNE - SEPTEMBER
E Coli
1600
1400
1200
1000
800
600
400
200
0
20
19
18
17
16
15
14
13
12
11
10
9
8
RIVER MILE
(20)
(20)
(20)
(20)
(20)
(20)
(18)
(20)


Upper Slough E Coli October - May
1995-1998
OCTOBER - MAY
E Coli
900
800
700
600
500
400
300
200
100
0
(19)
(19)
(19)
(17)
(20)
(20)
(18)
(18)
20
19
18
17
16
15
14
13
12
11
10
9
8
RIVER MILE

APPENDIX D
GLOSSARY OF TERMS

GLOSSARY

Action level (for chlorophyll *a*): According to OAR 340-41-150, an average chlorophyll *a* level of 15 ug/L is set to identify rivers where algae may impair the beneficial uses. This value is not a numeric criteria, rather it triggers a requirement for DEQ to conduct studies. When this action level is exceeded, DEQ will conduct studies to determine the probable causes of the exceedance and develop a control strategy for attaining compliance with the action level.

Best Management Practice (BMP): A physical, structural, non-structural, or managerial practice, when used singly or in combination, prevents, reduces, or minimizes water pollution and/or water quantity.

Biochemical Oxygen Demand (BOD): The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements are usually conducted over specified time intervals (5, 10 ,20 ,30 days). The term BOD generally refers to the standard 5 day BOD test.

Combined Sewer Overflow (CSO): Discharges from sewer systems that are designed to carry storm water rainfall and snowmelt runoff, along with sanitary sewage, pretreated industrial wastewater, and a certain quantity of flow from storm and groundwater infiltration.

Designated Management Agency: The agency required to develop a Water Quality Management Plan (WQMP) under a Total Maximum Daily Load (TMDL) and having authority to implement the specified control recommendations.

Epiphyte: a plant growing on another plant.

Eutrophication: Enrichment of an aquatic ecosystem with nutrients (nitrates, phosphates) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.

Illicit Discharge: any discharge to a municipal separate storm sewer system that is not composed entirely of storm water (except discharges covered under an NPDES permit).

Loading Capacity (LC): The greatest amount of loading that a water can receive without violating water quality standards.

Load Allocation (LA): The portion of a receiving water's loading capacity that is attributed to either to one of its existing or future nonpoint sources of pollution or to natural background sources. Wherever possible, natural and nonpoint source loads should be distinguished.

Macrophyte: A large, vascular, rooted aquatic plant.

Margin of Safety (MOS): A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS can be incorporated into conservative assumptions used to develop TMDLs, generally within the calculations or models. An additional MOS can be added as a separate component of the TMDL. Quantitatively this is expressed as:
$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$

Memorandum of Agreement: A mutual agreement between Oregon Department of Environmental Quality (DEQ) and the Designated Management Agencies (DMAs) for implementation of the Water Quality Management Plan (WQMP).

National Pollutant Discharge Elimination System (NPDES) Permit: A license to discharge pollutants, as prescribed by the Clean Water Act.

Storm water: storm water runoff, snow melt runoff and surface runoff and drainage

Total Maximum Daily Load (TMDL): The sum of the individual WLAs for point sources and LAs for nonpoint sources and natural background.

Wasteload Allocation (WLA): The portion of a receiving water’s loading capacity that is allocated to one of its existing or future point sources of pollution.

Water Quality Criteria: Water quality criteria consist of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

Water Quality Limited Segments: Those water segments that do not or are not expected to meet applicable water quality standards even after the application of technology based effluent limitations.

Water Quality Management Plan: A watershed enhancement approach which includes goals and objectives that focus on achieving water quality standards at the earliest possible date.

Water Quality Standards (WQS): A law or regulation that consists of the beneficial use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

APPENDIX E
SUMMARY RESPONSE TO COMMENTS

General Comments:

Comment:
Object to dumping of any chemicals into the ground or water
Response:
The State of Oregon has established water quality standards which are designed to protect the beneficial uses of the water. Any actions taken by the Oregon Department of Environmental Quality in regards to the Columbia Slough must lead to the attainment of the standards. When the standards are attained, human health and aquatic life are protected from pollutants that may enter the Slough.

Comment:
Appendices should be numbered distinctly from the main text, Table of Contents should include the appendices, page numbering should be consistent. The document should include a preface "how to read this document' and an executive summary should be added. The glossary should be expanded. Cite references fully.
Response:
The document has been revised to address these comments.

Comment:
Appendices 2 and 3 are difficult to understand, even for technical readers.
Response:
The documents have been revised.

Comment:
Inadequate data to assess sources and substantiate waste load allocations. Toxics requirements are based on limited fish tissue data.
Response:
DEQ disagrees with this comment. There have been extensive data collection efforts on the Columbia Slough. These efforts are extensively documented and are summarized below:

- As part of the Screening Level Risk Assessment (SLRA), fish and crayfish were collected during the summer of 1994 at 10 different locations in the Columbia Slough, and tested for 110 different chemicals. A combined database of SLRA and historical fish, crayfish and shellfish tissue monitoring data contains sample results for 120 chemicals, with between 55 and 94 sample results available for each chemical.
- The City of Portland has monitored water quality in the Lower, Middle and Upper Columbia Slough since 1992. The monitoring has included synoptic and continuous monitoring for dissolved oxygen, pH, temperature, biochemical oxygen demand (BOD), fecal coliform, nitrate, nitrite, total phosphorus, ortho phosphate, turbidity, TSS, ammonia and chlorophyll *a*.
- Municipalities have conducted storm water sampling as required to apply for a NPDES storm water permit. Pollutants measured included BOD, metals, bacteria, and organics. The results of this monitoring are summarized in the permit applications for the City of Portland, the City of Gresham and the co-permittees (Portland MS4

NPDES Municipal Storm water Permit Application, Volume II, submitted by City of Portland and co-applicants, prepared by Woodward Clyde Consultants, May 17, 1993; MS4 NPDES municipal storm water permit application, Part II, Submitted by City of Gresham, City of Fairview, Multnomah County, and Oregon Department of Transportation, May 17, 1993).

This data, along with review by DEQ of point source and Environmental Cleanup Site records, allows for a comparison of the relative loads of the pollutant sources and development of an allocation strategy. DEQ believes that this data set is adequate to set allocations. Uncertainty in the allocations is addressed by the Margin of Safety (MOS) and continuing monitoring requirements.

Comment:
The Total Maximum Daily Loads (TMDLs) do not show that they will lead to attainment of standards.
Response:
DEQ has followed EPA guidance as described in “Guidance for Water Quality Based Decisions: The TMDL Process” (EPA 440/4-91-001, EPA Office of Water, April 1991). This guidance states that a TMDL = Loading Capacity (LC) = ∑Waste Load Allocations (WLAs) + ∑Load Allocations (LAs)+ Margin Of Safety (MOS). The TMDLs developed for the Columbia Slough include an evaluation of the loading capacity of the Slough for each parameter. The loading capacity (LC) is determined by the criterion times the flow, as with Pb, or by modeling, as with dissolved oxygen. DEQ then developed an allocation strategy for each parameter, and assigned an allocation to each identified source. A margin of safety (MOS) to account for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody was developed for each parameter. Assurance of the implementation of controls is provided by the issuance of an NPDES permit, development of a Memorandum of Agreement or development of an agricultural plan. Additionally, DEQ has outlined the requirements of Phase I and Phase II of the Columbia Slough TMDL. These Phases include “monitoring requirements and a schedule for re-assessing TMDL allocations to ensure attainment of water quality standards” (EPA 1991, page 15).

Comment:
The TMDLs do not evaluate the most sensitive uses. The TMDLs do not identify the use of the Slough as for subsistence level fishing (consumption of fish at higher than average levels, consumption of species that have higher than average levels of contamination due to lipid content, consumption of full body rather than fillets).
Response:
The City of Portland conducted fish consumption surveys in the Columbia Slough in1994 and 1995. The surveys were conducted to: identify those fish and shellfish species harvested by local anglers, and obtain detailed information on the fishing habits, fish consumption preferences and fish preparation methods of the anglers (memo to Chee Choy, City of Portland, BES, April 19, 1996, from Adolfson Associates). From this site specific information it was determined that carp was the most commonly caught fish in the Slough. To calculate the human health risk assessments, the site specific fish

consumption rate was used (from the consumption surveys) and consumption rates were calculated for the general population and the high use population. The general population was assumed to eat only fish fillets and the high use population was assumed to eat whole fish (Endangerment Assessment Report for Buffalo Slough, Columbia Slough Sediment Remedial Investigation/Feasibility Study, January 1997, City of Portland BES). The fish consumption rates were used to back calculate to what concentration in fish tissue was necessary to meet the 10^{-6} risk level. DEQ and City of Portland Bureau of Environmental Services (under the oversight of DEQ) continue to work on areas within the Columbia Slough that were identified in the Screening Level Risk Assessment as high priority sites (per consent order DEQ-ECSR-93-09).

Comment:
DEQ uses the terms criteria and water quality standards incorrectly.
Response:
DEQ has changed the language within the Columbia Slough TMDL to clarify that water quality standards include three elements: designated uses for the waterbody, criteria to protect the designated uses, and an anti-degradation statement (EPA 1991, page 11).

Comment:
The TMDL does not describe the source of funding needed to implement many of the control strategies.
Response:
NPDES permit holders secure their own funding to implement the requirements of the permits.
To implement the requirements of the Lower Willamette subbasin plan, several sources of funding are currently available, either through federal programs administered by Natural Resource Conservation Service (NRCS) or a local soil and water conservation district (SWCD). There are also state cost sharing dollars which may be available through the SWCD or through a local watershed council. The state also has funding under the Oregon Plan for Salmon and Watersheds that landowners, associations, or commodity groups can apply for directly. Finally, Oregon is applying to United States Department of Agriculture for additional funding under the Conservation Reserve Enhancement Program.

Comment:
The length of Phase I and Phase II of the TMDL should be specified. Phase II should be described.
Response:
DEQ has included a schedule of Phase I and Phase II. Activities and proposed timelines are in the schedule.

Comment:
Describe the requirements of the Willamette Subbasin Plan (agricultural sources) and include the projected completion date. Assurance that nonpoint source reductions will

occur must be provided in the TMDL (where both point sources and non-point sources receive an allocation).

Response:

The Lower Willamette Subbasin Plan has a tentative completion date of spring 1999 (Peggy Vogue, Oregon Department of Agriculture, personal communication, April 21, 1998).

According to Senate Bill 1010, the Oregon Department of Agriculture may determine which agricultural lands are subject to a water quality management plan due to the establishment of a TMDL for a body of water. Requirements for the agricultural water quality management plans are described in Oregon Administrative Rules, Oregon Department of Agriculture, Chapter 603, Division 90. As stated in OAR 603-90-030 the plans shall include the following:

- a statement that the goal of the plan is to prevent and control water pollution from agricultural activities and soil erosion and achieve applicable water quality standards
- a description of the pollution prevention and control measures necessary to achieve the goal
- a schedule for implementation of the necessary measures
- a strategy to ensure that the necessary measures are implemented

The plan is developed by a local advisory committee, and will not specifically tell farmers what management practices they have to use. Individual water quality farm plans may be developed and would contain practices and strategies the agricultural land owner can implement over time in order to address erosion, use of fertilizer and manure, and other issues that can affect water quality.

Several sources of funding are currently available, either through federal programs administered by Natural Resource Conservation Service (NRCS) or a local soil and water conservation district (SWCD). There are also state cost sharing dollars which may be available through the SWCD or through a local watershed council. The state also has funding under the Oregon Plan for Salmon and Watersheds that landowners, associations, or commodity groups can apply for directly. Finally, Oregon is applying to United States Department of Agriculture for additional funding under the Conservation Reserve Enhancement Program.

Comment:

An explanation of why the flow rates used in developing the loading capacities were chosen must be included.

Response:

The Columbia Slough is a managed system to provide flood control for the lowlands surrounding it. A dike physically separates the Upper Slough from the Lower Slough. Water flows through the Slough by gravity and by periodic pumping at Multnomah County Drainage District Pump Station No.1 (MCDD1). The flow rates of 2.83, 5.66, 8.5 and 11.3 m^3/sec encompass the range of flows possible by pumping at MCDD1. A flow gage was installed in the Lower Slough in 1989. According to this gage, the range of mean daily flow is from a high of 400 CFS (11.3 m^3/sec) to a low of about -240 CFS (the effect of inflows from the Willamette River). This record is summarized in the waterbody assessment (CH2MHill, 1995, Part 2).

Comment:
Air deposition should be added to the list of suspected sources.
Response:
The document has been revised to reflect this comment.

Comment:
All industrial permit holders, as well as those that could be permitted, should be accounted for in the load allocations. The load from industrial sites is under-estimated.
Response:
To estimate the contribution of permitted industrial storm water, DEQ used the simple method (EPA 1992), using an estimate of the area covered by industrial storm water permits. DEQ agrees that there are likely unpermitted industrial sites that are not accounted for in this calculation. The allocations were based the relative contribution of permitted industrial storm water to the overall industrial storm water load. The overall industrial storm water load was obtained from the MS4 permit applications. These loads were derived using an estimate of the area within each basin that fit the industrial land use category. Therefore, all industrial storm water sources were included in the overall industrial load. Industrial facilities that do not have permits are under the jurisdiction of the MS4, until the site is required to apply for a storm water permit. At that time, the allocation for the newly permitted sites will be moved from the MS4 (DMA, as described in the TMDL) allocation to the permitted industrial storm water allocation.

Comment:
The basin specific industrial storm water permit should be issued prior to 2002 (expiration date of the new permit).
Response:
DEQ will develop and issue the basin specific industrial storm water permit according to the schedule described in Phase I of the TMDL. Those industrial facilities within the Columbia Slough basin with storm water permits have not been issued the new 1200z permit. These facilities will be required to apply for the new permit when it is finalized. DEQ currently has the permit on hold and will initiate modifications as soon as the TMDL is approved.

Comment:
DEQ should expand the list of industrial facilities that are included under the storm water industrial permit. DEQ needs to state whether industries will be required to get a storm water permit on the basis of erosion potential alone. TMDL should require BMPs for industrial permittees, as it does for DMAs.
Response:
DEQ will issue a basin specific general permit for industrial storm water. The permit will be required for those industries that fall under the current industrial storm water program. DEQ will add specific facilities and general categories of industries based on information demonstrating that runoff from the sites is leading to water quality

impairment. Such information may include monitoring results from storm water outfalls and determination of exposure based on site visits. Because some of the pollutants are associated with sediment (organics), DEQ will consider requiring permits for sites with erosion potential. Under the permit, DEQ will require BMPs to reduce the pollutant contribution from storm water runoff.

Comment:
All sources should participate in required monitoring.
Response:
All permitted sources will be required to monitor for the 303(d) parameters. The designated management agencies will also be required to monitor, both storm water effluent quality and instream water quality. The memorandums of agreement (MOA) will contain the specific monitoring requirements. DEQ is developing a memorandum of agreement with the Oregon Department of Agriculture (ODA) to implement the SB 1010 plans. Any monitoring requirements will be described in the MOA with ODA.

Comment:
The document must address the eutrophication problem for Fairview Creek and Fairview Lake to be approved as a TMDL for these waters.

A TMDL specifically for bacteria in Fairview Creek must be developed.

The TMDL only addresses phosphorus as a pollutant in Fairview Lake. Sediment should be regulated. Other historical pollutants should be regulated. Loads from Osborn Creek, No Name Creek and Clear Creek should be regulated.
Response:
Fairview Lake and Fairview Creek were placed on the 1994/1996 303(d) list for phosphorus because they are tributaries to the Columbia Slough. However, during the summer months, when algal growth is of concern in the Columbia Slough, the largest source of nutrients to the Slough is groundwater, not Fairview Lake or Fairview Creek. TMDLs for Fairview Creek and Fairview Lake must be developed which contain the required components of a TMDL (calculation of a loading capacity, load and waste load allocations and a margin of safety). A TMDL for Fairview Creek will be developed at a later date to address the water quality limited status for bacteria (1994/1996 303(d) list) and pH (possible 1998 303(d) list). The cities of Gresham, Fairview, and Wood Village will be required to develop and implement management plans to address pollutants in this TMDL. Further efforts may be required to address TMDLs for specific waterbodies within the Columbia Slough basin.

DEQ has no data demonstrating the impact of other pollutants on water quality in Fairview Lake and Fairview Creek.

Comment:
The document incorrectly refers to Oregon Fresh Farms as Oregon fresh Foods
Response:
The document has been revised to reflect this comment.

Comment:
Oregon Fresh Farms is primarily carrot packaging, not processing
Response:
The document has been revised to reflect this comment.

Comment:
Language in the document should be changed from "DEQ may" to "DEQ will" to avoid the impression of unfairness between the DMAs and DEQ.
Response:
Language regarding DEQ activities to implement the TMDL (e.g. development of a basin general industrial storm water permit) has been changed to read “DEQ will” and a schedule for Phase I and Phase II activities has been added to the TMDL.

Comment:
References to the Port of Portland or the Port should be changed to PDX.
Response:
The document has been revised to reflect this comment.

Comment:
Storm water should not be given numerical load allocations.
Response:
According to EPA guidance (EPA Region 10 TMDL Review Framework, draft, November 7, 1997), the TMDL must identify, to the maximum extent practicable, pollutant sources that contribute to the impairment. Storm water has been identified as a source of many pollutants to the Slough, including bacteria, Pb and pesticides. DEQ has developed allocations for the identified sources, to meet the requirements of a TMDL. These allocations are expressed as a mass per time, per EPA guidance. Storm water permits will be implemented through BMPs rather than specific effluent limits. The MOAs will be used to develop and implement strategies and monitoring to show the BMPs will achieve allocations.

Comment:
Multnomah County and DEQ agreed to enter into a Memorandum of Agreement to implement the TMDL. The document should reflect this agreement.
Response:
On December 24, 1997, DEQ issued a modification to the NPDES MS4 permit for Multnomah County. The following statement was added to Schedule A, Condition 2: “This condition 2 of Schedule A to the permit is not applicable to Multnomah County”. Schedule A, Condition 2 states that DEQ will be developing TMDLs, including an implementation program, for several of the receiving streams listed in the permit, including Columbia Slough. Condition 2 also states that DEQ will use memorandums of agreement to insure compliance with the storm water component of the TMDL program. Because this condition is not applicable to Multnomah County, DEQ will likely have to enter into both a memorandum of agreement with Multnomah County and modify the

existing MS4 permit with Multnomah County to include the necessary TMDL components in the permit.

Comment:
The terms Waste Load Allocation and Load Allocation are used incorrectly. Storm water should be given a Load Allocation.
Response:
Storm water is subject to a NPDES permit, and is a point source. The document correctly refers to storm water allocations as waste load allocations.

Comment:
Oregon Department of Transportation has no agreement with DEQ identifying it as a Designated management agency.
Response:
The Oregon Department of Transportation has storm water control responsibilities as a co-permittee of the City of Portland MS4 permit and the City of Gresham MS4 permit. According to the MS4 permits, DEQ will enter into memorandums of agreement (MOAs) with each of the designated management agencies to implement the TMDL requirements. The MOA "will establish mutually agreeable commitments for each jurisdiction" (MS4 permit No. 101315, Schedule A, 2). DEQ and Oregon Department of Transportation are currently developing a statewide MOA.

Comment:
ODOT can not regulate activities that are outside of its highway right of way.
Response:
DEQ expects that ODOT will only regulate activities that are within its highway right of way.

Comment:
Selected transportation BMPs may decrease pollutants such as lead and sediments in storm water, but may decrease dissolved oxygen and increase temperature.
Response:
DEQ is aware that BMPs may affect different water quality parameters. BMPs or a system of BMPs should be selected to address the parameters addressed by the TMDLs. There may be a trade off between pollutants so BMPs should be evaluated and chosen on a site specific basis.

Eutrophication TMDL Comments

Comment:
Document should allow for new discharges of phosphate (may or may not use groundwater in processes).
Response:
Modeling has indicated that new point source wastewater discharges will lead to an increase in pH. New wastewater point sources are given an allocation of zero, spring through fall, when the Columbia Slough is water quality limited because of algal growth.

Comment:
New discharges of groundwater should be allowed. Groundwater extraction operations should be given a waste load allocation other than zero. The groundwater contribution of phosphate must be remediated. Nutrients from local groundwater remediation programs should be regulated.

Response:
Local groundwater remediation programs may result in the discharge of groundwater to the Columbia Slough. Levels of total phosphate in the discharge are by product of the water source and not added during the remediation process. Discharges of groundwater from remediated sites must meet an average concentration of 0.12 mg/L, which is the predicted instream total phosphate concentration in the Slough. The allocation for discharged groundwater is included in the overall groundwater allocation.

Comment:
Oregon Fresh Farms does not have data on phosphorus level in their effluent. Oregon Fresh Farms permit should allow for a monitoring program over the first permit term and use the second permit term for testing of the new treatment system

Response:
DEQ will re-issue the permit for Oregon Fresh Farms when the permit is up for renewal. Specific monitoring requirements, including a schedule and the parameters to be monitored, will be developed at that time. The permit will also include the schedule for compliance with the waste load allocation.

Comment:
The waste load allocation for Oregon Fresh Farms should be included as a load, not a concentration. The use of 20:1 dilution ratio should be explained.

Response:
The mass balance to estimate the effluent concentration for Oregon Fresh Farms was recalculated using flow measurements in Whitaker Slough and measurements of flow from Oregon Fresh Farms. The Whitaker Slough flow was calculated from data provided by Bureau of Environmental Services. There were 161 values for daily flow from July - February, encompassing the time period when Oregon Fresh Farms discharges. The flow for Oregon Fresh Farms was calculated as the average of the average flows recorded in the discharge monitoring reports. The resulting daily average total-phosphate load was calculated and added to the phosphate allocation table.

Comment:
It is unclear whether new storm water outfalls are included in the prohibition of new point source discharges of phosphate.

Response:
The modeling described in the TMDL indicated that additional phosphate loads from waste water point source discharges would cause an increase in algal growth and an increase in pH. The TMDL has been revised to clarify this result

Comment:

Loads and load allocations listed in Tables 5 and 6 should be in kg/day. The load allocations for phosphate should be in a kg/time unit. The months covered by the allocation should be stated. Allocations for new points sources and the individual existing point source should be included in Tables 5 and 6. In Tables 5 and 6 industrial and municipal storm water should be separated.

Response:

The allocations are listed in kg/day and the applicable time period has been identified. Allocations for identified sources are included.

Comment:

MCDD should not be responsible for evaluating the effect of the macrophytes on any beneficial uses except effects related to its flood control operations.

Response:

The eutrophication TMDL states "The DEQ will work with MCDD to develop a management plan and to document the influence of the macrophyte growth on beneficial uses of the Slough." DEQ intends to develop a management plan with MCDD. DEQ will document the influence of macrophyte growth on beneficial uses with DEQ laboratory staff. DEQ, will however, require cooperation of MCDD to access sites for evaluation. DEQ will develop the MOA with MCDD within six months of EPA approval of the TMDLs for the Columbia Slough.

Comment:

There is no MOS for nutrients.

The document does not demonstrate how water level management will result in achievement of the water quality standards for DO, pH, chlorophyll *a* and phosphorus.

The description of eutrophication modeling seems to contradict the assertion that water level management will result in the attainment of the pH and DO criteria. Explain

The TMDL does not address the contribution of particulate phosphates.

If summer storm water loads become more significant as ground water loading decreases, is the affect significant enough to be accounted for in the allocations and the implementation strategy?

Response:

As explained in the eutrophication TMDL, water level management is occurring in the Columbia Slough. To demonstrate the effect of the management on instream DO and pH, additional modeling by Berger (memo from Chris Berger, Portland State University to DEQ, draft May 15, 1998) simulated the current load of total phosphate to the Slough. The effect of nutrient uptake by macrophytes was included in the analysis. Resulting pH is summarized in Figure 10 in the eutrophication TMDL. The results predict that water level management leads to the attainment of the DO and pH criteria. This conclusion is supported by recent instream data included in the TMDL.

Phosphorus is not a water quality criteria. Chlorophyll *a* is an action level, not a water quality criteria. If the action level is exceeded the State is required to initiate a study to determine the cause of the high algal growth. The eutrophication TMDL addresses the cause of algal growth in the Columbia Slough. Attainment of the water quality standards is measured by compliance with the DO and pH criteria.

Dissolved ortho phosphate is the form of phosphate available for algal growth. When algal growth was modeled, the transformation of organically bound phosphate and detrital matter (which are the primary forms of particulate phosphate) to dissolved ortho phosphate was simulated (memo from Chris Berger, Portland State University to DEQ, draft May 15, 1998).

The effect of summer storm water loads was also modeled and compared to the base run, which simulates existing conditions. Results indicate that the effect of summer storm water loads is minimal, with the predicted DO and pH meeting the criteria. These results are summarized in the following table. Run 1 is the base case. Run 2 simulated the effect of summer storm water on pH and DO. Runs 3 and 4 simulate the effect of a 50% and 90% reduction in storm water loads , respectively.

Run #	MCDD Flow (CFS)	Total P (mg/L)	pH (max)	DO (minimum)	DO (7 day mean, minimum)	DO (30 day mean minimum)
1	70	0.12	8.14	7.33	9.44	9.99
2	variable	0.40	8.15	6.01	8.73	9.62
3	variable	0.20	8.15	7.00	9.17	9.83
4	variable	0.04	8.15	7.33	9.58	10.01

The effect of summer storm water on DO and pH is not significant in comparison with the base case (Run 1). Reduction of the storm water load by 50% and 90% did not affect the resulting pH, although the dissolved oxygen did improve.

EPA guidance allows a margin of safety to be developed either by conservative modeling or by establishing a specific allocation. A margin of safety was addressed both by conservative modeling and by setting aside remaining loading capacity and setting a zero allocation for new wastewater point sources of total phosphate. The TMDL and MOS vary by flow and management strategy. These changes reflect the influence of management strategies on the assimilative capacity of the Columbia Slough. Flow management provides the advantage of greater assimilative capacity as well as providing a return to more natural conditions. A TMDL is also presented for the base case to demonstrate the greater nutrient control associated with lower assimilative capacity.

Comment:

The appropriate OAR citation should be included with references to the water quality standards. The language for the pH criteria should be updated to reflect the current regulatory language. A definition for "action level" should be included.

Response:

The language for the pH criteria has been updated.

According to OAR 340-41-150, an average chlorophyll a level of 15 ug/L (a minimum of three samples collected over any consecutive months) is set to identify rivers where algae may impair the beneficial uses. This value is not a numeric criteria, rather it triggers a requirement for DEQ to conduct studies. When this action level is exceeded, DEQ will conduct studies to determine the probable causes of the exceedance and develop a control strategy for attaining compliance with the action level. Language defining an "action level" has been added to the text of the eutrophication TMDL and the glossary. The required studies and control strategies have been developed.

Comment:
If nutrients are stored in the sediment they should be accounted for in the TMDL.
Response:
There is no data quantifying the flux between sediment and Slough water quality. Sediment may act as a sink for nutrients as well as a source. There are numerous interactions that take place in the Slough, (i.e. groundwater contribution of phosphate and phosphate uptake by algae) and the effect of these interactions are likely to have a greater effect on Slough water quality than sediment loads during the winter and subsequent sediment flux in the summer.

Comment:
The TMDL does not account for the impact of summer storm water loads.
Necessary load reductions for storm water BMPs should be stated.
Response:
Modeling by Wells (EWR-2-95) simulated the effect of various management strategies on water quality in the Slough. The time period simulated was August 1 through September 30, 1992. The results from this effort indicated that removal of the storm water load of ortho-phosphate would lower the phosphate concentration in the Upper Slough from 0.07 mg/L to 0.06 mg/L, while the chlorophyll *a* concentration would change from a mean of 54 ug/L to a mean of 52.3 ug/L. The effect of removal of summer storm water loads was not significant.

Comment:
The parameters to be measured in Fairview Lake and Fairview Creek should be specified.
Response:
Water quality parameters will include DO, pH, temperature, chlorophyll *a*, dissolved ortho phosphate, total phosphate and bacteria.

Comment:
The TMDL should establish required flows to lead to the attainment of standards. The flows should be included in the allocation tables.
Response:
The influence is more than flow and depends on water level management. MCDD has agreed to enter into a MOA with DEQ to maintain water level strategies in the Slough to enhance water quality. The MOA will express the conditions needed to meet water quality standards. If conditions of the MOA are not met, DEQ will re-assess the TMDL

and the allocations to attain water quality standards and take available regulatory actions needed to attain water quality standards.

Comment:
The TMDL does not adequately address the contributions of point sources to the eutrophication problem.
Response:
Source modeling has indicated that groundwater is the major source of ortho-phosphate in the summer. Existing point sources are mainly cooling water discharges, and as such have ortho-phosphate levels that are a byproduct of the water source. One point source has been identified as possibly contributing phosphate, and has received an allocation that will result in no measurable increase in ortho-phosphate levels instream. Additional modeling has indicated that new process wastewater point sources of phosphate will lead to increased pH and chlorophyll *a* concentrations, so new wastewater point sources are given a waste load allocation of zero, in the spring through fall.

Dissolved Oxygen TMDL Comments:

Comment:
DEQ should describe how new discharges would demonstrate that adequate reserve capacity exists to receive an allocation.
Response:
The allocation for future growth was calculated to account for the BOD load from the area in the Slough drainage basin that is not yet developed but will become urban. According to the allocation modeling, to meet the urban storm water allocation, the average storm water concentration should be about 8 mg/L BOD_5. If the DMAs design the BMPs to achieve the target concentration of 8 mg/L, the net load will meet the reserve allocation. If the area under development increases beyond that reserved in the future growth allocation, the concentration of the storm water will have to drop to meet the allocation. New industrial storm water point source discharges will be required to implement the BMPs to meet the BOD_5 target concentration as outlined in the storm water permit.

DEQ would determine if capacity exists in the future growth allocation to allow new point source (non storm water) discharges.

Comment:
No mechanism for effluent trading is described.
Response:
A process does not currently exist to allow for effluent trading. To be effective any effluent trading process would have to demonstrate the following: the loads traded were allocated loads; the trade would result in no net increase in BOD discharge; and the trade would continue indefinitely (i.e. one party would not fail to meet the traded allocation).

Comment:
The use of the proportional reduction of BOD is not explained.

The percent reduction equivalent to the relative contribution is unclear. The document appears to say that 3.8 lb. of de-icing fluid must be removed for every 1 lb. of urban storm water BOD, yet the allocation table (Table 2) does not reflect this ratio.

Response:

EPA guidance (Guidance for water quality based decisions: the TMDL process, EPA 440/4/-1/001) describes three common methods for allocating loads. The first is equal percent removal, the second method specifies equal effluent concentrations. The third method is a hybrid method in which the criteria for waste reduction may not be the same from one source to the next. A proportionality rule may be assigned that requires the percent removal to be proportional to the input source loading or flow rate. The allocations in the TMDL require PDX to reduce current BOD loads by 85-95% (based on comments provided by PDX). DEQ feels that it would be inappropriate to require urban storm water to meet the same percent reduction, or same effluent concentration, as PDX, when the de-icing and anti-icing load from PDX has been identified as the primary cause of the dissolved oxygen depletion during the winter in the Columbia Slough. DEQ, therefore, feels that allocations based on the relative contributions of the pollutant is appropriate for a situation in which one source causes most of the water quality impairment.

The ratio of 3.8 lb. of de-icing fluid to 1 lb. urban storm water load reflects the decrease from current BOD loads to meet the dissolved oxygen criteria. The ratio is based on data from one storm event. DEQ recognizes that the ratio will vary by event. The final allocations do not represent a ratio of 3.8 lb. of de-icing fluid to 1 lb. urban storm water, but a relative reduction designed to be proportional to the amount of BOD discharged to the Slough.

Comment:

The document assumes that all industrial facilities requiring a storm water permit have one, this is not true. Not all discharges from permitted industries are through a DMA.

Response:

The TMDL states that the calculations to estimate the contribution of permitted industrial storm water assumes that all facilities that require a permit have one. DEQ realizes that there may be many facilities within the Slough basin that are unpermitted. However, without an estimate of the area covered by unpermitted sites, there is no method to calculate their pollutant contribution. During Phase I of the TMDL, DEQ will work to increase the number of permitted facilities in the Slough basin. Monitoring data from these sites will help to refine the estimates of the relative contributions to the pollutant loads.

Comment:

There is no allocation for future growth at the airport.

Response:

Future growth at the airport does not receive a separate allocation. Increased load of BOD, such as that likely due to the addition of a runway, must be controlled by the permittee so that the permit limits for BOD are met.

Comment:
The Port should not be allowed to set their own allocation.
Response:
Allocations for PDX will be contained in an NPDES permit. PDX conducted monitoring in the winter of 1997/1998 to refine the estimates of the de-icing contribution to the BOD load as well as quantify the instream response. PDX proposed to conduct additional modeling, during the course of the permit term. DEQ recognizes that the modeling may result in changes to the loading capacity and allocations. All modeling would be reviewed by DEQ staff. Allocations would still be required to result in compliance with water quality standards and any changes to the allocations would be in a revised permit.

Comment:
Identification and implementation of BMPs (at the Port of Portland to control de-icing discharge) should be split into two phases.
Response:
PDX will implement structural and non-structural BMPs to meet the allocation for BOD. The selection and implementation of the BMPs may occur in parallel efforts, rather than sequentially. Time frames for implementation of the BMPs will be contained within the permit for PDX.

Comment:
A description of the BOD spreadsheet model should be included.
Response:
The document has been revised to address this comment.

Comment:
The Portland State Model should not be used to develop the Port's allocations.
Response:
DEQ agrees that the model used to develop the BOD allocations should be peer reviewed. DEQ does not object to the use of another model to simulate the instream response to the BOD load estimates. DEQ staff will review modeling results to assure that final BOD allocations are in compliance with water quality standards. Should PDX fail to refine the modeling with the additional monitoring results, the allocations developed in the TMDL will be PDX’s permit limits. These allocations were derived using the spreadsheet model described in the TMDL.

Comment:
Re-aeration should be included in the TMDL as a controllable variable. The Port should be required to reduce the de-icing load and take other appropriate measures to address the DO issue in the Slough.
Response:
As stated in OAR 340-41-445, the State water quality standards require “the highest and best practicable treatment and/or control of wastes, activities, and flows shall in every case be provided so as to maintain dissolved oxygen and overall water quality at the highest possible levels…”. Additionally, the water quality standards state “Oregon’s water quality management policies and programs recognize that Oregon’s water bodies

have a finite ability to assimilate waste. Unused assimilative capacity is an exceedingly valuable resource that enhances in-stream values specifically, and environmental quality generally" (340-41-026). These regulations emphasize the State's general policy that waste must be treated and instream treatment or use of the receiving water body to treat the waste is unacceptable.

Comment:
Flows of up to 11.33 m^3/sec should be included in the allocation table. Flows of 400, 500 and 600 CFS should be included in the allocation tables.

Response:
The Columbia Slough is a managed system to provide flood control for the lowlands surrounding it. A dike physically separates the Upper Slough from the Lower Slough. Water flows through the Slough by gravity and by periodic pumping at Multnomah County Drainage District Pump Station No.1 (MCDD1). The flow rates of 2.83, 5.66, 8.5 and 11.3 m^3/sec (100-400 CFS) encompass the range of flows possible by pumping at MCDD1. A flow gage was installed in the Lower Slough in 1989. According to this gage, the range of mean daily flow is from a high of 400 CFS (11.3 m^3/sec) to a low of about 240 CFS (the effect of inflows from the Willamette River). This record is summarized in the waterbody assessment (CH2MHill, 1995, Part 2).

Comment:
A loading allocation should not be defined for the non de-icing season. Specify applicable months for the BOD allocations.

Response:
The DO TMDL contains the loading capacity for BOD. The loading capacity section has been revised to read "The resulting load allocations are for the winter months of November through April. Allocations are not defined for BOD loads during the summer months." The summer dissolved oxygen depletion (see Figure 3) appear to be the result of stagnant water and algal processes, not BOD loads, so no BOD allocations are set for the summer months.

Comment:
The design temperature for the BOD modeling should not be 8 degrees C. The Lower Slough DO is impacted by more than de-icing discharges. The Port's permit should use a one in five year winter storm interval.

Response:
Loading capacity calculations and resulting allocations are for a 'reasonable worst case' storm event. The conditions for this event are described in Appendix B. These conditions include: freezing weather (with de-icing occurring) followed by warm weather and increasing instream temperatures and high stage in the Willamette River. DEQ acknowledges that these critical conditions may not be met every time a de-icing event occurs. However, DEQ must develop permit limits that will result in attainment of dissolved oxygen criteria when the "reasonable worst case" storm event occurs.

Comment:

The Port should be not be required to spend millions of dollars to treat a discharge which occurs a few days a year. The Port should be allowed to address other water quality problems instead.

Response:

Permits must result in the attainment of water quality standards. Water quality standards include: numeric and narrative criteria, beneficial uses and anti-degradation policy. EPA's policy is that of independent applicability, that is, all portions of the water quality standards must be attained, independent of each other. DEQ can not disregard the attainment of the dissolved oxygen criteria in favor of other water quality or habitat parameters.

Comment:

Five years of additional data should be collected before the Port receives an allocation. The date for model calibration should be changed to October 31, 2000. The final TMDL should not be set until the winter of 2000. Data should be collected for at least one more winter before an allocation is set.

Response:

DEQ has agreed to allow for two additional years of storm event monitoring. Monitoring will occur in winter 1998/1999 and winter 1999/2000 and will include both loading and instream sampling. DEQ will require PDX to use DEQ approved quality assurance/quality control plans. The additional data will be used to refine the dissolved oxygen model calibration and the loading capacity. The model calibration, revised loading capacity, and allocations will be complete by October 2000.

Comment:

Table 3 should be referenced in the text. Figure 6 in Appendix B has no title nor a legend for the y-axis. Several other figures have no titles.

Response:

The document has been revised to reflect this comment.

Comment:

The TMDL discharge limit on PDX is extreme.

Response:

DEQ used the best information available to develop the allocations contained in the DO TMDL. The allocations were developed so that the dissolved oxygen criteria would be attained, even under 'reasonable worst case' storm conditions. DEQ acknowledges that the allocation may require substantial reductions in the BOD load from PDX, however such reductions are required to attain compliance with the dissolved oxygen criteria.

Comment:

The TMDL was developed without adequate airline participation.

Response:

PDX is responsible for the BOD load discharging from their outfalls. The allocation set in the TMDL is for PDX, not for specific airlines. DEQ believes that it is the responsibility of PDX to confer with the airlines and any tenants at PDX to assure compliance with the allocation. Additionally, DEQ believes the 60 day public comment period provided adequate opportunity for review of the allocations. Prior to the issuance of any of the permits to be developed to implement the TMDL allocations, there will be an opportunity for additional comments, during the public comment period for the permits.

Comment:
Table 1 and 2 are inconsistent in the Margin Of Safety (MOS) column. The MOS (beyond 20%) should be allocated to the sources.
Response:
DEQ agrees that the MOS varies from Table 1 to Table 2. This variation occurred due to rounding in the calculations to allocate the loading capacity among the sources. The differences in daily mass (kg) were allocated to the MOS, providing a greater assurance of compliance with the dissolved oxygen criteria.

Comment:
The Port's outfalls discharge a combination of de-icing and storm water discharges. The storm water contributions should be subtracted from the de-icing allocation.
Response:
The allocation for PDX is specifically for de-icing and anti-icing fluid. Because PDX is also a co-permittee under a MS4 permit, a portion of the DMA allocation also is allocated to PDX, for its' non de-icing BOD load. According to the allocation modeling, to meet the urban storm water allocation, the average storm water concentration should be about 8 mg/L BOD_5. For those outfalls that discharge a combination of storm water and de-icing fluid, the storm water allocation is set at the target BOD_5 concentration of 8 mg/L times the volume of storm water flow. This allocation is then added to the de-icing allocation.

Comment:
The allocation to the Air National Guard is not discussed as a permit.
Response:
The Oregon Air National Guard (OANG) will be co-permittees and covered by the PDX permit. The OANG allocation is included in Table 2.

Comment:
It is not clear how the 20% MOS was developed.
Response:
A detailed explanation of the development of the 20% MOS is contained in Appendix B. To determine the MOS a range of BOD loading capacities were calculated. The loading capacity was calculated as the initial BOD that would create a dissolved oxygen deficit equal to the difference between saturation and the dissolved oxygen criteria of 4 mg/L. A range of values for decay, aeration and theta (variation with temperature) were used in these calculations. The 20% margin of safety represents one standard deviation around the average loading capacity calculated.

Comment:

It is questionable that DEQ is requiring reductions of 1/3 to 2/3 of current BOD levels for reaches 4 and 5.

The allocation formula anticipates a constant reduction in BOD loads from storm water. This is unachievable.

Response:

As explained in Appendix B, estimates of the current BOD_5 concentration in storm water range from 5 mg/L to 21 mg/L. The variability is due to differences in event mean concentrations used and whether losses of BOD were accounted for. According to DEQ's model estimates, when the criteria are met (after BMP implementation) the resulting storm water BOD_5 concentration will average about 8 mg/L. Based on these results, a reduction of 1/3 to 2/3 of the current BOD concentration is unlikely. Monitoring conducted in winter 1997/1998 will be used to refine the estimates of the BOD load (storm water and de-icing fluid) and the resulting instream concentration. The percent reduction targeted for storm water will be better quantified at that time.

Comment:

It is unclear how the expected 150% increase in storm water pollutant loading relates to the calculation for the allocation for future growth.

Response:

DEQ interpreted the results of the Simplified Particulate Transport Model (SIMPTM) to mean that storm water pollutant loads would increase 50% over the current estimated loads. This is reflected in the allocation calculation that sets aside 1/3 of the urban storm water allocation for future growth.

Comment:

Does future growth include discharges to an MS4 or only directly to the Slough?

Response:

The waste load allocation for future growth was derived by setting aside 1/3 of the total urban storm water waste load allocation. The allocation for future growth includes discharges to an MS4 as well as discharges directly to the Slough.

Comment:

Explain how the BOD levels from urban runoff do not correlate to instream BOD samples during storm events.

Response:

The water quality models used a mass balance to account for the mass of storm water BOD being added to the Slough base flow. The storm water mass was derived from the MS4 monitoring data. When added to the Slough, the models predicted much greater BOD mass in the Slough than observed. The discrepancy between loads and instream concentration is likely due to processes such as deposition and decay during the transport to the receiving water.

Comment:

In allocation equations, the term load allocation should be changed to waste load allocation.

Response:

The document has been revised to address this comment.

Comment:
The requirements for the DMAs should be included in the MS4 permits. The TMDL must implement enforceable waste load allocations in the MS4 permits.
Response:
DEQ will enter into memorandums of agreement with each of the designated management agencies that describe the time frames and activities to be completed to implement the TMDL. As stated in the MS4 permits, “the Department will utilize the MOAs in conjunction with this permit as the regulatory tool to insure compliance with the storm water component of the TMDL program”. Because the Multnomah County permit condition is different than the other MS4 permit it is likely that both a MOA and a modification to the permit will be necessary to have the appropriate implementation framework.

Comment:
The criteria used by DEQ are less protective than those cited in the regulations. The TMDL does not address whether the DO saturation standards will be attained.
Response:
The applicable dissolved oxygen water quality criteria are the cool water aquatic life criteria. DEQ has set the allocations to attain the cool water aquatic life criteria, so the criteria have been applied correctly.

Bacteria TMDL Comments

Comment:
There is no MOS for bacteria.
Response:
The bacteria TMDL has been revised to include a MOS for bacteria. The MOS is based on an analysis of the precision of bacteria modeling and analysis of the relationship between fecal coliform data and E. Coli data.

Comment:
There is no evidence to support the statement that bacteria prevents water contact recreation during fall through spring.
Response:
The fecal coliform and E.coli criteria are set to protect the water contact recreation beneficial use (swimming). Violation of the criteria indicates impairment of that use. The Columbia Slough is water quality limited for bacteria through all seasons.

Comment:
What is the frequency of exceedance of the bacteria criteria in the Upper Slough?
Response:

The Columbia Slough was designated as water quality limited for bacteria based on data collected throughout the Slough. The 16% exceedance rate for Reach 3, described in the TMDL, is predicted by modeling storm water loads with SWMM. An actual exceedance rate for Reach 3, based on current bacteria data, was not calculated.

Comments:
Numerical allocations should be given for sources.
Response:
DEQ has allocated the loading capacity (minus the margin of safety) to the sources.

Comment:
It should be specified that monitoring should be for E.coli.
Response:
The implementation strategy clearly states that monitoring in the Columbia Slough will be conducted to demonstrate the compliance with the E.coli criteria.

Comment:
There is insufficient information to determine whether removal of the CSOs will result in the attainment of standards.
Response:
As stated in the Waterbody Assessment (CH2MHill, 1995,) summer fecal concentrations are predicted to be less than 200 coliforms/100 mL about 90% of the time with the Columbia Slough CSOs removed.

Comment:
The CSO allocation should be the control level approved by the Environmental Quality Commission.
Response:
According to the Amended and Stipulated Consent Order (WQ-NWR-91-75) the City of Portland must eliminate all untreated CSO discharges to the Columbia Slough from November 1 through April 30 except during storms greater than or equal to a storm with a five year return frequency and to eliminate all untreated CSO discharges from May 1 through October 31 except during storms greater than or equal to a storm with a ten year return frequency. The City of Portland must eliminate all untreated CSO discharges to the Columbia Slough, except for the stated storm return frequencies, by no later than December 1, 2000.

Comment:
References to removal of Willamette River CSOs should be removed from the TMDL.
Response:
As stated in the bacteria TMDL, because the Lower Slough is tidally influenced, it is impacted by the presence of CSOs in the Willamette River. Removal of the Willamette River CSOs will improve water quality in the Lower Slough.

Comment:
A TMDL is more than a bacteria management plan.

Response:
According to EPA guidance (EPA Region 10 TMDL review framework, draft, November 7, 1997) specific components of a TMDL include the following; a description of applicable water quality standards, a loading capacity, identification of existing sources, technical assessment, load allocations and waste load allocations, a margin of safety, and an analysis of water quality attainment and public participation documentation. All of these components are included in the bacteria TMDL that DEQ has developed for the Columbia Slough.

Comment:
The TMDL does not assure that industrial storm water permittees will be required to eliminate discharges of human waste.

Response:
DEQ will develop a basin specific general industrial storm water permit that will include requirements to address the pollutants on the 303(d) list. Requirements to detect and eliminate discharges of human waste will be included in the permit.

Comment:
DEQ has not assessed the contribution of contaminated groundwater to bacteria levels in the Slough.

Response:
The transport of bacteria through soil is limited by straining and sedimentation. The soil acts as a filter and as the soil is disturbed, the dispersion of soil particles strains even finer particles. Adsorption also causes retention of bacteria by soil, but to a lesser extent. Because of these factors, transport of bacteria through groundwater is usually considered to be unlikely. DEQ has no data indicating any bacteria loads in groundwater.

Pb TMDL Comments:

Comment:
Hardness monitoring for industrial storm water discharges should be removed.

Response:
This requirement has been removed from the TMDL.

Comment:
Page 32, the footnote says that non-detect values are set at the detection limit while page 34 says that non-detect values are set at half the detection limit. The contradiction should be resolved.

Response:
In the frequency analysis, the samples that were non-detect values were set at the detection limit of 0.001 mg/L. The document has been revised to address this comment.

Comment:
Table 12 (summary of total lead loads to the Slough) underestimates the amount of lead sources because it does not include washwater discharges. Washing activities should also be listed as a source of lead in Appendix A.

Response:

The overall industrial storm water load was obtained from the MS4 permit applications. These loads were derived using an estimate of the area within each basin that fit the industrial land use category. Therefore, all industrial storm water sources were included in the overall industrial load. The industrial load estimate did not separate out the various categories of industries that would discharge storm water. The Pb allocations have been changed to include an allocation for storm water based on unit areas..

Comment:
In Appendix A, page 20, the document should state that generally, Pb is only detected in production wells just after the pump has been started up. This may be the result of leaching from the pumps.
Response:
Appendix A, which contains the source analyses for toxics, has been revised to address this comment.

Comment:
The air deposition of Pb has not been adequately estimated.
Response:
To estimate the contribution of single source air deposition (Oregon Steel Mill), DEQ water quality staff consulted with DEQ air quality staff and EPA regional water quality staff. Calculation of the load of a single air source is difficult, with no models readily available to estimate surface contribution from a single air source. As stated in Appendix A, DEQ used EPA modeling guidance to estimate the load from the single source. The estimated annual Pb load from Oregon Steel Mill was comparable to that estimated by DEQ air quality staff for a steel mill in McMinnville, OR. DEQ estimated the annual Pb load from that steel mill by measuring wet and dry deposition. The Pb deposition estimate was within same order of magnitude as that estimated for Oregon Steel Mill.

Comment:
It is not clear how the 10% MOS was developed.
Response:
The margin of safety has been re-calculated. As stated in the Pb TMDL, the criteria is set as the 5th percentile of the criterion calculated for each sample. Using the 5th percentile criterion means that 95% of the field samples should be < 0.0012 mg/L. The margin of safety is set to decrease that to 0.001 mg/L or the detection limit. This effectively means that only 5% of the samples to be measured can exceed the detection limit. The difference between the criterion of 0.0012 mg/L and the detection limit of 0.001 mg/L is 0.0002 mg/L, which is set as the margin of safety.

Comment:
The calculations for the load allocations for St. John's Landfill, NuWay Oil and sediment partitioning are not clear.
The Pb TMDL should address the load from the Willamette River.
Allocations should include the Willamette River, industrial permittees, industrial storm water and environmental clean up sites.
There should be an allocation for future growth.

Response:
In May, June, August and September 1997, the City of Portland collected metals samples from the Willamette River. These samples were analyzed using ultra clean methods. Twenty samples for dissolved Pb had a mean concentration of 0.0974 ug/L (data from fax from Eugene Lampi, City of Portland, Bureau of Environmental Services, May 4, 1998). The dissolved Pb concentration in the Willamette River is, therefore, less than the 5th percentile dissolved Pb criterion (1.2 ug/L) calculated for the Columbia Slough.

Allocations have been set for storm water and environmental clean up sites on a unit area basis. Allocations for future storm water or environmental clean up sites will be deducted from the future growth allocation. These allocations are also on a unit area basis. The calculations for the allocations were re-written to clarify them. Estimates of flow and concentrations used in the allocation calculations are detailed in Appendix A.

Comment:
There is no need to apply a 5th percentile criteria since DEQ calculated a criteria for each sample based on hardness.
Response:
The 5th percentile represents a "worst case" assumption (EPA, 1995). As stated in the Pb TMDL, using the 5th percentile criterion results in a 16.7% exceedance rate of the criterion. When the samples are compared to their respective criteria, the exceedance rate is 10.4%. Using either method, the criterion is exceeded at a rate to designate the Columbia Slough as water quality limited for Pb. Additionally, DEQ needs to apply one criterion to calculate the loading capacity of the Slough for dissolved Pb, so the 5th percentile criterion was used.

Comment:
Explain why effectiveness of BMPs at removing TSS is required. TSS has not been recommended as an indicator of Pb.

The TMDL does not address the accumulation of lead in sediment that will violate water quality standards.
Response:
DEQ reviewed data from the MS4 storm water permits. According to this data, correlation between total Pb and TSS vary with land use (Bob Baumgartner, DEQ personal communication, April 1998). The particulate Pb can and will settle to the sediments. The lead in sediments can partition to the pore water and flux to the surface water. If accumulation is great enough the sediments may become toxic. Lead may also enter the food chain from sediments by several mechanisms. Although no sediment Pb water quality criteria exist, DEQ believes it is appropriate to reduce the existing sources.

Comment:
How can a value be greater than the criteria if it was lower than the detection limit (page 37)?
Response:

To develop the table (referred to in the comment), the values measured instream were compared to the detection limit and the hardness specific criteria. Non detect values were set at the detection limit. The result referred to in the comment was for a sample that was a non detect. In the calculation, the criteria had more than three significant figures and was less than the detection limit. If the criteria was rounded up to three significant figures, the result would have been that the value was equal to the detection limit and equal to the criteria.

Comment:
DEQ should establish a site-specific lead criterion for the Slough, using the water effects ratio (WER) method.
Response:
DEQ used the existing water quality standards to develop the TMDL for Pb. No information was presented to suggest that a site specific Pb criteria is warranted to protect the designated beneficial uses. Site specific criteria can only be developed during triennial water quality standards review. Site specific criteria are subject to EPA review and approval under Section 303(c).

Comment:
A 10% exceedance of the lead criteria is not very large.
Response:
As stated in the water quality standards, “Levels of toxic substances shall not exceed the criteria listed in Table 20 which were based on criteria established by EPA...” DEQ has stated that a water quality standards violation occurs when “The water quality standard listed in Table 20 (see OAR 341-41) for the chemical is violated more than 10% of the time and for a minimum of 2 values” (Oregon Listing Criteria for 1994/1996 Section 303(d) list, June 1996). Waters that violate the water quality standard are placed on the 303(d) list. The listing criteria and the 303(d) list are derived with public review.

Comment:
It is improbable that lead is migrating in groundwater (page 35).
Response:
Lead is not generally very soluble in groundwater at or near neutral pH. Lead has a U-shaped solubility curve, and can be mobilized in very acidic or very basic environments. Such conditions usually don't exist in groundwater except where spills or releases of acids or bases have occurred. The lead at the NuWay Oil site is most likely a component of the used oil and can be transported with the oil to the sediments. Strong acids were used in the oil re-refining process, and the acidic clay residue was disposed of in a lagoon on the site. That acidic clay residue was removed from the lagoon a few years ago but the acid had many years to leach and mobilize lead before the removal. Acidic conditions may still exist in the groundwater at the site.

The estimate of Pb migrating in groundwater (other than at the NuWay Oil site) was re-calculated using ½ the detection limit of the dissolved Pb analysis. This calculation is a conservative estimate and the groundwater contribution is allocated at its current load.

Comment:
The relationship between modeling of storm water lead loads and observed instream concentrations is unclear.
Response:
The discrepancy between loads and instream concentration is likely due to processes such as deposition and partitioning during the transport to the receiving water.

Comment:
The level of lead contamination in sediment is never discussed.
Response:
The sources document, Appendix A, includes an estimate of the annual load of Pb from contaminated sediment. An allocation for sediment partitioning and diffusive flux is included.

Comment:
DEQ can not use the dissolved criterion for lead until it has been approved by EPA.
Response:
The water quality criterion is for total Pb. DEQ used a conversion factor developed by EPA to convert the total Pb criterion to a dissolved form. Because the dissolved criterion correlates to the total criterion, the loading capacity and the allocations, based on the dissolved form, will meet the total Pb criterion as well. Water quality standards will be met when the dissolved Pb criterion is met. The mean of the conversion factors is provided in the TMDL and the dissolved Pb allocations can be divided by it to obtain total Pb allocations.

Comment:
There is no assurance site specific information from clean up sites will be developed and used to measure compliance with water quality standards.
Response:
The TMDL for Pb and organics include waste load allocations based on unit area of storm water drainage basins and ECSI sites. Waste load allocations can, therefore, be calculated for individual ECSI sites as they are identified and remediated. Additionally, DEQ water quality staff has provided the clean up program with language for the “hot spot” guidance used by DEQ clean up staff to determine the applicable standards. Finally DEQ water quality staff will provide training for site response and clean up staff that describes a process to determine if a waste load allocation is necessary for a site and the desired clean up level necessary to meet water quality standards.

Comment:
There is no evaluation whether the loading capacity will result in fish tissue levels that meet water quality standards.
Response:
Table 20 (in OAR 340-41) includes criterion for the protection of aquatic life and human health. The total Pb criterion for the protection of aquatic life (chronic criterion) is 3.2 ug/L. The total Pb criterion for protection of human health, water and fish ingestion, is 50 ug/L. DEQ has set the allocations to meet a dissolved Pb criterion based on the total

Pb criterion. Because the aquatic life criterion is less than the human health criterion, if the aquatic life criterion is met the human health criterion is met.

Organics (DDE, DDT, Dioxin) TMDL Comments

Comment:
There is no MOS for organics.
It is unclear how the margin of safety was established.
The margin of safety does not account for the uncertainty in the analysis (use of the annual average flow, lack of information on sediment partitioning for dioxin).
Response:
The margin of safety for organics is set as ½ the loading capacity left after the allocation for sediment partitioning is subtracted. Storm water and sediment data collection efforts are continuing in the Slough. This information will be used to refine the modeling of the effect of sediment partitioning and storm water inputs on fish tissue concentration. In Phase II of the TMDLs, DEQ will use the results of the monitoring and modeling to refine the margin of safety and the waste load allocations

Comment:
Samples referenced in Table 20 were not storm water samples. Table 19 should include the frequency of detection. On page 41, the reference to Table 13 should be Table 20. Use consistent units in Tables 19 and 22.

Response:
Tables 20, 21 and 22 summarize the results of monitoring conducted as part of the Columbia Slough Sediment Remediation Project. Sampling occurred during a dry event and a storm event. The dry event samples were collected in mid summer when no storm water flows were present. Sample SW-3 was the only sample of sediment collected from the storm water system. This sample was collected from two storm water catch basins. Sediment samples SW-1, SW-2, SW-4 and SW-6 were collected in the receiving water. The storm water samples, summarized in Table 22, were collected in October during a representative storm event. These samples were storm water samples, collected at the first manhole upstream of the outfall opening. The exception is the storm water sample collected at SW-3, which was taken from a catch basin above the outfall (Chris Prescott, BES, personal communication, 1998). Table 20 summarizes the number of samples and number of detects from these samples. Because this information is also contained in Tables 21 and 22, Table 20 has been deleted from the TMDL. Data summarizing the results from sediment samples taken in the receiving waterbody has also been deleted, as these results may not represent the contribution of sediment from storm water. Additional text has been added to clarify the sampling conditions for the storm water samples. Within the text, references are made to the appropriate table numbers. The units for Tables 19 and 22 (now Table 21) remain as mg/L and ng/L as these were the units established for the detection limits.

Comment:
Buffalo Slough has identified pollutant sources. Are results from this Slough being used as the basis for requirements for all Reaches? Are Buffalo Slough results representative of the rest of the Slough? Are the levels of DDT, DDE, DDD and dieldrin present in these sediments a problem?

Response:
The screening level risk assessment (SLRA) for Columbia Slough evaluated and ranked 300 sediment sites on the basis of relative hazards to human health, aquatic life and wildlife. Buffalo Slough was chosen for a focused remedial investigation, in part, because of the potential to apply the results to other priority sites, as the conditions found in Buffalo Slough are similar to several of these other sites. According to the Columbia Slough Sediment Project (Focused Feasibility Report for Buffalo Slough, May 1997, Final Draft), several sites were prioritized on the basis of detected or non detected pesticides or PCBs in sediment. These sites include Johnson Lake, Peninsula Drainage Canal, and Whitaker Slough. Similar to Buffalo Slough, these sites pose potential risks to human health through consumption of fish tissue contaminated with PCBs. Additionally, fish tissue PCB levels are comparable to those found at the reference sites (Willow Bar Island Slough and Fairview Creek) and are indicative of urban background levels in the Portland area. For these reasons, results from Buffalo Slough are considered

representative of the Slough basin, and were used to develop the strategy to control organic loads into all reaches of the Slough.

Comment:
There are no detects of PCBs in storm water, there is not an adequate basis for a PCB TMDL for storm water.
Response:
Results from the Columbia Slough Sediment Project (Focused Feasibility Report for Buffalo Slough, May 1997, Final Draft) indicate that PCBs are carried into the Slough with sediment in storm water. Additional data collection is occurring to verify this conclusion. Monitoring (under the MS4 permit and the Buffalo Slough feasibility study) has also indicated that DDT, DDD and DDE are carried into the Slough with storm water and DDE with storm water sediment. DEQ has not yet developed an empirical relationship between TSS and organic concentrations, but a pilot project will be conducted to determine the relationship. In Phase I, the TMDL allocations are based on storm water loads, but the implementation strategy focuses on the reduction of sediment loads to the Slough. Phase II of the TMDL may include targets for % reduction of TSS, based on the empirical relationship.

Comment:
There is insufficient data to list dieldrin as a chemical of concern.
Response:
DEQ has developed a preventative TMDL for dieldrin. As discussed in the organics section of the TMDL document, dieldrin has been detected in 39% of fish tissue samples analyzed and all of the detected samples exceeded the Table 20 derived screening value.

Comment:
Only one of five samples of fish tissue had a detectable level of dioxin. A section on data validation for dioxin should be presented. Dioxin should not be included in this TMDL until the appropriateness of the 303(d) listing for dioxin is resolved.
A TMDL for dioxin in storm water should not be developed until there is evidence that dioxin is present in storm water or in storm water sediments.
Table 17 should include the detection limits. The discussion on the congeners should clearly indicate whether all dioxin congeners were analyzed.
The TMDL should explain EPA's methodology for accounting for the dioxin congeners. The discussion regarding dioxin is unclear.
Response:
Data quality appears to be an issue regarding the fish tissue data tested for dioxin, which was used to place dioxin on the 303(d) list. Previously, the City of Portland stated that the 1987 fish tissue data (DEQ, National Bioaccumulation Study) may have had elevated levels of 2,3,7,8 TCDD due to interferences from PCBs. Based on this comment, DEQ removed the 1987 fish tissue data from the TMDL document. However, DEQ laboratory staff has stated that they are unaware of such interference (Rick Gates, DEQ, personal communication, April 1998). The 1987 fish tissue data has, therefore, been included in the TMDL.

The appropriate forum to discuss listing issues is during development of the 303(d) list. DEQ water quality staff suggests that the commentor provide DEQ with data to de-list dioxin, including more recent fish tissue data indicating non-detectable levels of dioxin in fish tissue. The Columbia Slough TMDLs are for those parameters on the 303(d) list, so a TMDL for dioxin has been calculated.
Additionally, DEQ has a criteria for 2,3,7,8 TCDD only, so the estimated levels of congeners is not used to determine impairment of the beneficial use. For this reason, discussion of the congener calculations has been removed from the TMDL.

Comment:
Erosion may not be the only source of sediments and particulates for industrial storm water permittees.
Response:
BMPs for industrial storm water permittees will focus on the reduction of TSS loads to the Columbia Slough.

Comment:
To identify impaired beneficial uses, DEQ must determine what species are caught in the Slough, age, size, etc. and how much fishing is done in the Slough.
Response:
The City of Portland conducted fish consumption surveys in the Columbia Slough in1994 and 1995. The surveys were conducted to: identify those fish and shellfish species harvested by local anglers, and obtain detailed information on the fishing habits, fish consumption preferences and fish preparation methods of the anglers (memo to Chee Choy, City of Portland, BES, April 19, 1996, from Adolfson Associates). From this site specific information it was determined that carp was the most commonly caught fish in the Slough. To calculate the human health risk assessments, the site specific fish consumption rate was used (from the consumption surveys) and a consumption rate was calculated for the general population and the high use population. The general population was assumed to eat only fish fillets and the high use population was assumed to eat whole fish. The fish consumption rates were used to back calculate to what concentration in fish tissue was necessary to meet the 10^{-6} risk level.

Comment:
How does the organic monitoring data indicate that there is an unacceptable risk level for human health?
Response:
According to Oregon Listing Criteria for 1994/1996 Section 303(d) list(June 1996), DEQ uses fish or shellfish consumption advisories issued by the Oregon State Health Division to indicate impairment of a beneficial use. In August 1995, the Oregon State Health Division issued a fish consumption advisory that recommended limiting human consumption of fish caught in the Columbia Slough based on the presence of PCBs in the fish tissue. In August 1995, the Health Division concurred that DDT/DDE should be included in updates to the fish advisory. Additionally, DEQ determines an impairment of the beneficial use when the chemical has been detected in more than 10% of available fish tissue samples, and the mean of the detects exceeds a screening level value derived

from Table 20 criteria. In developing the 1994/1996 303(d) list DEQ determined that fish tissue data for 2,3,7,8 TCDD met the listing criteria. The determination of impairment of the beneficial use, therefore, is determined by fish tissue levels, not instream data or source data.

Comment:
It has not been shown that storm water and sediments are a significant source of pesticides and PCBs.
Response:
The pesticides and PCBs addressed in these TMDLs are no longer used and are present in the environment as a result of past practices. As such, the potential sources are limited (i.e. runoff, air deposition). DEQ feels that the data provided under the MS4 permits and the Columbia Slough Sediment Remediation Project demonstrate that pesticides are being contributed to the Slough system via storm water. Based on the dry weather sample taken at SW-3 (results summarized in Table 20) DEQ believes that sediment associated with storm water is likely contributing PCBs to Buffalo Slough. Additional monitoring is being conducted by the City of Portland to verify this conclusion. In the interim, DEQ has followed EPA guidance and developed the TMDL for PCBs and the pesticides based on best available information.

Comment:
Table 19 should indicate whether the results are for total or dissolved concentrations.
Response:
Samples for organic analysis are typically not filtered because volatile organics might be lost during the filtration. The samples collected for the municipal permits were not filtered, so data presented in the TMDL is the total organic concentration .

Comment:
The document states “Due to the toxicity and bioaccumulation of these materials, a low instream concentration causes fish tissue concentrations to exceed consumption advisory levels”. This is a general statement and should not be included in the TMDL document. DDT presence in the environment results in very low instream concentrations that generally do not cause fish tissue concentrations to exceed advisory levels.
Pesticides and PCBs are highly hydrophobic and are unlikely to be associated with storm water.
The fugacity model assumes that sediments are in equilibrium with the overlaying waters and fish tissue. It is unlikely that sediments are in equilibrium with fish tissue due to lack of exposure of the fish to the contaminated sediments.
Response:
These comments have been grouped together because they all address the hydrophobicity of the pesticides and PCBs and their likely location in the environment (i.e. fish tissue, instream, sediment). The fugacity model was used to determine in which “compartment” of the environment the pollutants were most likely to reside. In the fugacity model it is assumed that contaminants move from the sediments into the water of the Slough in two stages. First, contaminants on the materials desorb from the solid particles into the pore or interstitial water between the sediment grains. Then the contaminated interstitial water

is fluxed into the Slough by groundwater that flows through the sediments. Interstitial water concentrations were estimated from measured total sediment concentrations and adjusted for the adsorptive properties of sediment organic matter through standard formulas. The food chain model has three levels: phytoplankton (algae), zooplankton/small fish and large fish (carp). The initial input into the food chain is from the contaminants dissolved in the water, which are assumed to equilibrate rapidly with the algae. The contaminants then biomagnify to greater concentrations in the food chain. All of the contaminants were assumed to accumulate in fish tissues via the food chain rather than directly from the water. This is an appropriate assumption for the compounds given their affinity for carbon rich materials and extremely low water solubility (Columbia Slough Sediment Project Focused Feasibility Report for Buffalo Slough, May 1997, Final Draft). The fugacity model, therefore, does not assume that the fish are exposed to the sediments, rather that they consume algae contaminated with the pollutants. Additionally, although the pollutants modeled are hydrophobic, they are assumed to have some solubility in the groundwater which flows over the contaminated sediment. Recent fugacity modeling indicates that the groundwater flow rate is the most sensitive parameter in the model.

Additionally, as stated in the Organics TMDL, DEQ uses fish or shellfish consumption advisories issued by the Oregon State Health Division to indicate impairment of a beneficial use. In August 1995, the Oregon State Health Division issued a fish consumption advisory that recommended limiting human consumption of fish caught in the Columbia Slough based on the presence of PCBs in the fish tissue. In August 1995, the Health Division concurred that DDT/DDE should be included in updates to the fish advisory.

Comment:
Groundwater loading rates for PCBs should not be based on a single maximum concentration.
Response:
Estimates of the groundwater loads have been revised to use the average concentration of lead or PCBs. Where samples were measured at non detect levels, ½ the detection limit was used as the sample concentration.

Comment:
ODOT should not manage pollutants not associated with transportation corridors, such as PCBs and DDTs.
Response:
In previous studies of urban runoff, PCBs have been detected in runoff from traffic corridors (U.S. Geological Survey, Report 96-4234, 1996). ODOT will be expected to implement BMPs to reduce possible loading of PCBs from traffic corridors to the Columbia Slough.

Comment:
A TMDL must be established for DDE. Sources for loads, flows and concentrations should be cited. The sum of the allocations must not exceed the loading capacity.

Response:
DDE is included in the TMDL for DDT. The flow rates of 2.83, 5.66, 8.5 and 11.3 m^3/sec encompass the range of flows possible by pumping at MCDD1. Concentrations used to develop the allocations are discussed in Appendix A. The allocations have been re-calculated so that they do not exceed the loading capacity.

Comment:
Allocations should be assigned to industrial discharges and air deposition.
Response:
PCBs , DDT and its metabolites have all been banned. There are no industrial discharges of these pollutants. The contribution of contamination from atmospheric deposition is largely accounted for by storm water because the combined open surface area of the storm water drainage basin is large relative to the water surface area of the Slough *(*Columbia Slough Sediment Project Focused Feasibility Report for Buffalo Slough, May 1997, Final Draft). Air deposition of the organic pollutants is, therefore, included in the waste load allocations for storm water.

Comment:
DEQ did not apply the narrative criterion for toxics. DEQ must set numeric water quality standards for sediments.
DEQ should use the data and analysis of the risks posed by Slough sediments generated by the Sediment Remediation Project. The TMDL does not consider the additive and/or synergistic effects of multiple toxic pollutants. DEQ should not use bioconcentration factors that are chemical specific rather than species specific.
Response:
The allocations in the TMDL are based on the current State water quality standards and are set with the available data. The alternative to setting the allocations with current information is not to set any allocation, which DEQ does not believe is appropriate.

Comment:
The TMDL does not consider other existing uses, such as habitat for birds and mammals. The TMDL did not look directly at the habitat of the affected aquatic life, which includes the sediments for many of the invertebrate species. The TMDL fails to consider other designated and existing uses, such as piscivorous birds and mammals that may be affected by toxic contamination levels in sediments.
Response:
According to the Columbia Slough Sediment Project (Focused Feasibility Report for Buffalo Slough, May 1997, Final Draft), the levels of chemicals in fish are not high enough to pose potential risks to wildlife. Sediment bioassay studies have indicated that sediments in Buffalo Slough are not toxic to benthic organisms.

Comment:
The TMDL does not evaluate the contribution of sediments to fish tissue levels by direct consumption of bottom feeders.
Response:

In the fugacity modeling conducted to evaluate remediation alternatives in the Buffalo Slough, it was assumed that the carp do not eat the contaminated sediments, but consume algae. Standard ingestion rates for carp were used. The fugacity model is a food chain model and as such, allows for bioaccumulation of the contaminants up the food chain. It was therefore assumed that the algae would have greater concentrations of the contaminants than the sediment. If the carp were assumed to be eating sediment, they would consume less algae and therefore have less exposure to contaminants (Bill Fish, Oregon Graduate Institute, personal communication, April 1, 1998).

Temperature Comments

Comment:
The temperature management plan should be developed through a public process.
Industries with 100J permits or washwater activities should be required to develop a temperature management plan.
Implementation strategies are not provided. DEQ expectations should be identified.
A use attainability analysis has not been done to support the temperature criteria.
The TMDL relies on shading to decrease water temperature in the Upper Slough.
Response:
DEQ will develop a TMDL for temperature at a later date.

Hearing Officer's Report

A public hearing for the Columbia Slough Total Maximum Daily Load (TMDL) was held February 11, 1998 at Whitaker Middle School, N.E. 39, Portland, OR.
The hearing officer was Marilyn Fonseca, water quality division, DEQ, NWR

Summary of hearing:
Robert Baumgartner, (Manager technical services section, water quality division, DEQ, NWR) provided an overview of the pollution control strategies provided in the TMDL. Mr. Baumgartner also explained the process for TMDL development and approval. The floor was opened for a question and answer session, but no questions were asked.

The formal hearing then began, with five people providing oral testimony. An undetermined number of people will provide written comments.

The oral testimony is summarized below and the comments are followed by DEQ's response to the testimony.

Comment: (Troy Clark)
Mr. Clark was speaking for himself, not as a representative of the Columbia Slough Watershed Council, of which he is a member. Mr. Clark's primary concern is the lack of consistent standards for TMDLs on the Clean Water Act applied to streams everywhere. He is concerned that in such a complex situation as the Columbia Slough, where problems appear to not be resolvable, allowances might be made concerning permits or chemicals or runoff introduced into the Slough which may exacerbate the problem. Some of the process was motivated by a lawsuit under the Clean Water Act. This should be continuously on our minds as we attempt to find ways to resolve the problem.
Response:
DEQ agrees that addressing the pollution problems of a complex system like the Columbia Slough is difficult. It is DEQ's intention to have the TMDL program be consistent with the requirements of the Clean Water Act. Any actions taken to improve water quality in the Slough, such as the issuance of permits, are designed to meet water quality standards. To ensure this, the TMDLs includes a margin of safety for all the parameters. The margin of safety addresses the uncertainty about the relationship between the pollutant loads and the quality of receiving waterbody.

Comment: (Bryan O. Wigginton)
Mr. Wigginton read the Pb issues in the TMDL. The TMDL states that there is no model of Pb transport. The TMDL implies that storm water running into the Slough is not affecting the actual concentration in the Slough. The TMDL seems to say the dissolved lead concentration is 80% of the lead concentration in storm water. Current research indicates that the dissolved Pb concentration is 10-12% of the lead concentration in storm water. The focus of the TMDL should be suspended solids removal. Total suspended solids removal would be a good focus of the TMDL. Organics are also carried with suspended solids.
Response:

Monitoring under the municipal storm water permits was for total Pb. Source analysis indicates that storm water is the single largest source of total Pb to the Slough. The loading capacity was calculated using dissolved Pb. New monitoring requirements for the municipalities and industries with storm water permits will include dissolved and total Pb, as well as TSS. This data will help DEQ better quantify the impact of storm water on the instream Pb concentration. BMPs will focus on control of Pb in storm water, as well as reduction of TSS contributions. Management practices, will therefore address the contribution of both dissolved and particulate Pb to the Slough.

Comment: (Dana Siegfried)

Ms. Siegfried spoke as a representative for the Port of Portland. TMDLs were developed with stakeholder input. Allocation for the Port for de-icing fluids is very low due to the sensitive nature of the Columbia Slough. In anticipation of the TMDL the Port has been working with a stakeholder group to develop a long term solution to de-icing runoff into the Slough. This group was convened last September and includes airlines, DEQ, the Bureau of Environmental Services, neighborhood representatives, drainage districts and Portland State University. The Port and the airlines will be in a permit process soon and will provide more details on what the long term solution might be at that time.

Response:

No response is necessary.

Comment: (Peggy McCluskey)

Ms. McCluskey is an environmental manager with Alaska Airlines, but spoke as a representative of all the airlines at the Port. They are continuing to review the TMDL and its impact on aircraft de-icing activities and expect to provide written comments in March. The Federal Aviation Administration strictly regulates de-icing activities. Aircraft must be free of ice, snow and frost. Each airline performs de-icing in compliance with a de-icing plan approved by the Federal Aviation Administration. The proposed TMDL will require approximately an 85% reduction in the amount of de-icing fluid entering the Columbia Slough. The airlines have evaluated the de-icing processes to reduce discharges to the Columbia Slough. They continue to evaluate and implement improvements to the de-icing processes. The airlines reaffirm their commitment to flight safety for passengers, their employers and the community. The airlines reaffirm their commitment to responsible environmental stewardship.

Response:

No response is necessary.

Comment: (Jay Mower)

Mr. Mower is the coordinator of the Columbia Slough Watershed Council and spoke as the Council representative. The Council is a diverse group of stakeholders along the Columbia Slough including governments, neighbors, businesses, and recreational users. They meet to coordinate and debate public policy about the Slough. There is a subcommittee preparing comments about the TMDL. They expect to submit the comments by the March 5 deadline. The council is praiseworthy of the TMDL.

Response:

No response is necessary.

APPENDIX F
PHASE I and PHASE II SCHEDULE

	Phase I				**Phase II**
Parameter	**Control Strategy**	**Implementation Mechanism**	**Date**	**Monitoring**	**Control Strategy**
nutrients	water level management Allocation for Oregon Fresh Farms	MOA with MCDD Permit for Oregon Fresh Farms	Annual review of flow management options and effectiveness	continuous and grab samples	TMDL review as scheduled 2003/2004 New MOAs 2004/2005
pH	water level management	MOA with MCDD	April 1999	continuous and grab samples	
Dissolved Oxygen	set allocations for de-icing discharge attain compliance with de-icing allocation Implement BMPs to reduce storm water BOD load	PDX de-icing permit MOA with DMAs Lower Willamette Subbasin Plan	Summer 1998 Winter 2005/2006 April 1999 Spring 1999	continuous and grab samples	PDX new permit 2004
bacteria (E. Coli)	CSO removal Identify and connect to sewer direct discharges to Slough Identify and remove illegal discharges Implement controls to reduce agricultural bacteria load Develop bacteria management plan	MOAs with DMAs Storm water permit Lower Willamette Subbasin Plan	December 2000 April 1999 August 1999 Spring 1999 March 1999	grab samples determine compliance	

Phase I					**Phase II**
Parameter	**Control Strategy**	**Implementation Mechanism**	**Date**	**Monitoring**	**Control Strategy**
Pb	Implement BMPs to reduce Pb load to the Slough BMP monitoring Monitor contribution of ECSI sites Expand list of industrial categories covered by storm water permit Assure compliance with storm water permit by industrial facilities Monitor contribution of ECSI sites Allocations for ECSI sites	MOAs with DMAs Storm water permit Statement of work for Cleanup	April 1999 August 1999 April 1999	synoptic datasets of storm water and instream (as specified in MOA) Source monitoring	calibrate model of storm water loads of Pb, re-evaluate Pb allocations Estimate contribution from ECSI sites Re-evaluate ECSI allocation Review and update TMDL (2003/2004)
organics	Implement BMPs to reduce erosion and sedimentation into Slough Monitor effectiveness of BMPs Monitor contribution of ECSI sites Allocations for ECSI sites Remediate contaminated sediment in Buffalo Slough	MOAs with DMAs Storm water permit City of Portland pilot project for organics BMPs Statement of Work for Cleanup	April 1999 As defined in MOA	As defined in MOAs	Develop relationship between TSS, TOC and organics Estimate contribution from ECSI sites Re-evaluate ECSI allocation Review and update TMDL (2003/2004)
temperature	Model criteria and scenario selection Model runs done LC, LA, WLA identified MOAs	Temperature management plan MOAs	April 1999	grab continuous	Review and update TMDL (2003/2004)