CHAPTER 6
Water and Sediment Quality Characterization

GOAL

Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.

INTRODUCTION

The water quality of the Columbia Slough is important for both human health and ecosystem health. People use the Slough for recreation, including canoeing and fishing, and wildlife use it for habitat and food. This water quality characterization is a summary of the *Columbia Slough Water Quality Report* (available from the City of Portland Bureau of Environmental Services). Results of the data analysis and discussion of the findings can be found in that report.

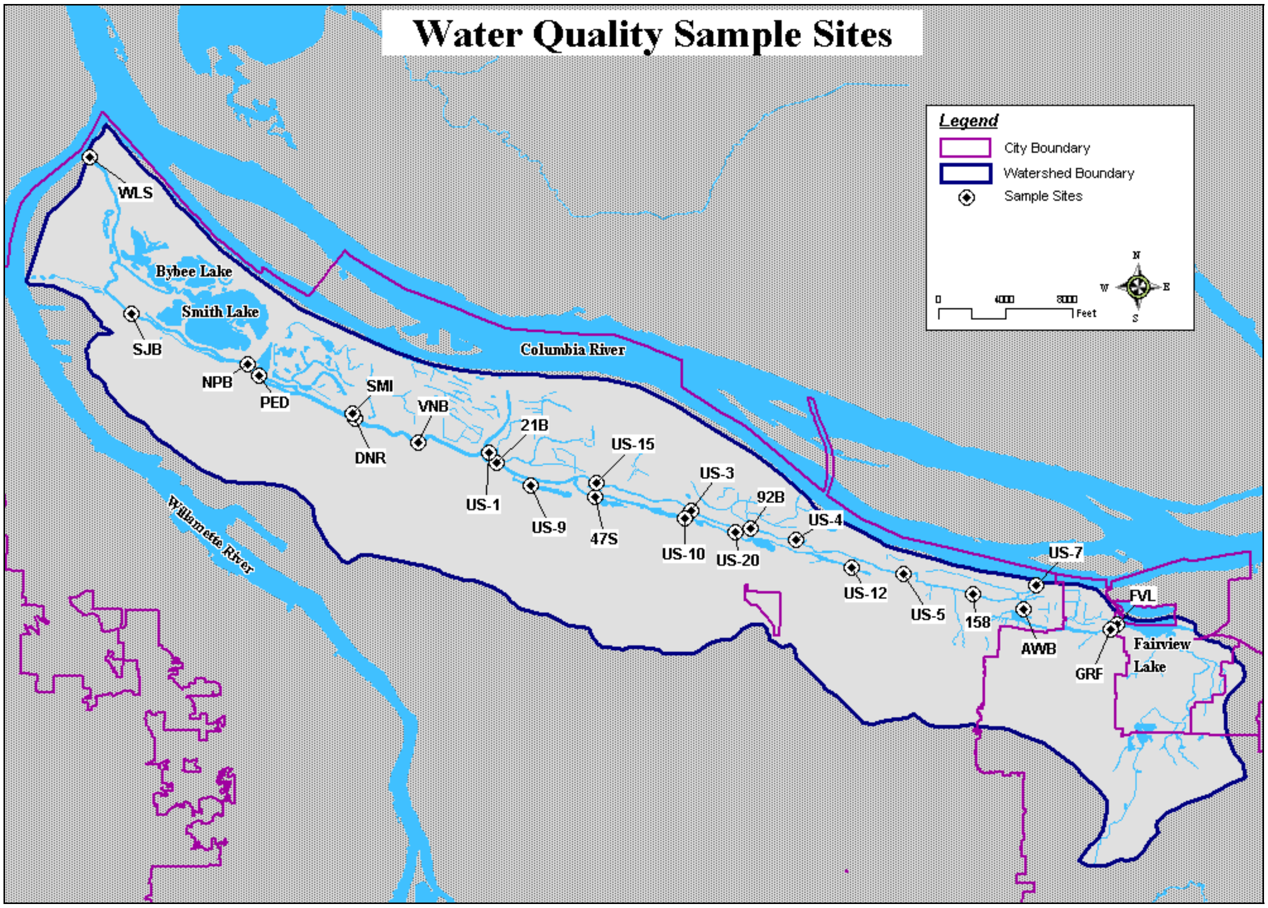
Sediment quality is important to fish and other aquatic species. It is covered in a separate section of this chapter.

Water Quality

OVERVIEW

Although water quality has been monitored since 1971, the Bureau of Environmental Services (BES) began extensive monitoring in 1994 to attempt to define and track conditions. Since then, BES has collected water quality data at 24 sites along the length of the waterway (Figure 6-1). The current in-stream monitoring program collects data from nine of these sites – three in each of the Upper, Middle, and Lower Sloughs. The program also includes "continuous" measurement of field parameters (temperature, pH, dissolved oxygen, and conductivity) at five of these sites and an additional site in Fairview Lake. All analysis and discussion are from water quality sample results taken between 1995 and 2002.

Figure 6-1: Columbia Slough Water Quality Sample Sites



The Oregon Department of Environmental Quality (DEQ) placed the Columbia Slough on the state's 303(d) list in 1994/1996 (DEQ 1999). The 303(d) list identifies water bodies that are "water quality limited" because they do not meet water quality standards for certain parameters. (See Appendix B: Regulatory Framework.) The Columbia Slough is water quality limited for many parameters (DEQ 1999). Water quality results were analyzed in the *Columbia Slough Water Quality Report* for the following parameters:

- Bacteria
- Temperature
- Dissolved oxygen and biochemical oxygen demand (BOD)
- Eutrophication
    - Phosphorus
    - Chlorophyll a
    - pH
- Toxics (DDT/DDE, dieldrin, dioxins, PCBs and lead) (Only lead is covered in the Water Quality section. Other toxic compounds are discussed in the Sediment Quality section.)
- Total suspended solids

DEQ has established beneficial uses (functions that a waterway provides to people or fish and wildlife) for all water bodies in Oregon. The following beneficial uses are established for tributaries of the Willamette River, including the Columbia Slough (Oregon Administrative Rules 340-41-442, Table 6):

- Irrigation
- Domestic and industrial water supply
- Livestock watering
- Anadromous fish passage
- Salmonid fish rearing
- Salmonid fish spawning
- Resident fish and aquatic life
- Wildlife and hunting
- Fishing
- Boating
- Water contact recreation
- Aesthetic quality
- Hydro power

DEQ establishes total maximum daily loads (TMDLs) for 303(d) listed parameters (DEQ 1999). TMDLs identify the "load capacity," which is the maximum amount of the parameter the water body can assimilate without violating the water quality standard. The TMDL also allocates the load capacity among the jurisdictions in the watershed.

In 1998, DEQ established TMDLs for all 303(d) listed parameters in the Columbia Slough, except temperature (DEQ 1999). DEQ is currently developing a TMDL for temperature. Total suspended solids are discussed by DEQ in the 1200-COLS stormwater discharge permit.

BACTERIA

Water Quality Standard

The purpose of the bacteria standard is to protect people from contact with and ingestion of human pathogens, which can occur during recreational activities such as swimming and boating. Contact with these pathogens can cause skin and respiratory ailments and gastroenteritis.

Fecal coliform bacteria are monitored to detect the presence of human pathogens. In 1996, DEQ adopted new standards for *E. coli*, which is an indicator species (i.e., a species that is easy to detect and indicates the presence of human pathogens). Under the standards, *E. coli* samples must not exceed a 30-day log mean of 126 colony-forming units per 100 milliliters (CFU/100ml), based on a minimum of five samples; this is the geometric mean standard. In addition, no single sample may exceed 406 CFU/100ml (DEQ 1999); this is the instantaneous standard.

Conclusions

In the Upper and Middle Slough, the water quality criteria for *E. coli* are nearly always met. The occasions when the *E coli* standards are not met are very few and follow no discernable pattern.

Since 2000, results from the Lower Slough have generally met water quality criteria, with a few exceptions. In the few cases criteria are not met in the Lower Slough, the magnitude of the concentrations is still greatly reduced from historic concentrations.

Upper Slough

- 96.4 percent of 277 samples met water quality criteria for *E. coli*. However, all five sampling sites had results that did not meet the criteria at least once. The potential sources of bacteria are likely wildlife feces, urban stormwater runoff, pump stations, and illicit discharge.

Middle Slough

- Overall, the main arm of the Middle Slough has low levels of *E. Coli*. Only two sites [US-4 (105th Avenue) and 21B (21st Avenue)] have results that did not meet the standards; three of 259 results, or 1.1 percent, of results did not meet the standards.

Whitaker Slough (a southern arm of the Middle Slough)

- 96 percent of 173 samples met water quality criteria. All four sites, except 47S (NE 47th Avenue), had results that did not meet the standards at least once.

Buffalo Slough (a southern arm of the Middle Slough)

- All samples taken in Buffalo Slough met water quality criteria.
- In 1999, sampling stopped in Buffalo Slough.

Lower Slough

- 89 percent of 276 samples taken during the sample period met standards. However, all five sites had samples that did not meet the standards at least once.
- Most results in the Lower Slough are from years prior to December 2000, when combined sewer overflows (CSOs) still occurred. During these events, raw sewage mixed with large volumes of stormwater was released into the water, and was a probable source of *E. coli* at the nearby sample sites (Figure 6-2). In December 2000, a major project, the Columbia Slough Consolidation Conduit, controlled over 99 percent of CSO volume, and virtually all sewage is now sent to the Columbia Boulevard Wastewater Treatment Plant. Other sources include bacteria in urban stormwater runoff, wildlife and pet feces, illicit discharge, and horse manure from Portland Meadows.

Figure 6-2: Combined Sewer Overflow Outfalls in the Columbia Slough

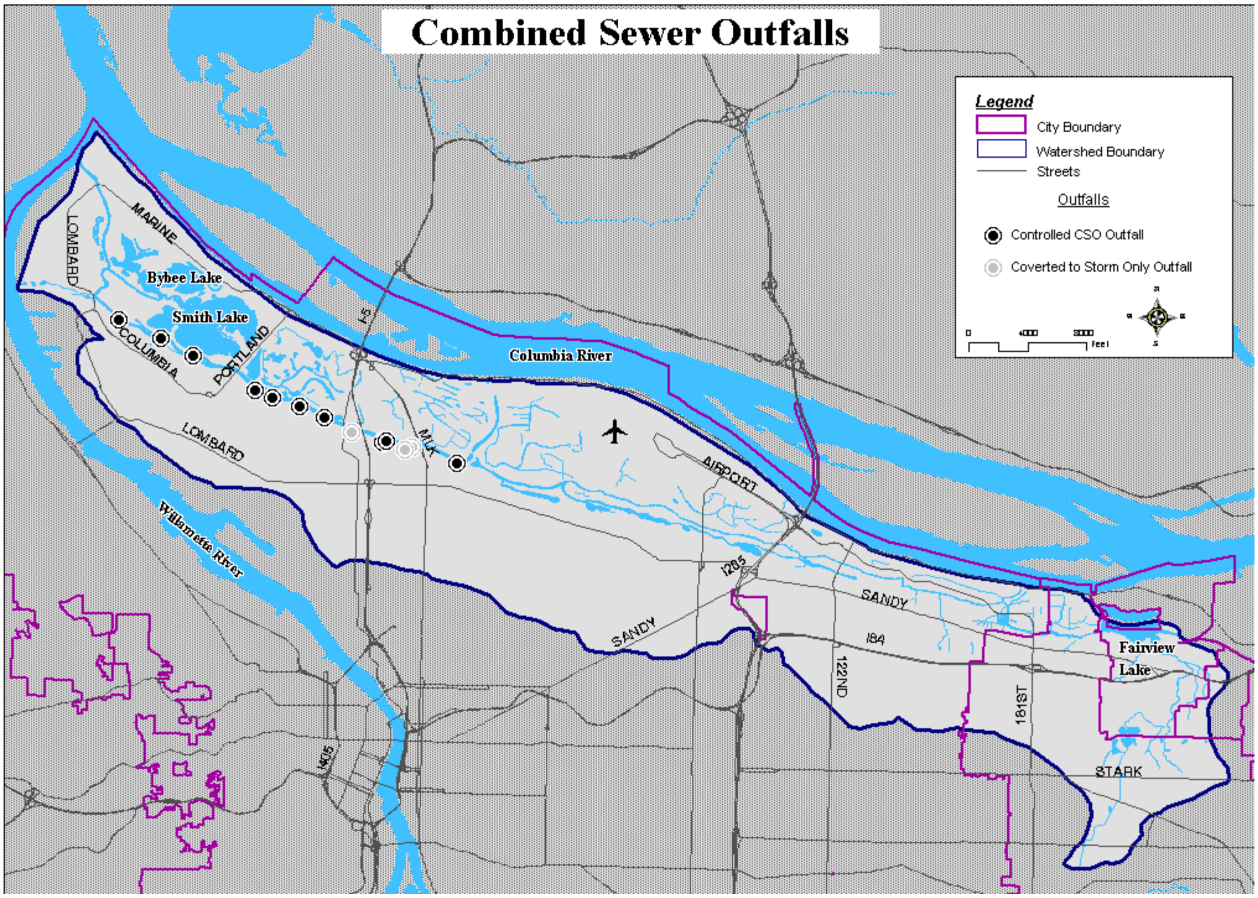
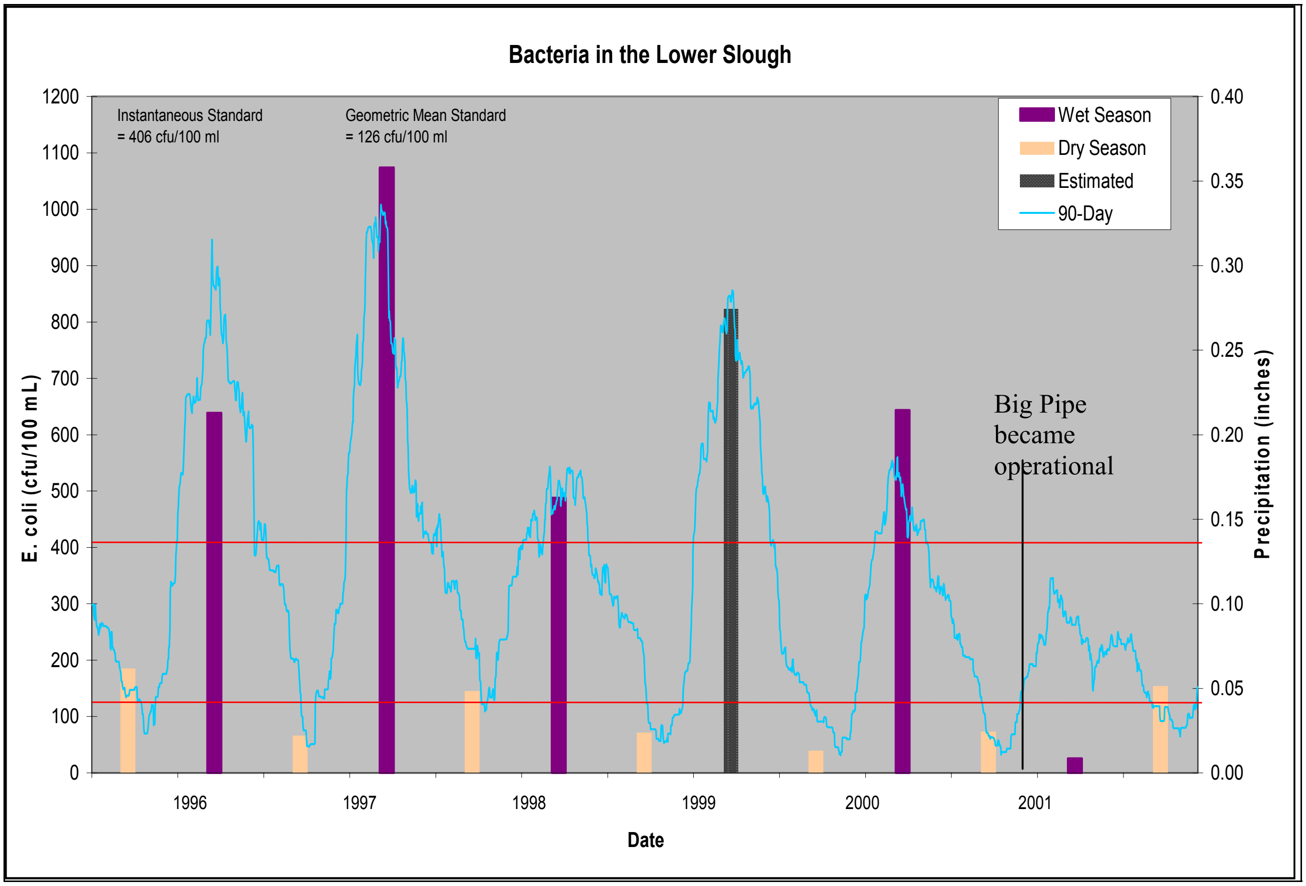


Figure 6-3 shows the effect of CSOs on the Lower Slough. The blue line is average precipitation over a three-month period; the two red lines are the two water quality standards; the purple bar is average *E. coli* for sample sites in the Lower Slough during the wet season (winter); and the tan bar is average *E. coli* for sample sites in the Lower Slough during the dry season (summer) for all sample sites in the Lower Slough. The graph shows that before 2000, *E. coli* was a problem in the winter. After the elimination of CSOs in 2000, winter results are significantly lower, generally below the standards.

Figure 6-3: E. Coli Results for the Lower Slough



Sources

E. coli has many possible sources, some of which are naturally occurring in the ecosystem. CSOs, the most significant anthropogenic source identified to date, have been controlled. More work is needed to determine remaining sources and implement controls. Possible sources include:

- Urban stormwater runoff contains *E. coli*, primarily from pet feces. Many of the sample site results have a strong correlation with precipitation, meaning that urban stormwater containing bacteria is the likely source of bacteria at those sites.
- Wildlife feces contribute bacteria to the Slough. Birds and wildlife using wetlands, Whitaker Ponds, Prison Pond, Fairview Lake, and Smith and Bybee Lakes are possible sources of *E. coli*.
- Multiple sanitary pump stations, which pump sewage to the Columbia Boulevard Wastewater Treatment Plant, are located in the watershed. The proximity of certain pump stations to samples sites in the Slough suggests that pump station leaks or overflows could contribute *E. coli*.

- Old or poorly maintained cesspools and septic systems along Whitaker Slough may be leaking.
- Illicit sewage discharge is a possible source of *E. coli* for all sites.
- Confined animal feeding operations (CAFO), such as animal manure from Portland Meadows, are a possible source of *E. coli* .

WATER TEMPERATURE

Water temperature has a large impact on the types of organisms found in a water body. Every species (microbes, fish, aquatic plants, etc.) is restricted to a certain temperature range. Most warm-water fish, such as bass, have an upper limit near 86°F (30°C) (Allan 1995). Warm-water fish usually can tolerate cold temperatures during part of the year because most warm-water streams are cool in the winter months. However, warm-water fish are absent from streams where the water temperature is cold year-round. Cool water is a basic requirement for native salmon, trout, some amphibians, and other cold-water aquatic species.

Growth and reproduction, for both cold- and warm-water fish, are adversely affected when the water temperature is outside the range to which these organisms are adapted (Allan 1995). Cold-water fishes can survive for a short time in water above 68°F (20°C), but cannot survive at all in water above 86°F (30°C) (Allan 1995). Temperature also plays a role in dissolved oxygen concentration, which is important for fish survival; generally, the colder the water, the greater amount of oxygen that can be dissolved in it.

Water Quality Standard

In the Columbia River and its associated sloughs and channels, the standard is a seven-day rolling average of the daily maximum water temperature not to exceed 68°F (20°C). The draft Columbia Slough TMDL, published in July 2003, states that "For purposes of this TMDL, the 68°F (20.0°C) salmonid rearing criterion is applied in the [Lower] Slough, which is still hydraulically connected to the Willamette River, and the criterion 64°F (17.8°C) is applied to the [Middle and Upper] Slough and Fairview Creek" (DEQ 2003).

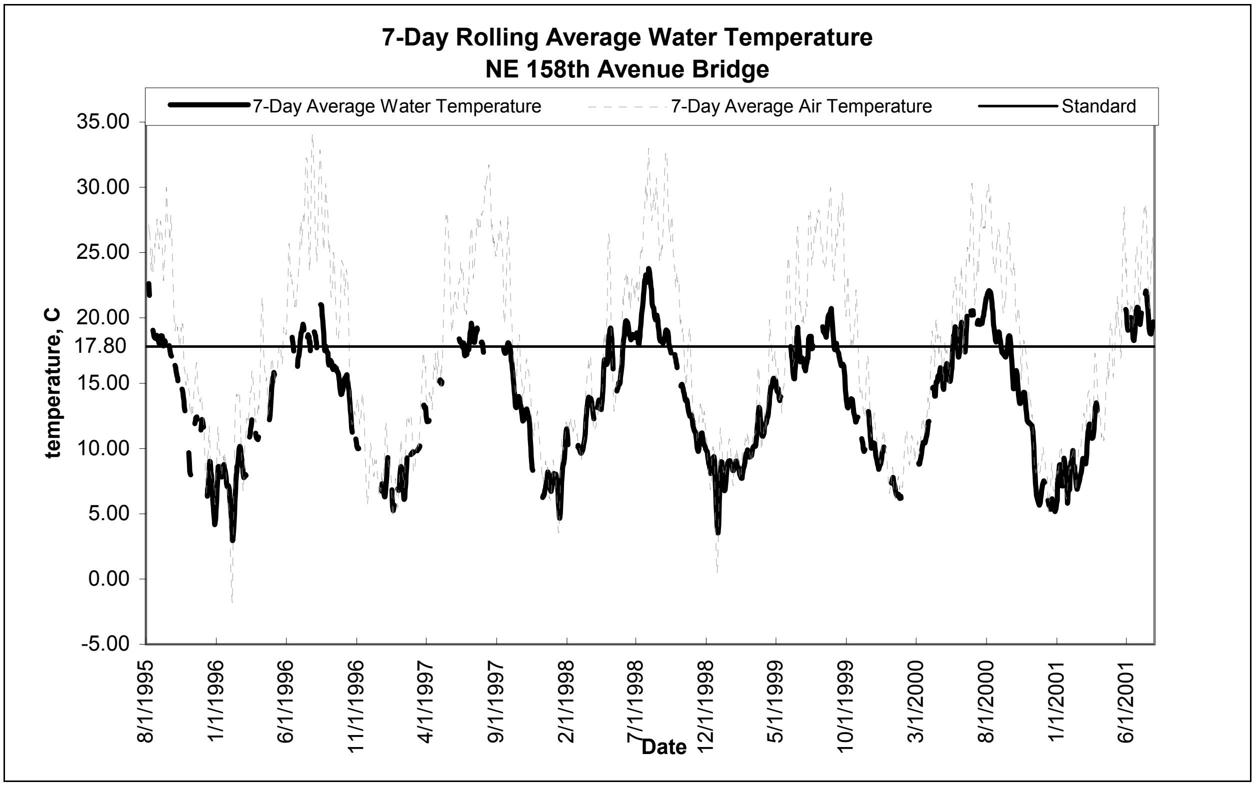
Conclusions

Past studies reveal that the Columbia Slough has had warm water temperatures since at least 1971, although the Slough has probably been a warm body of water since the installation of levees as a result of the levees and the Slough's physical features (BES 1995).

Upper Slough

- The Upper Slough meets water temperature standards during the late fall, winter and early spring months (Figure 6-4).
- The uppermost Upper Slough (along with the Lower Slough) has the warmest temperatures in the Slough.
- The water temperature standard is not met during the summer months, except in a few areas.
- Wilkes Creek (located near NE 154th Avenue) and the Alice Springs area are cold-water inputs to the Upper Slough, and are known or suspected to meet water temperature standards year-round.

Figure 6-4: Water Temperature Results for the Upper Slough



Middle Slough

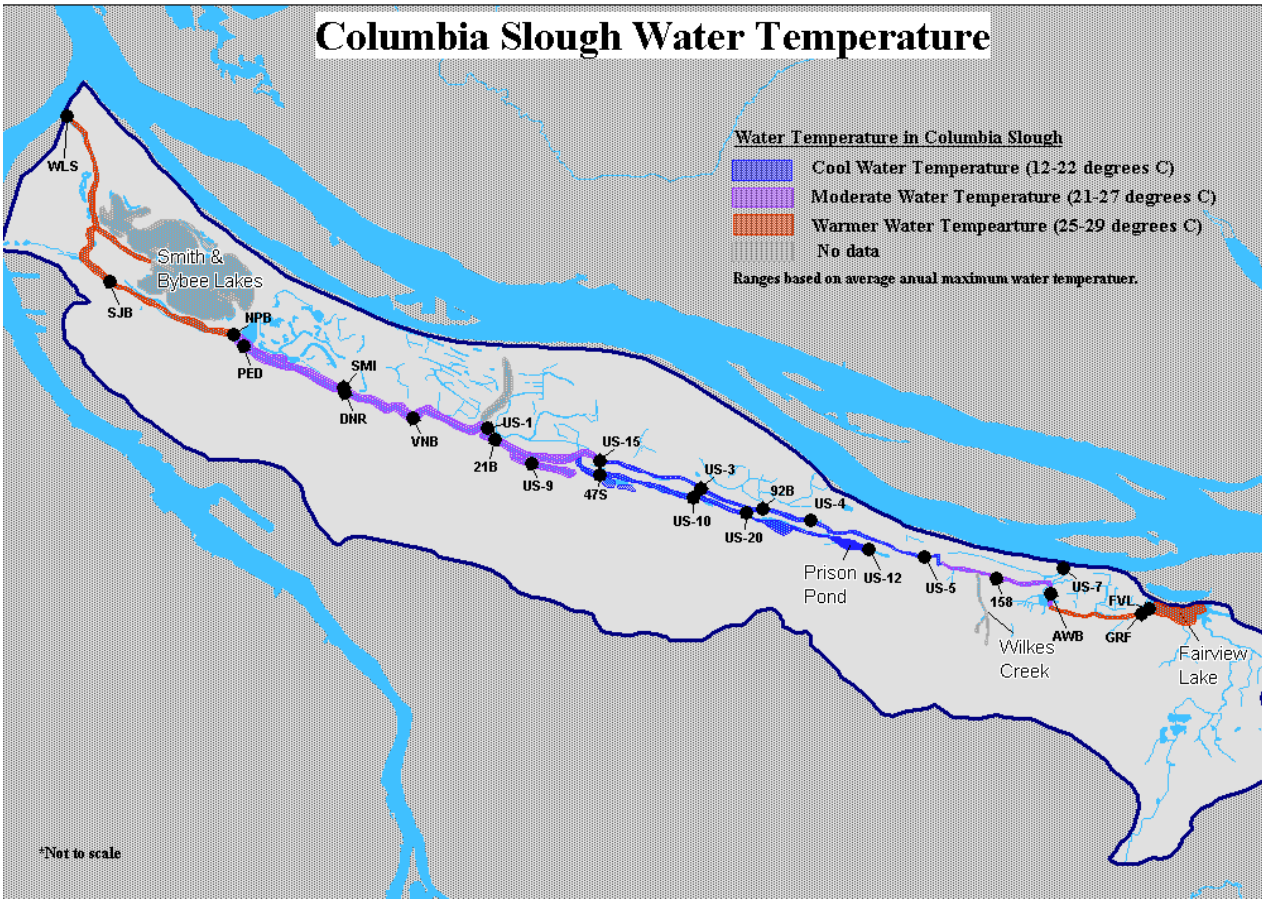
- The Middle Slough has moderate water temperatures compared with the Upper Slough and Lower Slough.
- Prison Pond (located near NE 112th Avenue) meets water quality standards year-round. This is mainly due to cool groundwater flow into the pond and large trees that shade the water.
- Cooler temperatures in Whitaker Slough may result from groundwater inflow to the Slough and from the presence of large trees that shade the water.

Lower Slough

- The Lower Slough is warmer overall than the Upper Slough and Middle Slough.
- Samples do not meet the water temperature standard during the summer.
- The Lower Slough provides refugia habitat for anadromous salmonids during fall, winter, and spring.

Figure 6-5 shows Columbia Slough summer water temperature ranges by reach.

Figure 6-5: Columbia Slough Summer Water Temperature Ranges by Reach



Sources

- Lack of shading is a source of warm water in the Columbia Slough.
- The physical features of the Slough are another source. The Slough is a low-gradient and shallow system that has long residence times.
- High culvert invert elevations cause impoundments that increase water residence time and reduce groundwater inflow.
- Extensive development has changed the hydrologic cycle, reducing aquifer recharge and potentially reducing cool groundwater inflow during the summer months.
- The Lower Slough is influenced by the Willamette and Columbia Rivers. Twice a day, tides bring water from the river into the lower section, and the Slough flows backward. In the summer, this brings cooler water into the Lower Slough. In the fall and early winter, this brings warmer water into the Lower Slough.

DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND

Dissolved oxygen (DO) is a very important water quality parameter for the Columbia Slough because low DO is one of the limiting factors for fish and benthic organisms. Fish use oxygen when it is transported across the gills by diffusion; this process relies on the difference in concentration of DO in the water versus in the fish.

Biochemical oxygen demand (BOD) is the amount of oxygen needed by microorganisms to break down organic waste. There is no water quality criterion for BOD (DEQ 1999). BOD is discussed in the TMDL based on how it relates to the criteria for DO. Within the TMDL, the loading capacity of BOD is determined based on the amount of BOD load that it takes to violate the three different criteria for DO.

Water Quality Standard

The Columbia Slough has been designated as salmonid rearing habitat, and DEQ has established a TMDL for DO. There are three water quality standards for DO (DEQ 1999):

- An absolute minimum of 4.0 mg/L (instantaneous standard)
- A 7-day minimum mean of 5.0 mg/L
- A 30-day minimum mean of 6.5 mg/L

DO is influenced by three factors: temperature, BOD, and algae/macrophyte growth (photosynthesis).

- An inverse relationship exists between DO and temperature: as temperature increases, the amount of oxygen that can dissolve in the water decreases.
- As water temperature increases, the metabolic rate of an organism increases, and the organism requires more DO.
- As BOD increases, DO decreases.
- In summer and fall, portions of the Slough produce excessive algae and macrophyte growth. These two aquatic plants use carbon dioxide and produce oxygen during the day (photosynthesis) and can cause the Slough to become supersaturated with DO. At night, algae and macrophytes stop producing oxygen but continue to respire, depleting DO.

Conclusions

- DO in the Columbia Slough would be expected to be low in summer because of warm water temperatures. However, DO is in fact high because macrophytes and algae add oxygen into the water through photosynthesis.
- DO in the Columbia Slough would be expected to be high in fall and winter because of cool water temperatures. However, DO is in fact low, and the Slough sometimes does not meet water quality standards in fall and winter
- Monitoring results for the Slough show that BOD within the water column is usually below the loading capacity that would result in a decrease of DO to below its TMDL. However, when algae and macrophytes die and decay in the fall, they contribute to increased BOD load and are a potential cause for low DO. No analysis of BOD load from the seasonal die-off has been performed.

Sources

- Until recently, one of the main sources of low DO in the Middle and Lower Slough in the winter was high BOD concentration in anti- and de-icing agents used at Portland International Airport and, to a lesser extent, the Oregon Air National Guard. During past de-icing events, very high BOD loads resulted in DO dropping far below the instantaneous standard of 4 mg/L, in some cases to zero, in the Lower Slough for several days. Since 1997, the Port has implemented best management practices to reduce discharge of anti- and de-icing agents to the Columbia Slough. In addition, in 2002 the Port completed the infrastructure needed to manage anti- and de-icing agents in stormwater runoff in compliance with the waste load allocations in the TMDL for DO.
- Until recently, another source of BOD in the Lower Slough was the raw sewage released during CSO events. CSOs have been virtually eliminated in the Columbia Slough (i.e., controlled to 99 percent). If a CSO event occurs, it can be expected that BOD will increase, and DO may consequently decrease.
- During the fall, algae and macrophytes die and stop producing DO by photosynthesis. Further, as algae and macrophytes decay, the decomposition creates a BOD load, which decreases DO.
- Another source of low DO is respiration by the excessive amounts of algae and macrophytes present during the summer.

EUTROPHICATION
(Nutrients, Chlorophyll a, and pH)

Eutrophication is a natural process by which nutrients and organic substances enter an aquatic ecosystem and increase the biological productivity, which leads to increased amounts of algae and macrophytes. Increased algae and macrophyte growth creates conditions that interfere with the health and diversity of indigenous fish, plant, and animal populations and make recreational use of the waterway difficult. Human activities can greatly accelerate eutrophication by increasing the rate at which nutrients and organic substances enter the water. Sources of nutrients include agricultural runoff, urban runoff, leaking septic systems, sewage discharge, eroded stream banks, and the annual recycling of nutrients.

Water Quality Standard

High nutrients stimulate excessive algal growth (measured by chlorophyll *a*), which causes daily pH variations. pH is the measure of the acidity and alkalinity of water. pH is measured on a scale of 1 to 14. One (1) is very acidic, 7 is neutral, and 14 is very alkaline. Both low (below 5) and high (above 9) pH values are harmful to organisms. Low pH can result in increased solubility of many metals that are toxic to aquatic species. High pH can increase the toxicity of ammonia to fish and other aquatic biota. In general, if the pH of a system is near neutral, small variations in pH have little effect on the biota. However, extreme variations in pH have a great effect.

Excessive algae in the system results in large daily fluctuations in pH. These fluctuations occur because during the day, algae use carbon dioxide for photosynthesis, which increases pH. At night, algae stop using carbon dioxide but continue to respire, which results in increased dissolved carbon dioxide and lower pH. For the Columbia Slough, DEQ has set a water quality standard for pH as a range between 6.5 and 8.5, based on the preferred range for species growth and health (DEQ 1999).

Nutrients are an important factor in eutrophication. Nutrients increase plant growth, causing variations in dissolved oxygen and pH. Nutrients include phosphorus and nitrogen, available in different chemical forms. The growth-limiting nutrient often is phosphorus, present in its bioavailable form of total phosphate. When concentrations of total phosphate are below 0.1549 mg/L, the upper limit for pH (8.5) can be met (DEQ 1999).

Chlorophyll *a* is a measure of phytoplankton. Oregon Administrative Rules [OAR-340-41-150(1)(b)] cite an action level for average chlorophyll *a* concentrations of 15 ug/L, based on an average of three samples taken over a 3-month period, to control nuisance phytoplankton.

In 1994 and 1995, to improve water quality and aesthetic issues, MCDD and BES drew down the Slough decreasing residence time and allowing for more cool groundwater influx. The increased flows did reduce the algal growth; test results that year showed a significant decline of chlorophyll *a* during the spring and summer months. However, removing the algae allowed sunlight to penetrate down in the water column, and macrophytes quickly grew from the native seedbed. The macrophytes cause similar problems as the algae with clogging culverts.

Conclusions

Upper Slough

- Most samples in the Upper Slough meet the lower limit for pH. A few samples periodically do not meet the lower limit.
- The Upper Slough generally meets both the upper and lower limit for pH in the fall and winter.
- Samples consistently violate the pH upper limit in the spring and summer months.
- The site at NE 158th Avenue has met the standard for chlorophyll *a* in summer and fall since 1998/99.

Middle Slough

- The Middle Slough generally meets both the upper and lower limit for pH in the spring and summer.
- Site 92B in the Middle Slough shows the lowest pH of all measured sites and violates the lower limit multiple times. Violations occur during all seasons and do not have a pattern. There is a strong correlation between pH and precipitation at this site, indicating that violations of the minimum standard are likely a result of stormwater runoff.
- There was a pH crash in the spring of 1998 at NE 21st Avenue.

Lower Slough

- Samples in the Lower Slough generally meet the lower limit for pH during all seasons.
- The Lower Slough consistently violates the pH upper limit in the spring and summer.
- The site at the St. John's Landfill bridge, in the Lower Slough, has the highest chlorophyll *a* levels. The chlorophyll *a* standards are not met during spring, summer, and fall during all years of testing.

Sources

- In spring and summer, pH results are strongly influenced by photosynthesis.
- A strong correlation between chlorophyll *a* and BOD exists at all sites in the Columbia Slough.
- During the annual die-off, some algae and macrophytes float downstream and are removed by MCDD. However, a significant portion sinks to the bottom of the Slough and decays, releasing nutrients back to the water. These nutrients act as a source in the following growing season.
- Nutrient inputs from stormwater and possibly from old and/or leaking septic systems and cesspools are a possible source.
- Spills and illicit discharges are another possible source of pH variations.

SUSPENDED SOLIDS

Suspended solids (fine soil particles that are suspended in the water column) pose a water quality problem for multiple reasons:

- Organics such as PCB, dieldrin, DDT, DDE, and dioxin and metals that are toxic to aquatic life bind to organic matter in soil particles.
- Suspended solids cause turbidity and siltation that cause breathing problems in fish and limit macroinvertebrates' ability to find food.
- Suspended solids can act as a BOD load.
- Suspended solids can decrease sunlight available to aquatic life.

Water Quality Criteria

In the Columbia Slough National Pollutant Discharge Elimination System (NPDES) 1200-COLS industrial stormwater discharge permit, total suspended solids (TSS) is used as a surrogate for the amount of organic chemicals in the stormwater (DEQ 1999). A surrogate is used because it is not feasible, due to detection limits, to measure organic chemicals in stormwater discharge or the water column. The NPDES 1200-COLS permit proposes a benchmark of 50 mg/L TSS for stormwater discharges to the Columbia Slough. Modeling of the Columbia Slough system determined a ratio of 2:1 between urban stormwater discharge and in-stream concentration (BES 1997a). Therefore, the in-stream target for TSS is 25 mg/L. In the absence of water quality criteria, this in-stream target will be used.

Conclusions

Upper Slough

- TSS concentration decreases from Fairview Lake downstream.
- Samples from the NE 158th site met the target 80 percent of the time.
- At the Fairview Lake (GRF) and Airport Way Bridge (AWB) sites, more than 50 percent of the samples did not meet the target.

Middle Slough

- TSS concentrations in the Middle Slough are significantly less than in the Upper or Lower Slough. More than 90 percent of the samples met the target at all sites.

Lower Slough

- TSS concentrations increase from the levee downstream to the confluence.
- At NE Vancouver Bridge (VNB) more than 90 percent of the samples met the target.
- At downstream sites, PED and SJB, more than 50 percent of the samples did not meet the target.

Sources

- Sources of TSS include sediments transported in stormwater from streets, parking lots, driveways, agriculture runoff, and construction activities.
- Another source of TSS is the re-suspension of sediment. The Slough is an aggrading stream, which means that it gradually accumulates sediment.
- Bank erosion is a potential source of TSS.

LEAD

In general, most of the metals that are of concern for the health of humans and aquatic species are not very soluble in water and are not usually found in water quality samples collected in the Columbia Slough. These metals are discussed in the Sediment Quality section or this chapter.

The exception is lead, which has been found in water samples of the Slough. When dissolved lead is consumed by humans, it can have adverse effects on the body, including kidney damage and impacts to the nervous system. Dissolved lead also has negative impacts on fish and wildlife.

Water Quality Standard

In the Columbia Slough TMDL, there are two criteria: one for total lead and one for dissolved lead. The criteria are calculated using hardness, which determines how much lead can dissolve in the water. Therefore, the criteria change based on the hardness. EPA recommends using the dissolved lead criterion because dissolved lead is the most biologically available form of lead (DEQ 1999).

Conclusions

Upper Slough

- Samples taken in the Upper Slough met the dissolved lead standard.
- Depending on the site, between 60 and 70 percent of the samples met the total lead standard.
- Dissolved lead results at AWB and NE 158th are decreasing over time. Results at GRF are increasing over time.

Middle Slough

- Samples taken in the Middle Slough met the dissolved lead standard.
- Approximately 80 percent of the samples met the total lead standard.
- Dissolved lead results at all sites in the Middle Slough are decreasing over time.

Lower Slough

- Samples taken in the Lower Slough met the dissolved lead standard.
- Total lead concentrations increase from upstream to downstream, with 90 percent of the samples meeting the standard at VNB and only 70 percent of the samples meeting the standard at SJB.
- Dissolved lead results at VNB are decreasing over time. Results at NPB and SJB are increasing over time.

Sources

- Transportation land uses are one of the largest contributors of lead. Stormwater runoff from streets, parking lots, and driveways transports lead, along with other pollutants, to the Slough.
- Other sources include industrial discharges, contaminated sites, auto wrecking yards, sediments, and air emissions.

STORMWATER RUNOFF

Stormwater runoff itself is not a pollutant, but it carries pollutants from many different land uses to water bodies and is a significant concern in all the City's watersheds. The densely developed Columbia Slough Watershed comprises about 54 percent impervious surfaces, such as roads, parking lots, sidewalks, and rooftops. This large impervious area has significantly increased stormwater runoff that now enters the Slough waterway within hours of a rainfall event. Rapid transport of water in the Slough channel as well as short-term changes in water level can erode the banks, introducing more sediment into the water.

Stormwater runoff also transports pollutants, such as bacteria, fertilizers, pesticides, and sediment, from urban and agricultural land uses to the waterway. The transportation system (streets, highways, the airport, and railways) is a source of pollutants such as heavy metals, oil and grease, brake and tire dust, and garbage. These pollutants degrade water quality and habitat for aquatic species. Further, many of the pollutants attach to soil particles and accumulate in the sediment, posing a risk to human health and wildlife.

HAZARDOUS SPILLS AND ILLEGAL DUMPING

Spills of hazardous materials, such as household hazardous wastes, oil, and industrial chemicals, occasionally occur. These spills can reach the Columbia Slough through the stormwater system if they are not reported and cleaned up in a timely way. These hazardous materials have the potential to impair water quality and harm wildlife and humans, depending on the type of material spilled.

Illegal discharges to the stormwater system occur occasionally. These illegal discharges include sanitary sewer, wash water, or other hazardous material discharges. These discharges are rarely reported to the City until they reach the Columbia Slough waterway. Once in the waterway, the discharge, depending on the type, has the potential of impairing water quality and harming fish, wildlife, or human health.

Illegal dumping of trash and debris on the banks of the Slough occurs. Significant amounts of trash can be found in the Columbia Slough Watershed. One particularly bad site is the Lower

Slough from approximately NE 13th Avenue to the St. Johns Landfill. This site contributes pollution to the waterway. During one cleanup of this site, 20 yards of garbage were removed. There are other sites notorious for large amounts of trash and debris. Not only can trash and debris potentially contain hazardous chemicals that can be harmful to wildlife and humans, large debris or significant amounts of trash can erode Slough banks and cause sedimentation in the waterway.

Sediment Quality

OVERVIEW

Sediments are soil particles, sand, clay, or other substances that settle to the bottom of a water body. They act like sponges that soak up a variety of chemicals. Of particular interest are compounds, such as heavy metals and toxic organic chemicals, that are often bound to sediment particles and are not readily broken down by microbes. These chemicals do not pose a great threat to the environment if they are inert or remain insoluble. Some of them, particularly toxic organic compounds, have a tendency to leave the sediment particles, dissolve in water, and eventually become accumulated by biological organisms. Over time, some of these chemicals move up the food chain from plants to insects to fish. In the process, they progressively increase in concentration (called biomagnification) in the tissues of the organisms. Through this biomagnification process, low concentrations of contaminants in the sediments eventually increase to more elevated levels in organisms higher in the food chain, to an extent that may be detrimental to the organisms' well-being and to the animals (e.g., fish) or people who eat them. If dissolved organic pollutants are in the water, biomagnification can also occur directly through the water column (the area between the bottom and surface of the water body), without sediment as an intermediary.

Other chemicals, such as heavy metals (commonly chromium, copper, lead, and zinc), may have a more direct effect on the environment through their toxicity to bottom-dwelling organisms, called benthics. Benthic macroinvertebrates (organisms lacking a backbone, such as fly nymphs, dragonfly nymphs, beetles, and true bugs) are the base of the food chain and therefore support higher organisms.

Sediments come from many sources:

- Natural weathering of rocks
- Erosion of upland soils, loose materials near stream banks, and non-vegetated or unstabilized river banks
- Particles from impervious surfaces, such as streets, parking lots, roofs, and buildings that are transported in stormwater runoff
- Vegetative debris and breakdown products
- Construction sites without adequate erosion control

Water bodies have different sizes and kinds of sediments, which provide important substrate (stream bottom) for benthic macroinvertebrates. The sediments of forested and faster-flowing streams and creeks in upper watershed areas tend to be composed mostly of sand, gravel, and rocks. As a waterway moves into the lowlands and flows more slowly, its sediment composition changes to include finer materials (such as silt and clay) and organic or vegetative matter. The Columbia Slough is a low-gradient stream much like the latter description. Sediments that contain higher amounts of organic matter (e.g., decomposed vegetation, dead macroinvertebrates, and microorganisms) tend to absorb more toxic organic chemicals because many toxic organic chemicals are hydrophobic (water-fearing) and therefore prefer to reside in the organic matter in the sediments. Despite their hydrophobic nature, however, a very minute fraction of these hydrophobic organic chemicals do sometimes leave the sediment particles and leach into the water, where they seek out media that have fats or lipids. Fish and other biota, including algae and aquatic plants, have lipids that will absorb these hydrophobic chemicals.

As is characteristic of a lowland, slow-moving water body, the Columbia Slough has fine, silty sediments with a fairly high organic matter content. Because the Slough is a water body in an urban and industrial watershed, the sediments contain elevated levels of contaminants compared to sediments in a pristine water body unaffected by human activity. A 1989 reconnaissance study (BES 1999) indicated elevated levels of heavy metals and some toxic organics. In 1993, a joint DEQ/Metro fish-sampling effort found elevated levels of PCBs and pesticides (such as DDTs and dieldrin, which are toxic organics) in tissues of a limited number of fish caught near the St. Johns Landfill (DEQ 1993; DEQ 2003). This finding of toxic organics in fish raised much concern about the people of immigrant communities who frequently fish from the Slough as subsistence anglers. In September 1993, the Oregon Health Division (now called the Oregon Department of Human Services) issued a health advisory about eating carp and black crappie from the Slough. However, a toxicologist from the former Oregon Health Division cautioned that this advisory was based on limited information and that further study was needed to define the extent and severity of fish contamination throughout the Slough. Subsequent sampling results confirmed elevated contaminant levels; however, levels were lower than the previous samples.

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY—OVERVIEW

The City of Portland and DEQ entered into a consent order agreement in late 1993 (see Appendix B: Regulatory Background) to conduct a remedial investigation and feasibility study (RI/FS) of sediment contamination along 30 miles of waterway, including all connected side channels, in the Columbia Slough system. This investigation entailed:

- Identifying areas with the highest levels of sediment contaminants
- Identifying problem chemicals and their potential sources
- Predicting the potential risk to human health and the environment
- Identifying sediment cleanup options and their associated costs

To help focus the large-scale RI/FS, the City used a tiered approach:

- A **screening level risk assessment (SLRA)** to identify the most contaminated sites or areas on which the City should first focus its efforts and resources
- **Focused remedial investigations and endangerment assessments** to conduct more in-depth site investigations and refine the SLRA risk assessment
- A **feasibility study** to identify technically feasible cleanup options
- **Implementation** to carry out the selected action(s) resulting from the feasibility study

These steps are described below.

SCREENING LEVEL RISK ASSESSMENT (SLRA)

The SLRA, completed in 1995, involved a general "screening" of the Columbia Slough to identify areas that present the highest potential risks to wildlife and human health (BES 1995). The SLRA analyzed 300 sediment samples from sites along 30 miles of the Slough for over 140 chemicals. Fish tissue samples were also collected and tested for a variety of toxic chemicals.

At each sampling site, the potential risks from sediment contaminants were assessed for different receptors: aquatic life (benthic organisms and fish), wildlife (great blue heron and river otter), and humans. The results of these assessments were combined to identify the most contaminated sediment sites in the Columbia Slough. Each sediment sample was given a "hazard score," based on the overall risks it poses. Based on their hazard score, the 300 sediment samples were then divided into four priority groups: A, B, C, and D. Priority A sites have the highest hazard scores and pose the greatest potential risk relative to all the sites, while Priority D sites have the lowest hazards scores and pose the lowest potential risk. This ranking helped set priorities for action by flagging the areas of greatest concern.

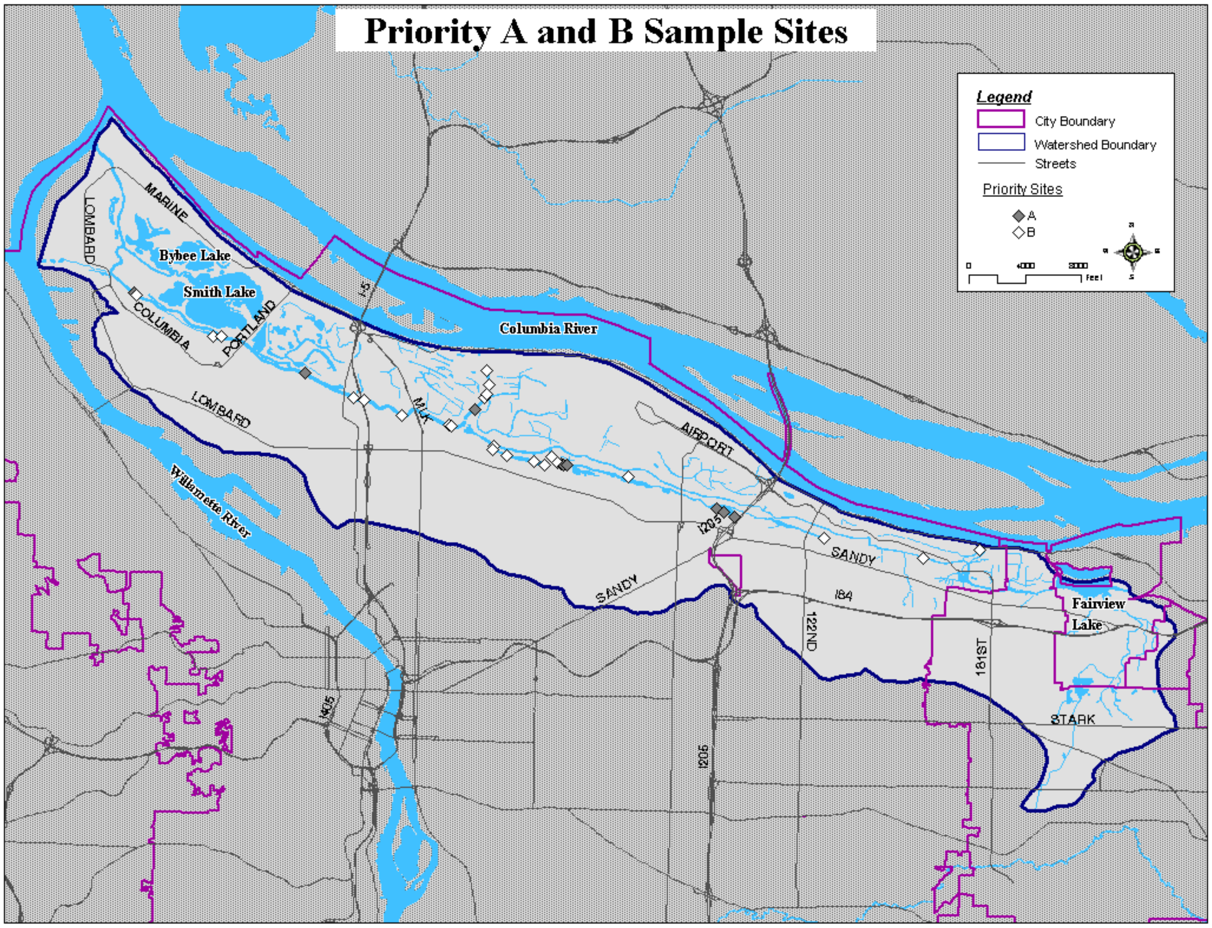
The SLRA identified 34 Priority A and B sites that require attention and additional in-depth investigation. Some of these sites are located close to each other, so were grouped into general areas with the most contamination, as shown on Figure 6-6.

Human Health Risks

The SLRA found that fish caught in the Columbia Slough contain chemicals that pose potential excess cancer risks to humans who eat them (Adolfson & Associates 1993). The primary chemicals of concern are PCBs and chlorinated pesticides. Because fish consumption data were not available at that time, to ensure a conservative risk assessment, it was assumed that people ate 26 kilograms (11 times higher than the EPA-recommended fish consumption rate for risk assessment purposes at that time) of Slough fish every year for 75 years. The cancer risk from eating this amount of fish ranges from less than 1 in 1,000,000 to 1 in 1,000. (A risk of 1 in 1,000 means that if 1,000 people eat Slough fish every week for 75 years, one of them could get cancer.) PCBs, which are not often detected in Slough sediments but are found in fish tissues, account for 68 percent of the predicted cancer risk. DEQ has determined that the acceptable excess human cancer risk is 1 in 1,000,000.

The Oregon Department of Human Services (ODFW) has issued a public health advisory about eating fish from the Slough (ODFW 1993; Oxman et al. 1993). The advisory is available in English, Spanish, Russian, Cambodian, Laotian, and Vietnamese.

Figure 6-6: Priority A and B Sediment Sample Sites



The SLRA also estimated health risks resulting from exposure to contaminated sediments through swallowing sediments and having skin contact with sediments when swimming in the Slough. It found that these risks are very low because sediment pollutant levels are not high enough to cause immediate acute toxicity if a person comes into contact with the sediments. It is therefore highly unlikely that people will get sick from chemical toxicity if they swallow some sediment during swimming. However, the sediments may contain bacteria and viruses that can cause acute health problems; it is therefore recommended that people should avoid coming into contact with the sediments.

FOCUSED REMEDIAL INVESTIGATIONS AND ENDANGERMENT ASSESSMENTS

The SLRA found that Buffalo Slough, a side arm near the downstream end of the Middle Slough, has six Priority B sites. Because of this clustering of high-risk sites, as well as the relatively small and contained area, a focused remedial investigation and endangerment assessment was conducted for Buffalo Slough.

The purpose of the **focused remedial investigation** was to determine the extent and nature of the contamination in more detail. Extensive testing for selected chemicals of potential concern was conducted in surface and core sediments, pore water in the sediment, and fish.

Toxicity assays were also performed as part of the focused remedial investigation. These are laboratory tests that determine if the sediments taken from an investigation area are actually bioavailable to (taken up by) benthics and other organisms and therefore toxic to them.

In the **endangerment assessment**, the results of the focused remedial investigation were used to predict risks. This endangerment assessment was more detailed than the SLRA risk assessment: more site-specific data were used, and the toxicity assays provided information about the bioavailability of the contaminants.

Similar focused remedial investigations and endangerment assessments were also conducted for other Priority A and B sites in the Middle Slough (including Whitaker Slough), Upper Slough, Peninsula Drainage Canal, and Wapato Wetlands in the Lower Slough system.

Findings of Focused Remedial Investigations and Endangerment Assessments

Table 6-1 summarizes the findings of the focused remedial investigations and endangerment assessments.

The most commonly found sediment contaminants include heavy metals (lead, zinc, chromium, copper) and toxic organic chemicals (pesticides and PCBs). Many of the toxic organic chemicals have been banned for many years, so these chemicals were either washed into the Slough years ago, are being newly introduced into sediments from "legacy" sources (i.e., the pollutants are still in the environment), or are still being used by people who have remaining supplies. Contaminant levels were fairly low and uniform throughout the Slough, indicating a non-point source. Levels of both heavy metals and persistent organics are not too different, and sometimes even lower, than DEQ-approved reference sites in waterways with no observed industrial discharges or combined sewer overflows. Pesticide levels are generally higher in the upper parts of the Middle Slough and Upper Slough compared to the lower sections of the Slough. This is probably due to historical agricultural pesticide use.

Sediment toxicity assays performed on sediments from Buffalo Slough and Wapato Wetland did not show toxicity to benthic organisms, implying that the contaminants, although elevated, were not bioavailable. The exception is the section of Whitaker Slough between NE 122nd and NE 128th avenues, where sediment toxicity to benthics was observed and was correlated to organochlorine pesticide in the sediments. The major source of the banned pesticides, most likely from historic uses, appears to originate from the nearby agricultural fields.

Table 6-1: Findings of Focused Remedial Investigations and Endangerment Assessments

Priority A and B Site Location	Results/Comments
Wapato Wetland	Found negligible risks. BES constructed a pollution reduction facility as a precaution to prevent potential future pollution. DEQ has issued a "no further action" letter for this site.
Peninsula Drainage Canal	Found risk marginally above acceptable levels for human health. In December 2002, DEQ issued a conditional "no further action" letter for this site. Long-term monitoring of this site is necessary.
Buffalo Slough (approximately 1-mile stretch)	Found high risk to humans from consuming contaminated fish, and moderate risk to wildlife. DEQ is evaluating the results.
NuWay Oil	DEQ is working on this site.
Whitaker Slough, NE 66th Avenue	Found risks were negligible. No further action is needed.
Johnson Lake	DEQ is working with potentially responsible parties (PRPs) on voluntary cleanup.
Whitaker Slough, NE 122-128th Avenue	Found highest levels of pesticides in sediments in the Slough; pesticides are toxic to benthics; potential sources are nearby farms. BES is looking into installing a pollution reduction facility in the storm sewer to treat stormwater. Also, the Natural Resources Conservation Service is working with farms to implement best management practices.
Private stormwater outfall near N.E. 158th Avenue	DEQ worked with PRP on voluntary cleanup. In August 2002, the responsible party removed approximately 300 tons of contaminated sediments and disposed the dredged materials at the Hillsboro Landfill. No further action is necessary.
MCDD Pump Station 4	MCDD removed the sediments to prevent clogging of its pumps. DEQ is satisfied with the disposal action, and no further action is necessary.

Conclusions

Upper Slough

- There are no identified SLRA Priority A and B sites.
- Legacy pesticides levels, such as DDTs, are generally higher in this reach than the Middle and Lower Slough. The most likely sources of the legacy pesticides are from historic use of pesticides and subsequent erosion of surface soils.

Middle Slough

- Almost all of the identified SLRA Priority and B sites are located in the slower-moving southern arms of the Middle Slough.

- More in-depth risk assessments of the identified Priority A and B sites indicated that the majority of these sites do not pose significant risk to human health and the environment. The two exceptions are the Buffalo Slough and the Marx-Whitaker Slough (between NE 122nd and 128th Avenues), which pose potential high risk to human health and the environment.
- The key risk driver in Buffalo Slough appears to be human health risk due to consumption of contaminated fish.
- Marx-Whitaker Slough has high levels of pesticides and petroleum hydrocarbons in its sediments. The level of pesticides in this part of the Slough was found to be toxic to benthic organisms. Fish in this reach do not pose significant risk to human health and wildlife. Soil erosion from the nearby agricultural fields accounts for a large portion of the sediment contamination. Two farms and the City of Portland were identified as the principal responsible parties for the contamination. These three parties will soon participate in DEQ's voluntary cleanup program to address this contamination.

Lower Slough

- There are several identified SLRA Priority and B sites.
- Of the identified Priority A and B sites, the Wapato Wetlands and the former Union Carbide site were found to pose no significant risk to human health and the environment and were given "no further action" letters from DEQ.
- Intensive source investigations are ongoing in the subbasins adjacent to the other Priority A and B sites.
- All sources of CSOs in the Lower Slough are controlled to 99.6 percent.

Slough-wide

- Extensive sediment sampling found that the level of sediment contamination was lower than originally anticipated. Low levels of sediment contamination exist throughout the Slough.
- Fish were uniformly contaminated at low levels throughout the Slough. The main risk drivers in fish tissues are PCBs and pesticides. The level of contamination poses human health risk and also potential ecological risk.
- No current point sources of PCBs and chlorinated pesticides were found in the Columbia Slough Watershed.

FEASIBILITY STUDY OF BUFFALO SLOUGH

A feasibility study was conducted for Buffalo Slough to identify sediment cleanup alternatives that are effective, reliable, implementable, safe, and reasonable in cost relative to risk (BES 1997b). The feasibility study used the results obtained in the focused remedial investigation and endangerment assessment. It addressed data gaps, established remedial action objectives to protect human health, characterized the behavior of contaminants, and developed and screened remedial alternatives.

A number of remedial alternatives were evaluated. After eliminating some alternatives, the following remaining actions were further considered, both alone and in combination:

- **Institutional Controls**: Implement source control measures, watershed improvement efforts, best management practices, and health advisory outreach to the public.
- **Enhanced Natural Recovery**: Incorporate a thin sand cap (less than 6 inches) to dilute contaminants and improve oxygen transfer and/or introduce microorganisms that can degrade PCBs and pesticides.
- **Sediment Capping**: Cover contaminated sediments with a 2-foot layer of cleaner materials (sand, clay, gravel, or all three).
- **Removal and Upland Disposal of Sediments**: Dredge contaminated sediments by mechanical dredging, excavation by backhoe or loader, or hydraulic dredging by a cutterhead.
- **Stormwater Treatment**: Reduce the amount of suspended solids entering the system.
- **No Action**.

The feasibility study found that it is impracticable to meet the remedial action objectives for protection of human health, for the following reasons:

- Modeling (called fugacity modeling) predicted that baseline concentrations of PCBs and chlordane in sediments and stormwater would need to be lowered by 100 to 1,000 times to achieve the remedial action objectives. The most rigorous and costly cleanup alternatives are expected to reduce baseline concentrations by only about 10 times over the long term. In order to meet acceptable human health criterion (1 in1,000,000 excess cancer risk), all sediments need to be removed and over 99.99 percent of stormwater discharges need to be eliminated.

- The chemicals associated with fish consumption (PCBs and chlordane) are introduced into Buffalo Slough from many diffuse sources that cannot be readily controlled, such as stormwater runoff and atmospheric deposition. To meet the human health objectives, all stormwater and atmospheric inputs of PCBs and chlordane would need to be eliminated.

The study found that sediment capping, in combination with stormwater treatment, provides the highest overall effectiveness, long-term reliability, implementability, and safety for Buffalo Slough. This evaluation did not consider a cost-effectiveness criterion, which is usually evaluated by DEQ. In 1999, the cost of this alternative ranged from $2.7 million to $6.1 million for the 1-mile stretch of Buffalo Slough. Additionally, this alternative would drastically alter the habitat and hydrology of Buffalo Slough, which ranges from 1 to 3 feet in depth. This alternative, like all others, is not expected to fully achieve the remedial action health objectives.

Phytoremediation

BES studied the feasibility of using the abundant floating aquatic plants (mostly algae) and also the rooted aquatic plants (macrophytes) in the Buffalo Slough system to soak up and clean up sediment contaminants. This cleanup method is called phytoremediation.

A field study showed that the aquatic plants did take up metals and toxic organics, but the levels of both metals and organics in the plant tissues were very low (BES 2001). It is estimated that the possible amount of PCBs in the Buffalo Slough system is from a low of 250 grams (or 250 milliliters, which corresponds to approximately one teacup) up to a high of 3.25 kg (13 teacups). A conservative estimate is that about 150.75 million kg (wet weight) of plant materials would be needed to remove 250g of PCBs, while about 1,960 million kg of plant materials would be needed to remove 3.25 kg of PCBs. The conclusion appears to be that a substantial amount of plant materials, more than is feasible, would need to be harvested to substantially reduce or eliminate the total PCB mass in the system.

CURRENT APPROACH TO SEDIMENT MANAGEMENT

The Columbia Slough SLRA revealed that virtually every sediment sample analyzed contained one or more contaminants that exceeded conservative screening levels based on impacts to fish and fish consumers. This type of area-wide contamination is indicative of diffuse urban area pollution in which, for many years, the Slough has been receiving discharges and stormwater runoff from a wide variety of land uses throughout its 60 miles of waterways. However, this low-level, widespread pollution makes it difficult to establish remedial action goals for sediment at a specific site.

To address this issue, DEQ analyzed the existing database of sediment sampling results to determine "baseline" concentrations of frequently detected contaminants of concern. The baseline concentration for a particular contaminant reflects the upper end of the range of concentrations of the contaminant that could be expected to be pervasive throughout the Slough sediment. This concentration range should not include concentrations indicative of an isolated source of contamination, but should reflect levels of contamination resulting from non-point, or widespread sources. The process for determining baseline concentrations in the Slough and a table of baseline values is provided on the DEQ web page at www.deq.state.or.us/nwr/Columbia_Slough/cs.htm.

DEQ is using the baseline values to determine practical cleanup levels for individual contaminated sites. DEQ also developed a preliminary set of risk-based sediment concentration goals, which are the ultimate objective for the long-term, watershed-based remedial approach. These risk-based concentrations will likely be refined as additional studies are completed. The DEQ web page has a list of sites currently identified, their status, and a Slough map showing site locations.

The current watershed-based approach will address both general water quality issues and particular sediment and fish consumption concerns. This approach recognizes the uniqueness of the low-level contamination of the Columbia Slough sediments, which is a widely distributed problem that requires an ecosystem-level strategy.

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