Appendix C

The Health of Our Waters, Water Quality Monitoring Results for 2007

Contents

This appendix presents a summary of the quality of King County's marine water and freshwater bodies in 2007. The summary is followed by more detailed information on water quality monitoring locations, procedures, and results. The information satisfies the RWSP reporting policies that call for inclusion of yearly water quality monitoring results as a part of the RWSP annual report.

Summary of 2007 Water and Sediment Monitoring

To protect public health and its significant investment in water quality improvements, King County regularly monitors wastewater treatment plant effluent, marine water, fresh water, and sediments (Table C–1 at the end of this summary). The biological, chemical, and physical parameters used to assess a water body's health under Washington State Water Quality Standards are fecal coliform bacteria, dissolved oxygen, temperature, pH, nutrients, turbidity, and a variety of chemical compounds. King County uses other indicators in addition to these parameters.

Monitoring activities in 2007 found that in general, the quality of marine and fresh waters in King County is fair to good.

Some water quality indicators…

Fecal coliform bacteria. The presence of fecal indicator bacteria indicates that the water has been contaminated with the fecal material of humans, birds, or other warm-blooded animals. One type of fecal indicator bacteria, fecal coliforms, may enter the aquatic environment from domestic animals, wildlife, stormwater runoff, wastewater discharges, and failing septic systems. Although these bacteria are usually not harmful, they often occur with other less easily measured disease-causing bacteria and their presence indicates the potential for pathogens to be present and to pose a risk to human health.

Dissolved oxygen. Aquatic plants and animals require a certain amount of dissolved oxygen (DO) for respiration and basic metabolic processes. Waters that contain high amounts of DO are generally considered healthy ecosystems. DO concentrations are most important during the summer season when oxygen-depleting processes are at their peak.

Temperature. Temperature influences many of the chemical components of the water, including DO concentration. Temperature also exerts a direct influence on the biological activity and growth and, therefore, the survival of aquatic organisms. Temperature levels in waters that bear salmonids (cool water fish) are also very important.

Treatment Plant Effluent

King County regularly samples wastewater effluent from its three secondary wastewater treatment plants—West Point, South, and Vashon plants—and analyzes these samples at process laboratories at the plants and at its environmental laboratory in Seattle. The plants discharge their effluent into Puget Sound through deep outfalls. Discharges continue to be in compliance with the terms and conditions of the National Pollutant Discharge Elimination System (NPDES) permit for each plant, and so are in compliance with the Washington State Water Pollution Control Law, the Federal Water Pollution Control Act, and the Federal Clean Water Act.

Marine Water and Sediment

King County's marine water quality monitoring program routinely collects samples near treatment plant and CSO outfalls to assess potential effects to Puget Sound water quality from

wastewater discharges. Additional samples are collected at ambient locations in the Sound to better understand regional water quality and to provide data needed to identify trends that might indicate impacts from long-term cumulative pollution.[1] Seventeen sites were monitored in 2007 for nutrients, fecal coliform bacteria, dissolved oxygen, turbidity, temperature, salinity, chlorophyll, stratification, and other parameters.

The quality of Puget Sound is evaluated by two fecal coliform bacteria standards—the geometric mean and the peak. All offshore marine monitoring locations—both ambient and outfall locations—met these fecal coliform bacteria standards in 2007. One nearshore site in Elliott Bay along the Seattle waterfront and another nearshore site at the mouth of the Lake Washington Ship Canal failed fecal coliform bacteria standards. Both sites are near freshwater bacteria sources such as storm drains and the mouths of streams and creeks.

The program also monitors for fecal coliform bacteria levels at Puget Sound beaches, including beaches near outfalls. Twenty-five beach sites were monitored in 2007. Twelve of the 25 monitoring locations at Puget Sound beaches in King County met fecal coliform bacteria standards. Most of the beach sites that failed both standards are near freshwater sources. Of the six beach sites near outfalls, only two met both standards (compared with all sites in 2006), most likely because 2007 was a wetter year. Sites near freshwater sources that failed standards in 2006 also failed standards in 2007.

The overall quality of marine water is evaluated through the water quality index (WQI). Results of 2007 monitoring indicate that overall water quality in Puget Sound is good. Two of the fourteen monitoring sites, both in Quartermaster Harbor near Vashon Island, received a WQI score of high concern. All of the six marine outfall sites were classified as having good water quality (low level of concern).

Sediment quality is monitored near outfalls, at ambient locations in Elliott Bay and the Central Basin of Puget Sound, and as part of projects to remediate sediments contaminated from historical CSO discharges. Sediment quality in ambient locations in Elliott Bay and the Central Basin of Puget Sound is generally good, with some isolated impacts from human activity.

Lake Water and Sediment

The Major Lakes Monitoring Program has been collecting samples from 25 open-water sites in Lake Union and the Ship Canal, Lake Washington, and Lake Sammamish since the early 1970s. Sampled parameters include temperature, dissolved oxygen, pH, conductivity, clarity (Secchi transparency), phosphorus, nitrogen, and fecal coliform bacteria.

The quality of the three major lakes in King County is evaluated by using two fecal coliform bacteria standards—one for ambient lake water and the other for swimming beaches. Ambient water quality, as indicated by fecal coliform bacteria levels, is generally good. In 2007, 100 percent of the Lake Sammamish stations, 85 percent of the Lake Washington stations, and 60 percent of the Lake Union stations achieved the exceptionally high standard used to assess

[1] Ambient monitoring measures surrounding (background) conditions.

ambient lake water. Fewer Lake Washington samples met the standard in 2007 than in 2006. This decrease was due to high concentrations recorded in two different samples at each of two stations, one at the south end and one on the southwest side of the lake. Lake Union/Lake Washington Ship Canal waters showed a similar decrease, mainly because of high concentrations measured at two stations. Six of the eleven highest bacteria concentrations were collected after record rainfall the first week of January 2007, with accompanying increases in volume of combined sewer overflow (CSO) and stormwater discharges into Lakes Washington and Union.

Summer phosphorus concentrations are converted to a trophic state index to assess overall water quality in Lakes Washington, Sammamish, and Union. The 1994–2007 results for Lakes Sammamish and Washington show that phosphorus concentrations fluctuated between the low and moderate thresholds from year to year, indicating that the water quality varies from good to moderate with low potential for nuisance algal blooms (algae feeds on phosphorus). Lake Union typically shows phosphorus concentrations in the moderate water quality range. In 2007, however, high phosphorus levels placed Lake Union in the poor water quality range. High phosphorus concentrations in urbanized areas can result from poorly designed drainage systems, inadequate maintenance of sewer infrastructure, and home and business landscaping practices.

The Major Lakes Sediment Monitoring Program monitors sediment in Lakes Washington, Sammamish, and Union. Five stations are monitored each year for trends. Other stations are sampled to investigate sediment quality in swimming beaches, nearshore habitat, and in areas with known contamination. Samples are analyzed for metals, organics, and physical parameters.

The Swimming Beach Monitoring Program assesses 17 beaches on Lake Sammamish, Lake Washington, and Green Lake every summer. This effort, ongoing since 1996, tests for fecal coliform bacteria as an indicator of risk to human health. Monitoring of these swimming beaches during summer 2007 shows that the higher concentrations of fecal coliform bacteria occur at beaches adjacent to streams that drain urbanized drainage basins. Bacteria levels were low in Green Lake for the fifth year in a row (all samples met the standard). Lake Sammamish levels remain consistently low, with slight variability from year to year (about 90 to 100 percent of samples have met the standard since 1999). High bacteria levels resulted in the closure of four beaches on Lake Washington in 2007: Juanita, Magnuson off-leash area, Gene Coulon, and Meydenbauer Bay swimming beaches. There were no beach closures in 2006.

Stream and River Water and Sediment

The Stream and River Monitoring Program targets rivers and streams that cross sewer trunk lines and those that are considered a potential source of pollutant loading to a major water body. This long-term program has collected samples at 56 sites on four rivers and twenty-eight streams for many years. Overall water quality of rivers and streams in King County, as measured by the water quality index for rivers and streams, varies between and within streams. Increased urbanization has resulted in more surface runoff and changes to peak streamflow that cause flooding, channel erosion, and increased contaminant loading.

In 2007, the water quality index indicated that 45 percent of the fifty-six sampling sites—compared to 63 percent in 2006—were of moderate or high water quality (moderate or low concern) and 55 percent were rated to be of low water quality (high concern). Of the sixteen sites

in WRIA 9, six sites were rated of low concern, six sites were of moderate concern, and four sites were of high concern. Of the forty sites in WRIA 8, one site was rated of low concern, twelve sites were of moderate concern, and twenty-seven sites were of high concern.[2] All sites rated of high concern were impacted in part by excessive nitrogen and/or phosphorus loading, and most of these sites were affected by high fecal coliform bacteria (97 percent of all sites), low dissolved oxygen (74 percent of all sites), high temperatures (58 percent of all sites), and high suspended solids/turbidity (32 percent of all sites).

The Streams Sediment Monitoring Program monitors sediment in small wadeable streams in WRIAs 8 and 9. Samples are collected at one location in 10 index creeks each year and analyzed for trends. In addition, one-time samples are collected every creek-mile in approximately three stream basins each year. All 30 streams in the program will be monitored within 10 years. Samples are analyzed for metals, organics, and physical parameters.

Other Monitoring

In addition to ongoing water and sediment quality monitoring, the county conducts special intensive investigations. Recently, studies were completed to understand water quality issues and needs, to project future impacts of population growth, and to identify any needed improvements to salmon habitat in the two primary watersheds in King County (WRIAs 8 and 9).

Other studies are under way to support decision-making, siting, and construction of wastewater capital projects. For example, the wetland that will receive effluent from the new Carnation Treatment Plant is being monitored both before plant startup to establish a baseline and after discharge begins to monitor for any trends in water and sediment quality.

Availability of Monitoring Data on the Web

In 2007, King County's regional data management program continued to maintain and upgrade the methods used to store and disseminate monitoring data so that the public can directly download substantial amounts of data from the Web:

- The Puget Sound Marine Monitoring Program page provides tables and graphs of measurements of Puget Sound water quality collected from the surface to the bottom. This page was upgraded in 2007 to provide data for continuous water quality meters in Elliott Bay and Quartermaster Harbor. The page is found at http://dnr.kingcounty.gov/wlr/waterres/marine/Index.htm.
- The Swimming Beach Monitoring Program page provides tables, graphs, and maps of monitoring results as they become available each week and provides the most current information on beach closures. The page is found at http://dnr.kingcounty.gov/wlr/waterres/swimbeach/default.aspx.

[2] The two major watersheds—called Water Resource Inventory Areas (WRIAs)—in King County are the Lake Washington/Cedar/Sammamish watershed (WRIA 8) and the Green/Duwamish and Central Puget Sound watershed (WRIA 9).

- The Major Lakes Monitoring Program page and the Stream and River Monitoring Program page provide tables and graphs of monitoring results as they become available each month. These pages continue to allow for direct data download from the Web. A substantial upgrade to the Stream and River monitoring page was released in May 2008. The major lakes monitoring page is found at http://dnr.kingcounty.gov/wlr/waterres/lakes/index.htm; the stream and river monitoring page is found at http://green.kingcounty.gov/WLR/Waterres/StreamsData/.
- The Hydrologic Information Center page provides the public with access and robust ability to download rainfall, streamflow, water quality, and other hydrologic data collected at King County gauge sites. It also offers a summary of the year's precipitation and provides access to presentations made by King County's hydrology staff. The page is found at http://green.kingcounty.gov/wlr/waterres/hydrology/.
- The Lakes Stewardship Program page was upgraded to provide the ability to download data and to access graphs and maps of the lakes and the monitoring data. The page is found at http://dnr.kingcounty.gov/wlr/waterres/smlakes/index.htm.

Table C-1. Summary of King County Water Quality Monitoring Programs

Program	Media and Locations	Parameters	Methods	Sampling Frequency	Program Purpose	Duration
Ambient Monitoring						
Marine monitoring	Water and sediment in areas of Puget Sound away from outfalls and CSOs; shellfish (butter clams) from Puget Sound beaches	Water: temperature, salinity, clarity, DO, nutrients, chlorophyll, and bacteria Sediment: metals, organics, and physical properties Shellfish: lipids and metals	Water samples collected at multiple depths, ranging from 1 to 200 m Sediment: VanVeen grab sampler for subtidal sediments; sediment corer for intertidal sediments[a] Shellfish: shovel	Water: monthly Sediment: biannually (Elliott Bay), every 5 years (Puget Sound) Shellfish: semi-annually	To assess potential effects to water quality from point and nonpoint pollution sources and to compare quality county wastewater sources	Ongoing
Major lakes monitoring	Water and sediment in Lakes Washington, Sammamish, and Union at ambient locations and near stormdrains and CSOs	Water: temperature, DO, pH, conductivity, clarity, phosphorus, nitrogen, and fecal coliform; micorcystin is measured at select stations Sediment: metals, organics, and physical properties	Water samples collected every 5 m from 1 m below the surface to bottom at one station in center of lake and from the surface around various locations around the shoreline Sediment: surface, petite ponar	Water samples: biweekly during the growing season; monthly during the rest of the year Sediment: yearly	To identify impacts from the wastewater conveyance system and to document the condition of lakes	Ongoing
Small lakes monitoring	Volunteers monitor 50 small lakes in King County	Precipitation, lake level, temperature, Secchi depth, phosphorus, nitrogen, chlorophyl-a, phytoplankton	Single-point and vertical profiles	Rainfall & lake level: daily Temperature & Secchi depth: weekly Other parameters: every 2 weeks April to October	To characterize and identify trends in water quality	Ongoing

BMP = best management practices; BOD = biochemical oxygen demand; DNR = Washington State Department of Natural Resources; DO = dissolved oxygen; Ecology = Washington State Department of Ecology; HPA = Hydraulic Permit Approval; SAP = sampling and analysis plan; TMDL = total maximum daily load; TOC = total organic carbon; TSS = total suspended solids.

[a] Intertidal zone is the area that is exposed to the air at low tide and submerged at high tide; subtidal zone is the area below the intertidal zone that is always covered by water.

[b] Petite ponar is a type of grab sampler that can easily be carried by one person in the field and can be deployed without the use of a winch or crane recommended for larger samplers.

Table C-1. Summary of King County Water Quality Monitoring Programs

Program	Media and Locations	Parameters	Methods	Sampling Frequency	Program Purpose	Duration
Rivers and streams monitoring	Rivers and streams of both watersheds; emphasis on wadeable streams that cross wastewater conveyance lines or that could be a source of pollution Stream sediment samples for trends analysis at 10 sites, plus spatial analysis of stations every creek mile	Baseflow and storm samples: turbidity, TSS, pH, temperature, conductivity, DO, nutrients, ammonia, bacteria Storm samples: trace metals Sediment: metals, organics, and physical parameters	Various methods for collecting water samples Sediment: surface sediments, core tube, petite ponar	Monthly sampling under baseflow conditions; three to six times per year at mouth of streams under storm conditions Sediment: yearly	To identify impacts from the wastewater conveyance system and to document the condition of streams and rivers	Ongoing
Swimming beach monitoring	Cedar-Sammamish Watershed: Lake Washington, Lake Sammamish, and Green Lake	Bacteria; microcystin is measured at select stations	Water samples at swimming beaches	Weekly, in the summer from Memorial Day through end of September	To evaluate human health risks and necessity for beach closures	Ongoing
Benthic macroinvertebrate monitoring	Wadeable stream sub-basins	Size and distribution of aquatic macroinvertebrate populations	Samples colllected with a Surber stream bottom sampler	Annually	To establish a baseline for identifying long-term trends	Ongoing
Wastewater Treatment Plant Outfall Monitoring						
Marine wastewater plant outfall water column and beach monitoring	Puget Sound water column at treatment plant outfalls; water and shellfish (butter clams) at beaches near outfalls	Water: temperature, salinity, clarity, DO, nutrients, chlorophyll, and bacteria Shellfish: lipids and metals	Water samples at outfalls collected at multiple depths, ranging from 1 to 200 m Shellfish: shovel	Water samples: monthly Shellfish: semi-annually	To assess potential effects to water quality from wastewater discharges	Ongoing
Marine NPDES sediment monitoring	Sediments in Puget Sound near treatment plant outfalls and the Denny Way CSO	Grain size, solids, sulfides, ammonia-nitrogen, oil & grease, TOC, metals, organic compounds, and (at South and West Point plants) benthic infauna	Sediment samples in a grid pattern as defined in the SAP approved by Ecology	Sediment samples at outfalls once per permit cycle (about every 5 years)	NPDES permit requirement	Ongoing

BMP = best management practices; BOD = biochemical oxygen demand; DNR = Washington State Department of Natural Resources; DO = dissolved oxygen; Ecology = Washington State Department of Ecology; HPA = Hydraulic Permit Approval; SAP = sampling and analysis plan; TMDL = total maximum daily load; TOC = total organic carbon; TSS = total suspended solids.

Table C-1. Summary of King County Water Quality Monitoring Programs

Program	Media and Locations	Parameters	Methods	Sampling Frequency	Program Purpose	Duration
Special Studies						
Brightwater Outfall Studies	Water, sediment, and eelgrass for the Brightwater outfall site Upland soils at outfall Portal 19	Water: temperature, salinity, DO, nutrients, and fluoresence Sediment: benthic community and chemistry	Water column samples and continuous buoy readings Surface sediments Eelgrass survey	Annual	To meet HPA and DNR outfall lease requirements	Through 2014
Brightwater Construction NPDES Stormwater Monitoring	Stormwater and surface water	Stormwater quality	Various	Intensive	To meet NPDES Construction Stormwater permit	Through 2010
Elliott West/Denny Way CSO sediment monitoring	Sediment near the new Denny Way Regulator and Elliott West CSO Treatment Facility outfalls and in sediment cleanup areas associated with the old Denny Way CSO discharge site	Benthic communities, sediment chemistry	Sediment samples per approved SAP	Variable	To meet U.S. Army Corps of Engineers permit requirements and an Ecology cleanup order	Through 2021
Diagonal/Duwamish post-remediation sediment monitoring	Sediment near the Seattle Diagonal storm drain (includes city and county CSO outfalls) and the county's Duwamish CSO outfall	Sediment chemistry, turbidity, cap surveys	Sediment samples per approved SAP	Annual	Under an EPA/Ecology Consent Order	Through 2013
Wetland monitoring for Carantion Treatment Plant	Water quality in discharge wetland, existing tributaries, and outflow Sediment quality in wetland pond	Water: metals, organics, nutrients, bacteria Sediment: metals, organics, and physical parameters	Water column Surface sediments	Variable	Determine conditions before and after treatement plant discharge	2006–2010

BMP = best management practices; BOD = biochemical oxygen demand; DNR = Washington State Department of Natural Resources; DO = dissolved oxygen; Ecology = Washington State Department of Ecology; HPA = Hydraulic Permit Approval; SAP = sampling and analysis plan; TMDL = total maximum daily load; TOC = total organic carbon; TSS = total suspended solids.

Marine Water Monitoring Results

This section describes the results of marine monitoring activities in 2007 in terms of fecal coliform bacteria levels and overall water quality rankings (water quality index).

Monitoring Locations

Figure C-1 shows ambient and outfall water quality monitoring locations in Puget Sound. Offshore, nearshore, and beach areas are monitored. Ambient sites are monitored to gauge general environmental conditions. Outfall monitoring sites are located near King County wastewater treatment plant and CSO outfalls.

Fecal Coliform Bacteria

Ambient and Outfall Locations

Levels of fecal coliform bacteria at 17 offshore and nearshore Puget Sound locations were measured monthly in 2007 to gauge the risk posed to human health from recreational uses of these waters. Two sites were added to the 15 sites monitored in 2006. A site in Salmon Bay was added because Salmon Bay is a high-use area and is close to the mouth of the Lake Washington Ship Canal. Another site in Fauntleroy Cove was added because of several potential sources of bacteria in the cove and the need for data from an offshore station to compare with the data from the beach site in the cove.

For marine surface waters, two fecal coliform standards are used: a geometric mean standard of 14 colony-forming units (CFU) per 100 mL and a peak standard that specifies that no more than 10 percent of the samples used to calculate the geometric mean exceeds 43 CFU/100 mL.[3] The period of averaging for the geometric mean standard should not exceed 12 months. Because samples are collected monthly, a total of 12 samples was used to calculate the geometric mean for each location.

All 13 offshore (7 ambient and 6 outfall) sites met the fecal coliform standards in 2007 (Figure C-2). Results for the 4 nearshore stations were mixed. The two nearshore sites in Quartermaster Harbor met both of the fecal coliform standards; the site at the mouth of the Lake Washington Ship Canal at Shilshole passed the geometric mean standard but failed the peak standard; and the site in Elliott Bay along the Seattle waterfront failed both standards. Bacteria levels tend to be higher along the waterfront than at offshore sites in Elliott Bay because of freshwater input from the Duwamish River and stormwater outfalls.

Ambient and Outfall Locations at Puget Sound Beaches

In 2007, fecal coliform bacteria levels at 25 Puget Sound beach sites were measured monthly to assess the risks to human health from direct contact with marine waters during activities such as

[3] A colony-forming unit (CFU) is a measure of viable bacterial numbers. Unlike in direct microscopic counts where all cells, dead and living, are counted, CFU measures only viable cells.

swimming, wading, scuba diving, and surfing. Nineteen sites are located in ambient areas, and six sites are in the vicinity of treatment plant and CSO outfalls. Although all of King County's treatment plant and CSO outfalls are located in offshore waters, beach areas that are inshore of the outfalls are considered as beach outfall sites.

Ten more beach monitoring sites were added in 2007 to the total of 15 sites monitored in 2006. The sites were added in order to increase spatial coverage, to monitor sites with stormwater discharges, and to support the BEACH (Beach Environmental Assessment, Communication and Health) Program, administered by the Washington State Departments of Ecology and Health, at locations with observed diminished water quality. More information on the BEACH Program can be found at http://www.doh.wa.gov/ehp/ts/waterrec/beach/default.htm.

Monitoring results in 2007 show that 12 of the 25 sites met both the geometric mean and peak standards, 5 sites met the geometric mean standard but not the peak standard, and 8 sites failed both standards (Figure C-2). The greatest determination of compliance with bacteria standards tends to be proximity to a freshwater source. Most of the sites that failed both standards are near freshwater sources such as storm drains and the mouths of streams and creeks. Sites near freshwater sources that failed standards in 2006 also failed standards in 2007. The site at Redondo, which is not near a freshwater source, had some of the highest bacteria counts of all the beach stations. The bacteria source is not evident and will be investigated further.

Although all beaches in the vicinity of outfalls met fecal coliform standards in 2006, this was not the case in 2007. The northern West Point and Vashon sites met both the standards, but other sites failed either both standards or the peak standard. Fluctuations in bacteria levels are likely caused by annual variability in amount and intensity of rainfall. For example, lower bacteria counts were recorded at all stations during 2004, 2005, and 2006—which were drier than normal years. On the other hand, 2007 was wet compared to recent years, particularly during the summer months, which would likely explain the higher fecal coliform levels.

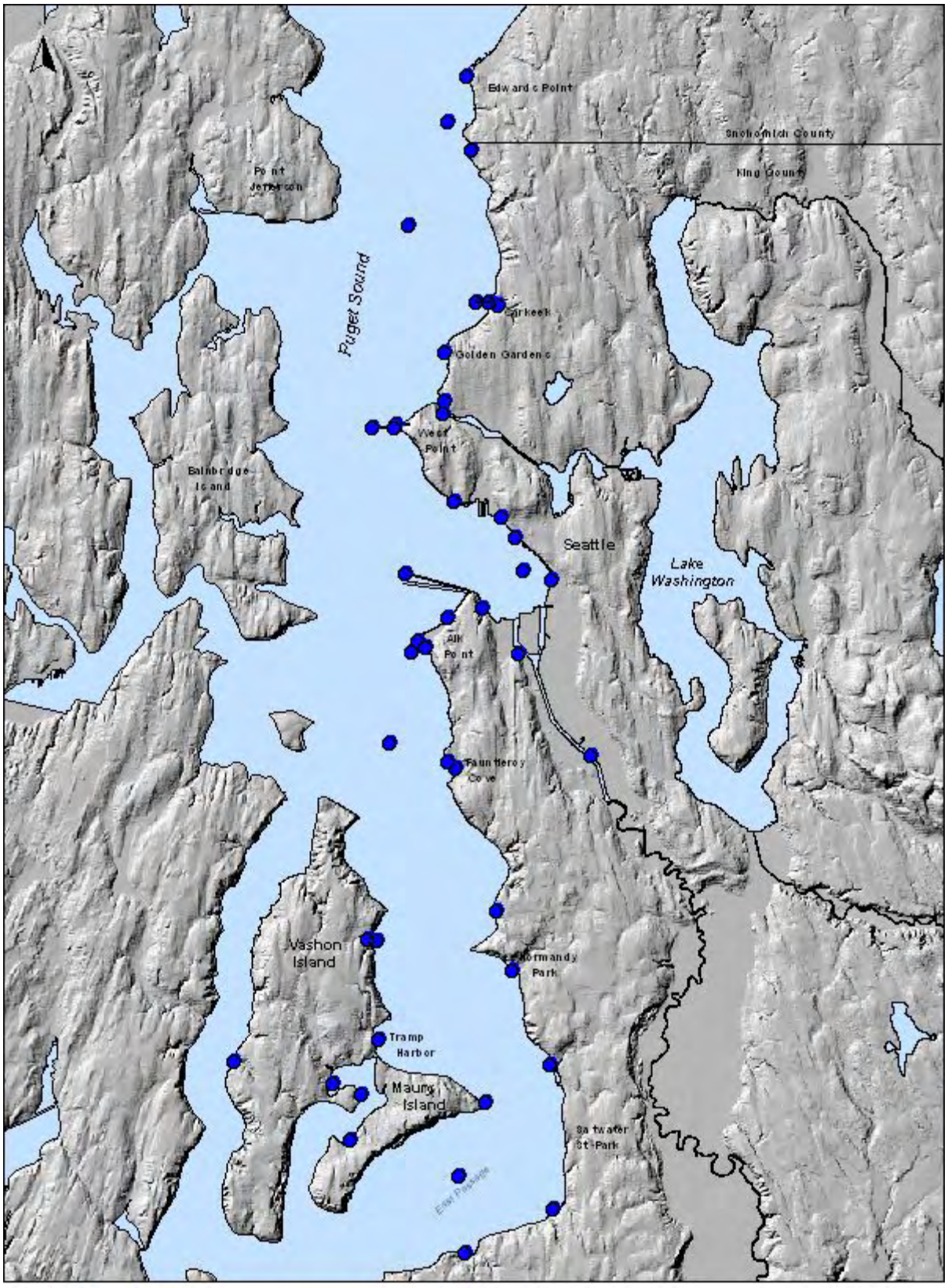

Figure C-1. Ambient and Outfall Water Monitoring Locations in Puget Sound

Figure C-2. Fecal Coliform Bacteria 2007 Results for Puget Sound Monitoring Sites

Overall Offshore Quality in Puget Sound—Water Quality Index

In 2007, King County monitored 14 sites each month to assess overall quality of offshore marine water. Two sites were added to the 12 sites monitored in 2006. Both sites are in Quartermaster Harbor near Vashon Island—one site is in the inner harbor and the other site is off the Dockton Park dock.

To determine overall water quality, the county uses a modified version of the water quality index (WQI) developed by the Washington State Department of Ecology (Ecology). The determination is based on four indicators: dissolved oxygen, dissolved inorganic nitrate and nitrite (nitrate+nitrite), ammonia, and density stratification strength and persistence. Each monitoring site is categorized as low, moderate, or high concern.

Low dissolved oxygen (DO) serves as an indication of both stratification strength and high primary productivity, driven by high nutrient concentrations. DO values of 5.0 mg/L and 3.0 mg/L are used as threshold indicators. The 5.0 mg/L value is a Washington State water quality guideline that indicates "good quality"; the 3.0 mg/L value is used because at this level, biological effects can be seen. Low dissolved nitrate and nitrite concentrations for consecutive months indicate that phytoplankton growth may be nutrient limited and that the site may be at risk for eutrophication (the process by which excess nutrients lead to excessive phytoplankton and algal growth), while high ammonia concentrations indicate the presence of a nutrient source. Strong and persistent stratification indicates reduced mixing between surface and bottom waters, which can trap waters with low DO near the bottom where many invertebrates live.

Figure C-3 shows the locations and WQI determinations for all offshore sites in 2007. Water quality at 11 of the 14 offshore sites , including the 6 outfall sites, was ranked as low concern. Although some sites in the Central Basin of Puget Sound experienced moderate-infrequent stratification, low DO levels were not observed.

This is the first year since 2003 that some sites were ranked as either moderate or high concern (Figure C-4). The three sites ranked as either moderate or high concern—representing about 21 percent of the sampling sites—were in embayments. Water quality at the Elliott Bay site was ranked as moderate concern. The ranking was based on strong-intermittent density stratification and DO values of less than 5.0 mg/L for two consecutive months.[4] The DO level in Elliott Bay was never less than 3.0 mg/L. The two Quartermaster Harbor sites had a high level of concern in 2007, the first year these sites were sampled. The ranking was based on nitrate+nitrite concentrations that were below the detection limits for five consecutive months.

[4] The Elliott Bay station showed five months of density stratification greater than 2.0 sigma-*t* and a mean annual sigma-*t* greater than 2.0.

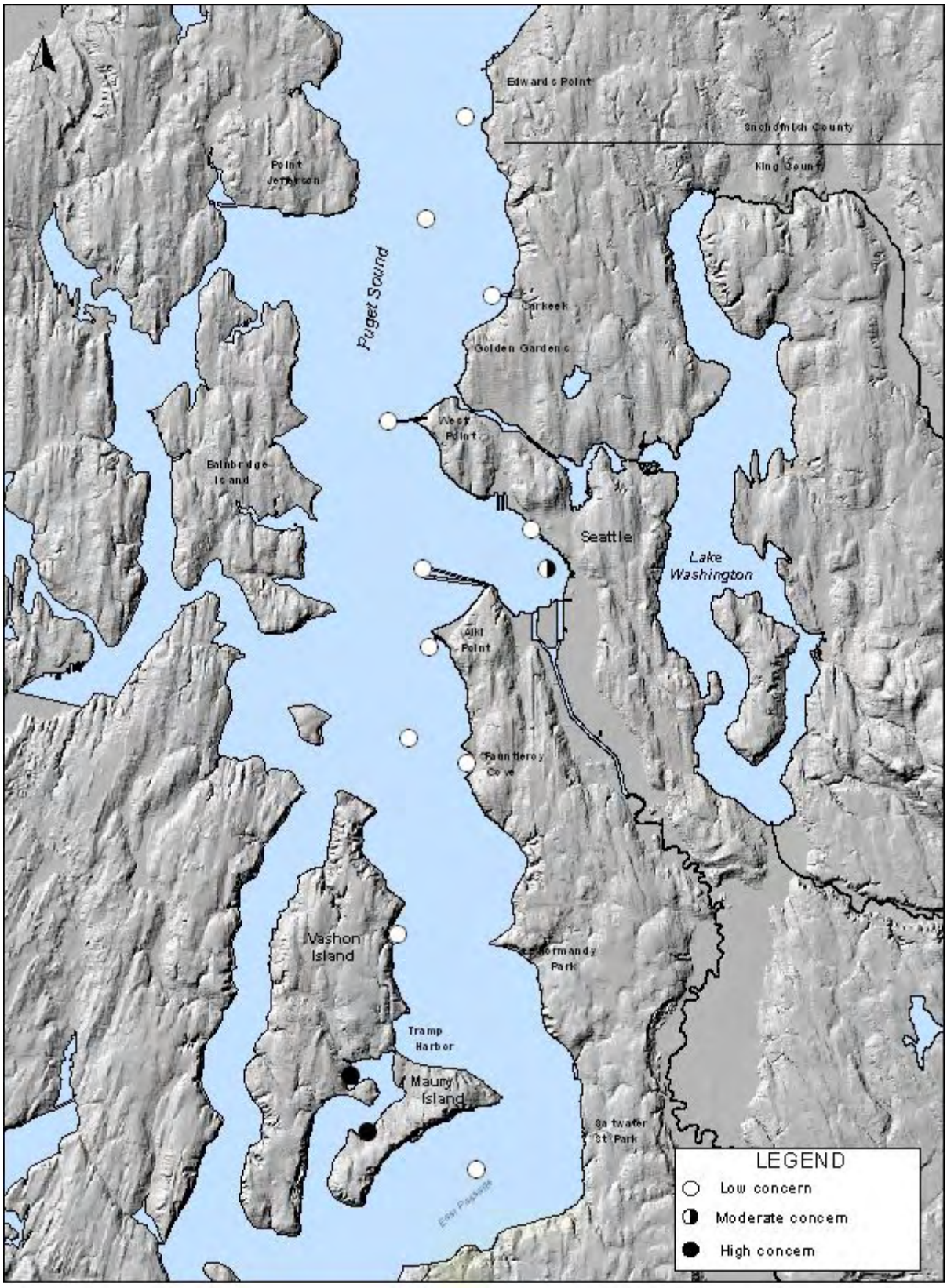

Figure C-3. Water Quality Index Scores for King County Offshore Stations in 2007

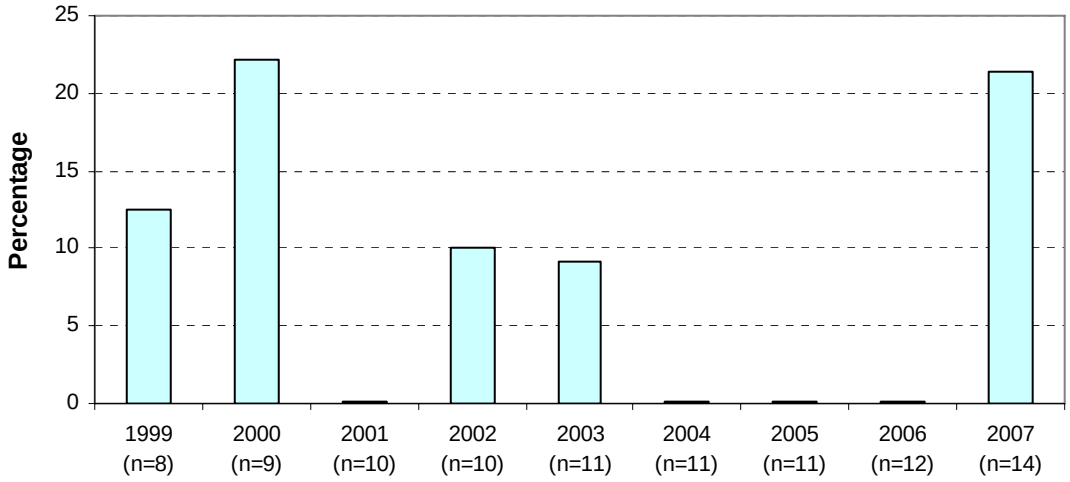

Figure C-4. Percentage of King County Offshore Stations with Moderate or High Concern Rankings Based on Water Quality Index, 1999–2007

Marine Sediment Monitoring Results

Sediments not only can be impacted by pollutant discharges but also can be a source of pollution through resuspension to the water column and through the food chain as benthic organisms and shellfish are consumed. This section discusses methods and results of sediment sampling and analysis conducted in 2007 at ambient locations throughout King County, at the West Point Treatment Plant outfall in support of NPDES permit requirements, and at the Elliott West CSO Treatment Facility/Denny Way CSO outfall areas in support of U.S. Army Corps of Engineers permit requirements and an Ecology cleanup order. It also describes findings of a recent remedial investigation of contamination in the Lower Duwamish Waterway.

Ambient Sediment Quality in Puget Sound and Elliott Bay

King County collected sediment quality data from subtidal ambient monitoring stations for many years, annually at first and then biennially between 1996 and 2004. These subtidal monitoring stations were located in Elliott Bay and in the Central Basin of Puget Sound near the City of Seattle. Sampling stations were located in areas away from the direct impact of potential point-source pollution, such as wastewater and stormwater outfalls, and from the impact of general non-point sources such as the Duwamish Waterway. Samples were collected from the top two centimeters (0.8 inch) of sediment and analyzed for metals and organic chemicals to evaluate sediment quality in the most recently deposited material. Metals and organics concentrations were compared to the published sediment quality chemical criteria of the Washington State Sediment Management Standards (SMS) and to region-wide Puget Sound sediment data.

The subtidal sediment monitoring program was temporarily discontinued after 2004 to enable King County staff scientists time to evaluate data generated from the program and from other

data collection efforts in the region. Following the review, King County began an expanded subtidal sediment monitoring program in 2007 that focuses on sediment quality in Elliott Bay while also monitoring ambient sediment quality in the Central Basin of Puget Sound and in three embayments of interest——Quartermaster Harbor, Fauntleroy Cove, and outer Salmon Bay.

Locations of sampling stations are shown in Figure C-5 (stations that are not in insets on the figure). The eight stations in Elliott Bay are sampled every two years, and the six ambient stations are sampled every five years. Four of the Elliott Bay stations and one of the Central Basin stations were part of the earlier sediment monitoring program.

In 2007, King County collected subtidal sediment samples from all 14 locations and analyzed them for metals and organic chemicals. Analytical results showed that 11 of the 14 stations met Washington State SMS chemical criteria for all regulated metals and organic compounds, which means that concentrations were below levels at which impacts to marine organisms might occur (Figure C-5). Three of the 14 stations showed exceedences of one or more regulated chemicals. The station in Quartermaster Harbor showed an exceedence for mercury, most likely from smokestack emissions from the old Asarco smelter.[5] The station located in Elliott Bay, just off Harbor Island, showed exceedences for mercury and butyl benzyl phthalate (an organic compound used as a plasticizer), most likely historical contamination from heavy industry on Harbor Island. The station located in East Passage, between Vashon–Maury Island and the south King County mainland, showed an exceedence for bis(2-ethylhexyl) phthalate, another plasticizer. No apparent source of bis(2-ethylhexyl) phthalate, other than introduction of contamination during sampling, could be identified for this deep ambient station.

In general, sediment quality at areas sampled by King County in Elliott Bay, Puget Sound, and three associated embayments are of good quality with some evidence of minor impacts from human activities at three locations.

Sediment Quality Near the West Point Outfall

Sediment samples are collected in the vicinity of the West Point Treatment Plant marine outfall once during each NPDES permit cycle (usually five years). Nineteen surface sediment samples were collected in September 2006 for analysis of chemical parameters including sediment conventionals, metals, and trace organics. A subset of these samples was also used for toxicity testing and benthic community analysis. In 2007, data analysis was completed and a final report was issued to Ecology to meet NPDES reporting requirements.

Samples from all 19 stations passed Washington State SMS chemical criteria. Samples from three stations near the end of the diffuser failed one or more sediment bioassays, exceeding SMS biological criteria (West Point inset, Figure C-5). These toxicity testing results, however, do not correlate well with sediment chemistry and benthic community analysis results. Sediment chemistry results at the three stations showed that chemical concentrations are well below SMS

[5] This assumption is based on the proximity of the old smelter to the sampling location and on elevated (but not above SMS chemical criteria) concentrations of lead and arsenic in Quartermaster Harbor compared with other Puget Sound ambient sites.

chemical criteria. Other chemical compounds not regulated under SMS, including pesticides, herbicides, brominated organic flame retardants, organotins, and other metals, that were analyzed to provide a complete picture of sediment quality at the location were not detected or did not show elevated concentrations.[6] Two of three stations also support a robust, diverse benthic community that has been stable over the last three monitoring events completed between 1998 and 2006.[7] (The third site was resampled for benthic community and results are being analyzed.) Benthic infaunal organisms are excellent biological integrators of chemical and physical sediment conditions and, as such, are considered a sensitive indicator of a healthy marine environment.[8]

Six stations were sampled and analyzed using the Puget Sound Sediment Quality Triad. Samples for analysis of sediment chemistry, toxicity, and benthic community assemblages were collected at the same time to classify sediment quality in one of four categories: high, intermediate/high, intermediate/degraded, and degraded. Sediments at four of the six stations were classified high quality. Two stations were classified as intermediate/high quality. These are the two stations whose toxicity results did not correlate with chemistry and benthic results.

Meetings will be held with Ecology to discuss these results and to determine whether additional sampling and monitoring are warranted and whether sediment monitoring will continue to be required as part of West Point's NPDES permit.

Sediment Quality Near the Future Brightwater Outfall

In 2001, 2006, and 2007, King County collected pre-construction baseline sediment quality data at 10 stations in the vicinity of the planned diffuser for the Brightwater Treatment Plant marine outfall and at one nearby reference station (Brightwater inset, Figure C-5). Additional sediment quality data will be collected following construction and prior to outfall operation.

Sediment data collected in 2007 were similar to data collected in 2001 and 2006. Chemistry analytical results show that sediments at all stations meet Washington State SMS chemical criteria for all regulated compounds. Additional chemical compounds, including pesticides, herbicides, brominated organic flame retardants, organotins, and other metals, were analyzed to provide a complete picture of sediment quality at the location. Results of the analysis indicate that chemicals are not present in sediments at the location of the Brightwater outfall diffuser at levels that would impact the marine environment. Benthic community data collected in 2001,

6 Organotin compounds or stannanes are chemical compounds based on tin with hydrocarbon substituents. Organotin compounds are used as a biocide in polyvinyl chloride (PVC), as a wood preservative, and as an anti-foulant in paints to protect the hulls of boats and ships, buoys, and pilings from marine organisms such as barnacles.

7 "Robust" means that it is a healthy and thriving benthic community that is able to stand up to the rigors of statistical analysis.

8 Benthic infauna live in sediment in soft substrate areas such as shallow mud flats and sand flats. They include worms, bivalves and crustaceans. All these species have burrowing mechanisms. Benthic communities provide a significant food source for many species of fish. Wading birds also rely on benthic infauna to form an integral part of their diet.

2006, and 2007 indicate a stable benthic community that is typical for sediments found in areas of Puget Sound with similar depth and physical properties.

In general, sediment quality at the location of the future Brightwater outfall diffuser is good, with a stable benthic community typical of the type of sediment found at the site and little evidence of impacts from chemical compounds.

Sediment Quality Near the Denny Way/Elliott West CSO Outfalls

Two new outfalls went online in 2005 as a part of the Denny Way/Lake Union CSO control project. One outfall discharges primary-treated effluent from the new Elliott West CSO Treatment Facility; the other outfall discharges untreated CSO from the Denny Way Regulator Station and replaces the previous outfall that was closer to shore. In 2006 and 2007, King County collected sediments from 16 stations in the area to meet long-term monitoring requirements of a U.S. Army Corps of Engineers permit and an Ecology cleanup order for the project (Denny Way inset, Figure C-5).

The sediment samples collected in 2007 were analyzed for chemical parameters and benthic community assemblages. Results indicate that concentrations of one or more chemicals at 13 of the 16 stations exceeded Washington State SMS chemical criteria and that benthic assemblages in both the new and former CSO outfall locations show minor impacts from outfall operation.

The area is undergoing remediation of historical sediment contamination resulting from CSO discharges from the Denny Way outfall before the site was controlled and from other unrelated inputs. Remediation of a nearshore subarea was completed in early 2008. A six-year monitoring program will track results of the remediation. King County and Ecology are monitoring three other subareas to see whether they will recover naturally or will require further remediation.

Sediment Quality in the Duwamish Waterway

King County has been coordinating its sediment management efforts in the Duwamish Waterway with two federal Superfund projects: the Harbor Island and the Lower Duwamish Waterway projects.[9]

The county has been working in partnership with the Port of Seattle since 2003 on the Harbor Island Superfund project. The project is remediating historical sediment contamination at the county's Lander and Hanford CSOs.

In 2001, EPA added about five miles of the Lower Duwamish Waterway (LDW) to its list of Superfund cleanup sites. Nine county CSOs are located in this stretch of the waterway. King County, the Port of Seattle, the City of Seattle, and Boeing became involved early in the process

[9] Superfund is the common name for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Enacted by Congress in 1980 and amended in 1986, this law provides broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

before the site was listed under Superfund and initiated work in support of the remedial investigation and feasibility study (RI/FS). Phase 1 of the RI examined existing data on the risks to human health and the environment from sediment-associated chemicals in the LDW. As a result of the Phase 1 study, EPA identified seven early action sites. Two of the seven early action sites were near the county's Norfolk and Diagonal/Duwamish CSOs. Sediment near the Norfolk site had already been remediated in 1999; remediation of the Diagonal/Duwamish sediment was completed in 2004.

Phase 2 of the RI generated additional data and estimated risks that will remain after completion of early remedial actions. The draft RI was circulated for public review in November 2007. Some key findings are as follows:

- The waterway contains a diverse assemblage of aquatic and wildlife species and a robust food web that includes top predators.
- Much of the sediment contamination resulted from historical releases that are now generally buried under cleaner more recently deposited sediment. Almost all new sediment that enters the waterway comes from the Green River.
- In general, high concentrations of chemicals, including polychlorinated biphenyls (PCBs) were detected in surface sediment in localized areas—frequently called "hot spots"—separated by larger areas of the LDW with lower concentrations. Relatively high surface sediment contamination is present in some areas as a result of a number of processes, including low net sedimentation rates in a few areas with primarily historical contamination or because of the presence of ongoing localized sources.
- The highest risks to people are associated with consumption of fish, crabs, and clams, with lower risks associated with activities that involve direct contact with sediment, such as clamming, beach play, and netfishing.
- Most of the human health risk is from PCBs, arsenic, cPAHs, and dioxins and furans.
- Ecological risks to fish and wildlife were relatively low, with the exception of risks to river otter from PCBs.

Some Chemicals Defined…

PCBs (polychlorinated biphenyls). Used in electrical equipment, paints, plastics, dyes, and other products, before being banned in the U.S in 1977. Known to cause cancer in animals and produce health effects in humans.

PAHs (polycyclic aromatic hydrocarbons). Byproducts of combustion of coal, oil, gas, wood, garbage, and tobacco, and in charboiled meat. May cause cancer, reproductive problems, birth defects, impaired immune function, and other health effects. (cPAHs are carcinogenic PAHs.)

EDCs (endocrine disrupting chemicals). May be in natural or synthetic hormones, personal care products, industrial byproducts, plastics, and pesticides. Mimic, inhibit, or alter the hormonal regulation of the immune, reproductive, or nervous systems or other parts of the endocrine system.

TBT (tributyl tin). An EDC used in paints and as a pesticide. Is stable, persists in the environment, and is toxic to aquatic life.

Phthalates. Used in a variety of consumer products such as deodorant, nail polish, and perfume. Found to cause adverse health effects, including cancer, in laboratory animals.

Furans (and related dioxins). Byproducts of combustion, manufacture of herbicides, and bleaching of paper pulp. Found to cause adverse effects, including endocrine disruption, in laboratory animals. May cause cancer in humans.

- Sediment contamination in approximately 75 percent of the LDW is estimated to have no effect on the benthic invertebrate community; approximately 7 percent of the surface sediment has chemical concentrations exceeding the higher of the two state standards associated with potential adverse effects to the benthic invertebrate community. The potential for effects in the remaining 18 percent of the LDW is more uncertain. Most of the state sediment standard exceedances were for PCBs and phthalates, although 41 different chemicals had at least one exceedance.

The draft RI included two recommendations in its key findings:

- The control of local sources of toxics is critical to the long-term success of specific remedial actions in the Lower Duwamish Waterway.
- Continued coordination of cleanup actions and source control will be necessary to ensure that any actions taken are not unduly impacted by local sources.

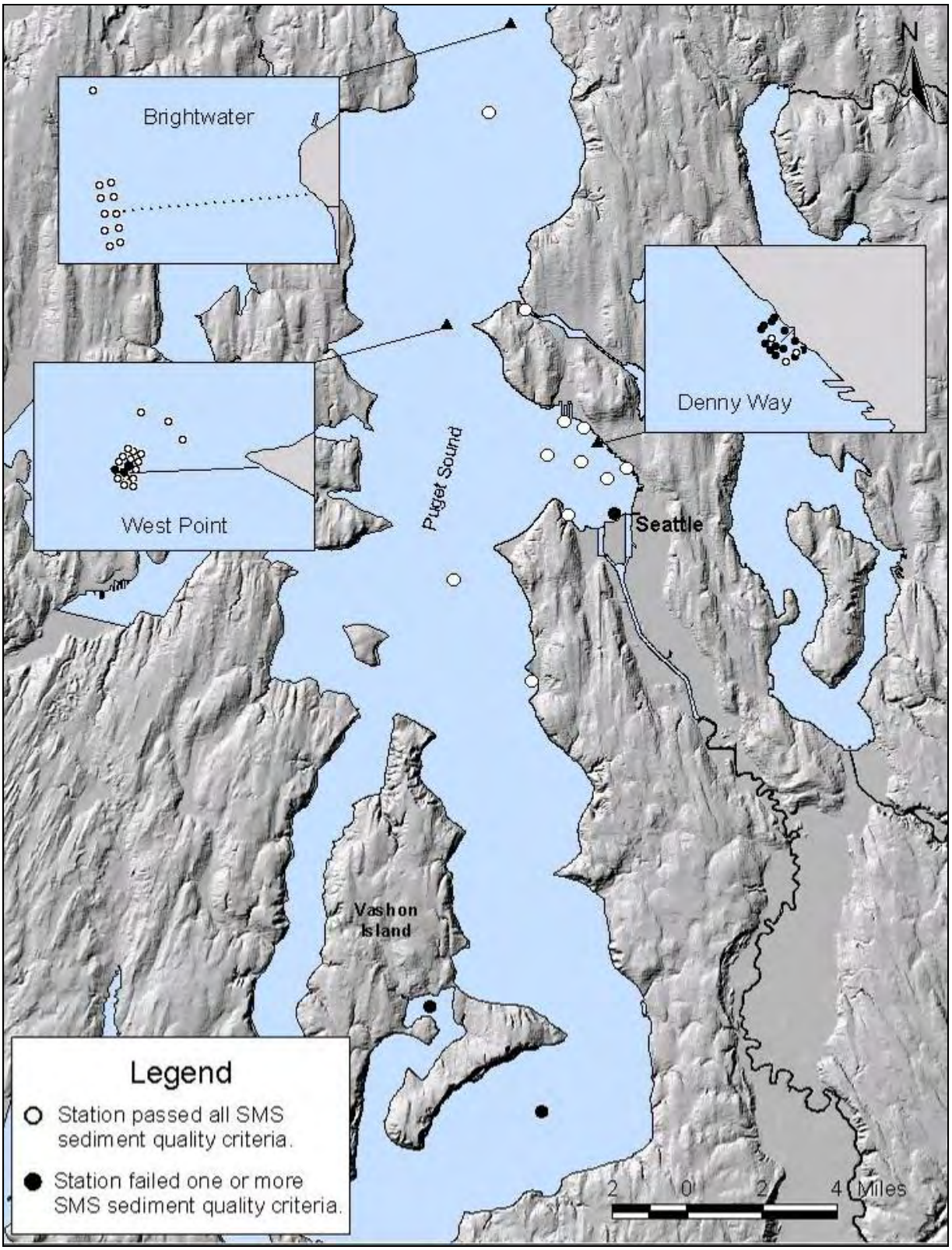

Figure C-5. Sediment Monitoring Stations in Elliott Bay and Central Basin of Puget Sound

Major Lakes Monitoring Results

This section describes the results of fecal coliform bacteria sampling at ambient and swimming beach locations in the major lakes of King County. It also describes overall water quality in these lakes based on calculation of their trophic state index.

Monitoring Locations

Figure C-6 shows the 25 ambient sampling locations in Lakes Washington, Sammamish, and Union and in the Lake Washington Ship Canal. Figure C-7 shows the 17 swimming beach sampling locations in Lake Washington, Lake Sammamish, and Green Lake.

Figure C-6. Ambient Monitoring Locations in Lakes Washington, Sammamish, and Union (including the Lake Washington Ship Canal)

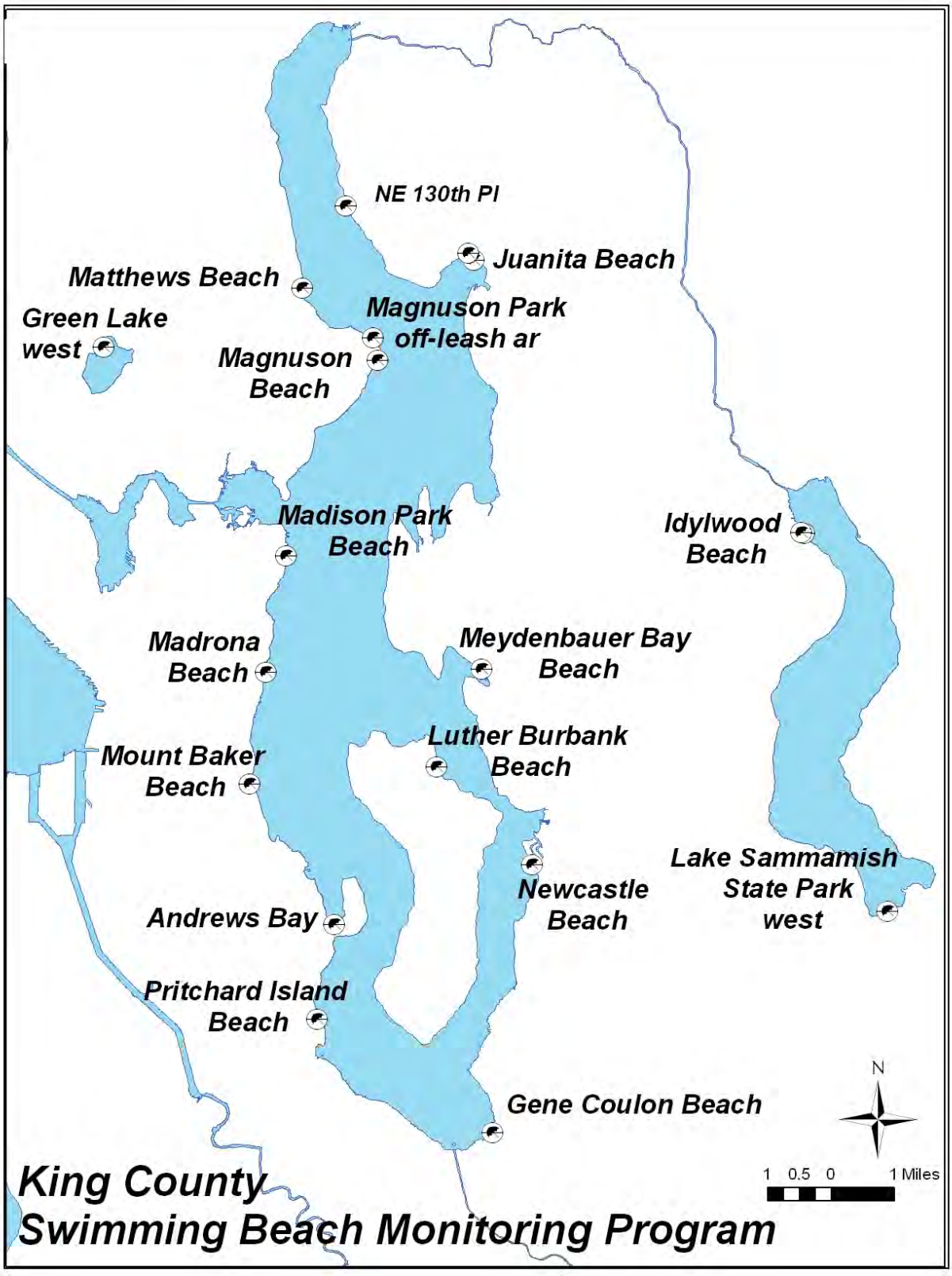

Figure C-7. Swimming Beach Monitoring Locations in Lake Washington, Lake Sammamish, and Green Lake

Fecal Coliform Bacteria—Ambient Mid-Lake (Open-Water) and Nearshore

Samples are collected for fecal coliform bacteria from both mid-lake (open water) and nearshore locations in Lakes Washington, Sammamish, and Union biweekly during the growing season and monthly during the rest of the year to measure.

The lake standard for fecal coliform bacteria addresses human health risk from direct contact with lake water during activities such as swimming and wading. The standard is a geometric mean value of less than 50 colonies per 100 mL with no more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies per 100 mL (WAC 173-201A).

Even though the lake standard for fecal coliform bacteria is exceptionally difficult to attain, 100 percent of the Lake Sammamish stations, 85 percent of the Lake Washington stations, and 60 percent of the Lake Union/Ship Canal stations achieved the standard in 2007 (Figure C-8).[10] Compared to 2006, fewer Lake Washington samples met the standard (92 percent in 2006). Two high concentrations were found at each of two stations in Lake Washington: Station 0829 at the south end of the lake and Station 4903 northwest of Station 0829. The number of Lake Union/Ship Canal samples that met the standard also decreased, from 80 percent in 2006 to 60 percent in 2007, because of high concentrations measured at Stations 0512 and 0518.

The two stations on Lake Washington and the two stations on Lake Union failed to meet both parts of the standard. Six of the 11 samples that had fecal coliform greater than 100 colonies per 100 mL were the result of unusual storm conditions. The highest bacteria concentrations were collected shortly after record rainfall swept through the region the first week of January 2007 (Stations 4903, 0512, 0518).

[10] Percentages shown in Figure C-8 for 2000–2006 are different from the percentages shown for the same years in earlier reports. Calculations were upgraded in 2007 to include both parts of the fecal coliform standard.

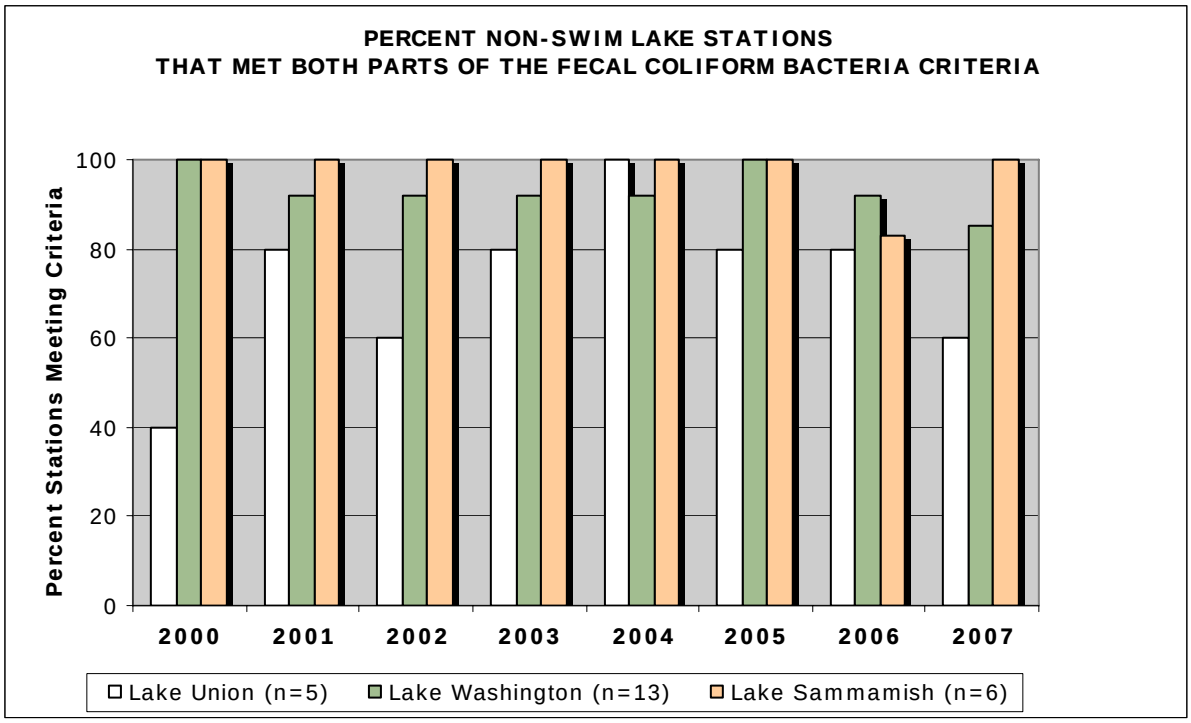

Figure C-8. Percentage of Ambient Stations in Lakes Washington, Sammamish, and Union that Met the Fecal Coliform Bacteria Standard, 2000–2007

Fecal Coliform Bacteria—Swimming Beaches

Samples are collected for fecal coliform bacteria each week between Memorial Day and the end of September at 17 swimming beaches in Lake Washington, Lake Sammamish, and Green Lake.[11]

King County's standard for acceptable fecal coliform bacteria levels in swimming beaches is that none of the testing sites violates both parts of the Washington State Department of Health's fecal coliform bacteria target, which is the geometric mean of 200 colonies per 100 mL with no single sample exceeding 1,000 colonies per 100 mL. Public Health–Seattle & King County and the Washington State Department of Health currently use this standard, which is called the Ten State Standard.

In 2007, 100 percent of samples from Green Lake and Lake Sammamish met both parts of the fecal coliform bacteria standard (Figures C-9 and C-10). This is the fifth year in a row that all Green Lake samples have met the standard. Lake Sammamish results vary slightly from year to

[11] The 2006 water quality report gave results for 21 swimming beaches, including beaches that King County monitors under contracts with other jurisdictions. This 2007 report does not include beaches monitored for other jurisdictions. The contracted beaches are not part of the county's Swimming Beach Monitoring Program and not included in the KingStat Web site (http://www.metrokc.gov/dnrp/measures/default.aspx).

year, showing percentages somewhere between the low 90s and 100 for the past nine years. For Lake Washington, 91 percent of the samples, compared to 96 percent in 2006, met the standard (Figure C-11).[12] High bacterial counts resulted in closures at four Lake Washington swimming beaches: Juanita, Magnuson off-leash area, Gene Coulon, and Meydenbauer Bay. There were no beach closures in 2006.

Fecal coliform bacteria can enter lakes from untreated wastewater effluent, household or farm animals, wildlife, stormwater runoff, sewage overflows,or failing septic systems. The most impacted beaches are adjacent to streams that drain urbanized drainage basins.

Overall Quality in Major Lakes—Trophic State Index

Samples are collected to assess overall water quality in Lakes Washington, Sammamish, and Union from both mid-lake (open water) and nearshore locations biweekly in the summer and monthly during the rest of the year.

Overall water quality is determined by measuring the summer (June–September) total phosphorus concentrations and converting them to the trophic state index (TSI-TP). The trophic state index relates phosphorus to the amount of algae that the lake can support. The potential for nuisance algal blooms is considered low if the TSI-TP is less than 40, moderate if less than 50, and high if greater than 50. High algae productivity often relates to poor water quality. Although such high productivity may not reduce beneficial uses in all cases, depending on the natural condition of the lake, a trend toward increased TSI-TP could indicate changes in the watershed.

TSI-TP results vary from year to year, depending on climate and biological interactions that create unique annual conditions in each lake (Figure C-12). The 1994–2007 results for Lakes Sammamish and Washington show that phosphorus concentrations fluctuate between the low and moderate thresholds from year to year, indicating that water quality varies from good to moderate with a low potential for nuisance algal blooms. Lake Union typically shows phosphorus concentrations in the moderate water quality range. In 2007, however, high phosphorus levels put Lake Union in the poor water quality range. These higher phosphorus concentrations may have been induced by stormwater runoff because precipitation in June, July, and September were above the historical average.

[12] Percentages shown in Figures C-9, C-10, and C-11 for 1996–2006 are different from the percentages shown for the same years in earlier reports. Calculations were upgraded in 2007 to include both parts of the fecal coliform standard. To comply with KingStat requests, the figures show data as far back as 1996. No data were collected at Green Lake beaches in 1997.

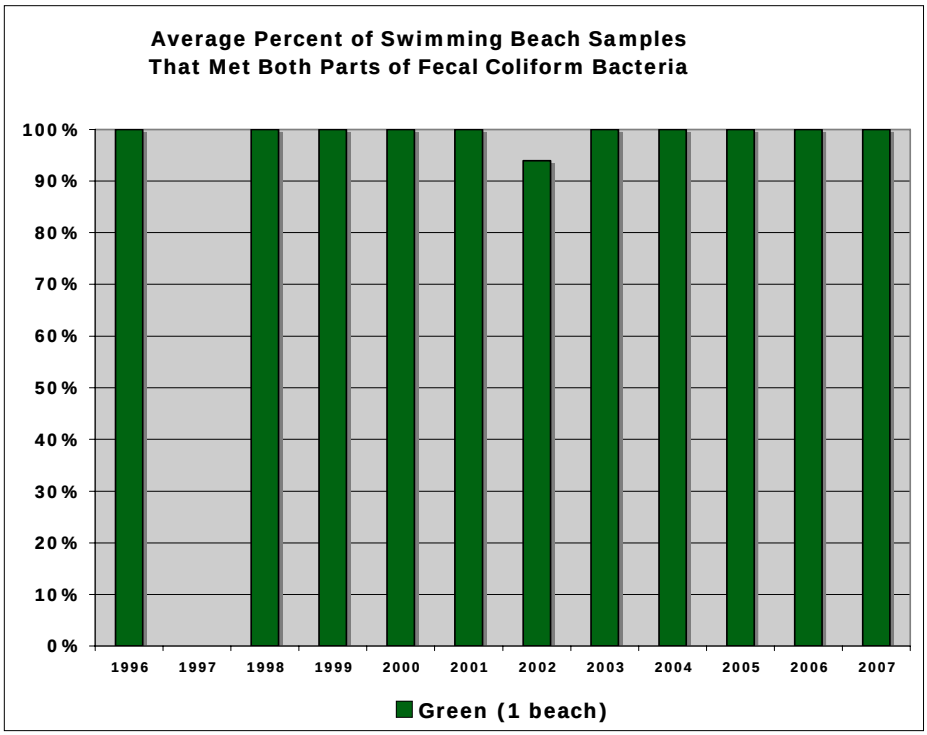

Figure C-9. Percentage of Samples that Met the Fecal Coliform Bacteria Standard at Green Lake Swimming Beaches, 1996–2007

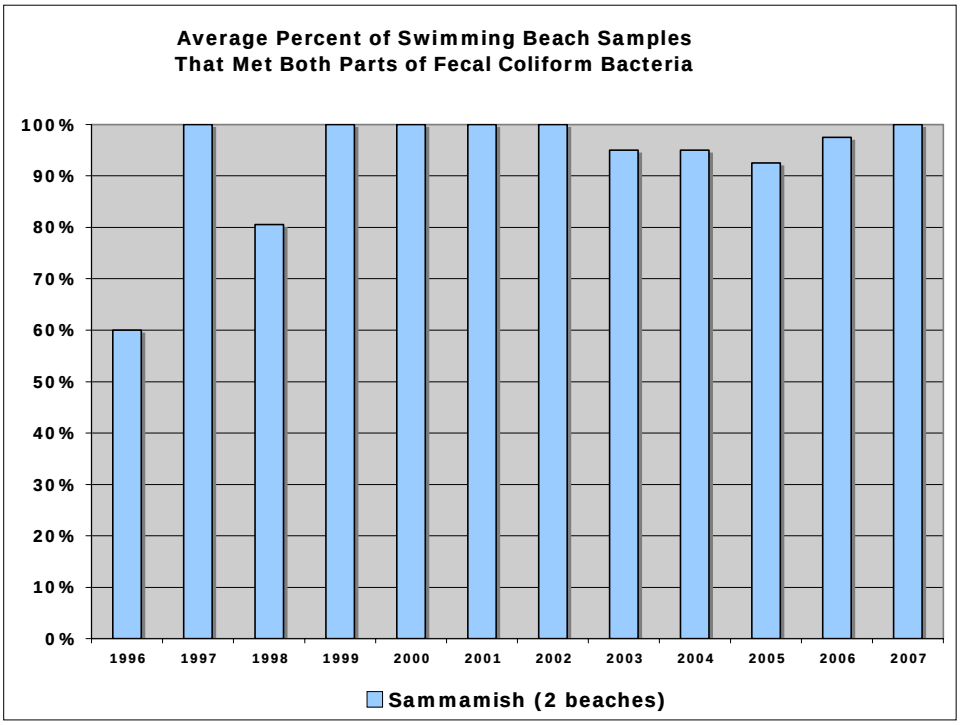

Figure C-10. Percentage of Samples that Met the Fecal Coliform Bacteria Standard at Lake Sammamish Swimming Beaches, 1996–2007

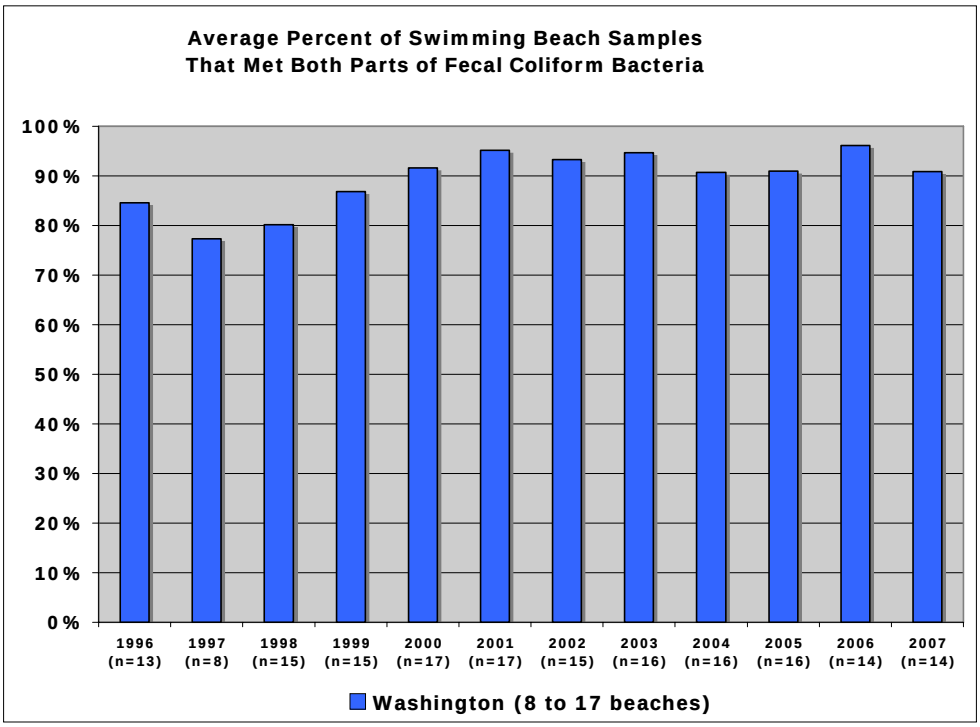

Figure C-11. Percentage of Samples that Met the Fecal Coliform Bacteria Standard at Lake Washington Swimming Beaches, 1996–2007

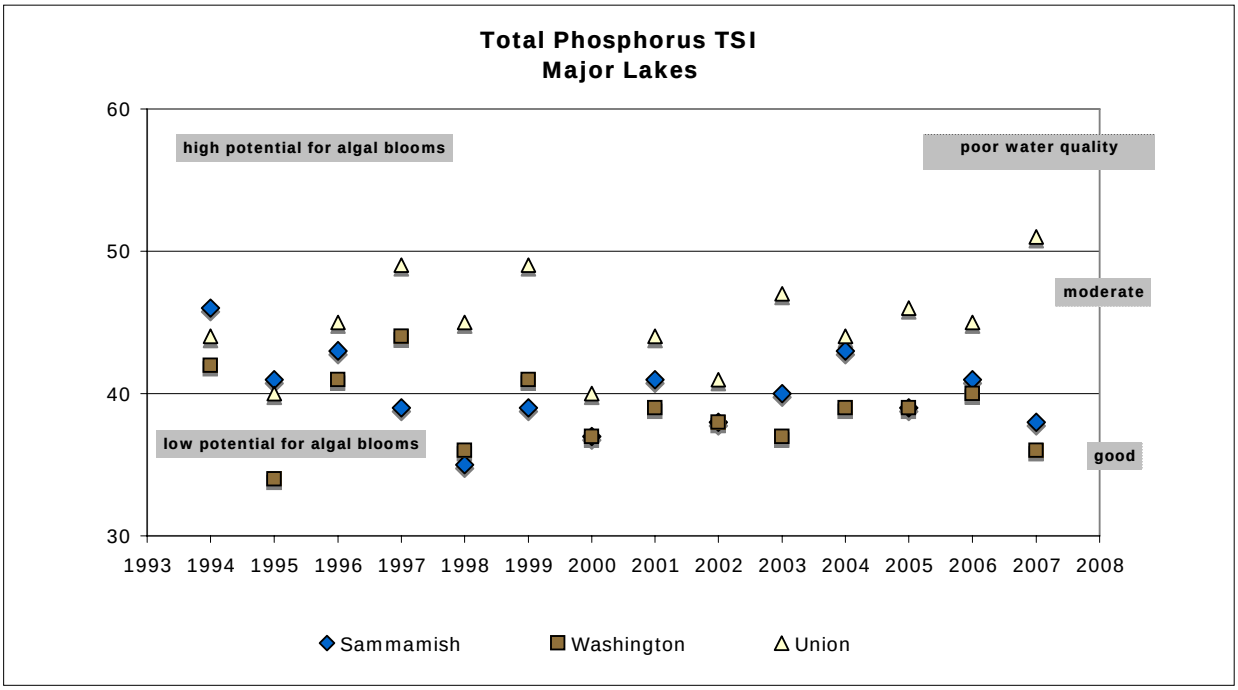

Figure C-12. Overall Water Quality in Lakes Washington, Sammamish, and Union Based on the Trophic State Index for Total Phosphorus, 1994–2007

Lake Sediment

Sediment quality is an important indicator of environmental health and, along with indicators of water quality, habitat, and the aquatic food web (plankton, invertebrates, and fish), can present a picture of environmental health. Chemical contaminants that are washed into streams and lakes from urban areas can attach to sediments, settle to the bottom, and act as record of both historical and recent contaminants discharged into surface waters.

Results of sediment monitoring in Lakes Sammamish, Washington, and Union between 1999 and 2001 indicate that sediment quality in the three lakes was generally good although certain areas showed contamination. Most of the contaminated areas were near stormwater outfalls and CSOs, indicating that stormwater and other runoff continue to affect sediment quality.[13] An updated 10-year program was designed in 2006. The purpose of the updated program is to determine long-term trends, if any, and to fill data gaps identified in the previous monitoring.

The program incorporates a stratified sampling strategy. The strata include deep water stations, swimming beaches, nearshore habitat, and areas that previous studies have shown to be contaminated. A total of 20 sediment samples will be collected each year. Five samples will be collected for long-term trend monitoring from ambient stations in the deep main basins of the lakes (Figure C-13). Fifteen one-time samples will be collected from the following locations:

- In the wading zone at public swimming beaches to better understand the public's exposure to sediment contaminants at swimming beaches.
- In shallow non-developed shoreline areas to determine if contaminant levels are a concern in the nearshore terrestrial/aquatic habitat.
- In areas where previous studies showed contaminant levels above sediment quality guidelines. Sampling grids will be used to determine the spatial extent of contamination.

Samples will be analyzed for metals, organics, and physical parameters. Results will be compared to sediment quality guidelines, including Ecology's floating percentile guidelines and guidelines developed as part of the International Association for Great Lakes Research, to understand their effect on aquatic life.[14]

The monitoring began in 2007 by collecting samples from Lake Sammamish.[15] It will move to Lake Washington in summer 2008, most likely focusing on Lake Washington for a few years

[13] The CSOs are at King County's East Pine Street, Rainier Avenue, Henderson, and Dexter Avenue locations.

[14] Smith, S. S., D.D. MacDonald, K.A. Keenleyside, C.G. Ingersoll, and L.J. Field. 1996. A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. *J. Great Lakes Res.* 22(3): 624-638. Internat. Assoc. Great Lakes Res.
Washington State Department of Ecology and Avocet Consulting. 2003. Development of freshwater sediment quality values for use in Washington State. Phase II Report: Development and recommendation of SQVs for freshwater sediments in Washington State. Washington State Department of Ecology, Olympia, WA.

[15] These data are still being analyzed.

before moving to Lake Union. The three lakes will be covered within the program's 10-year timeframe.

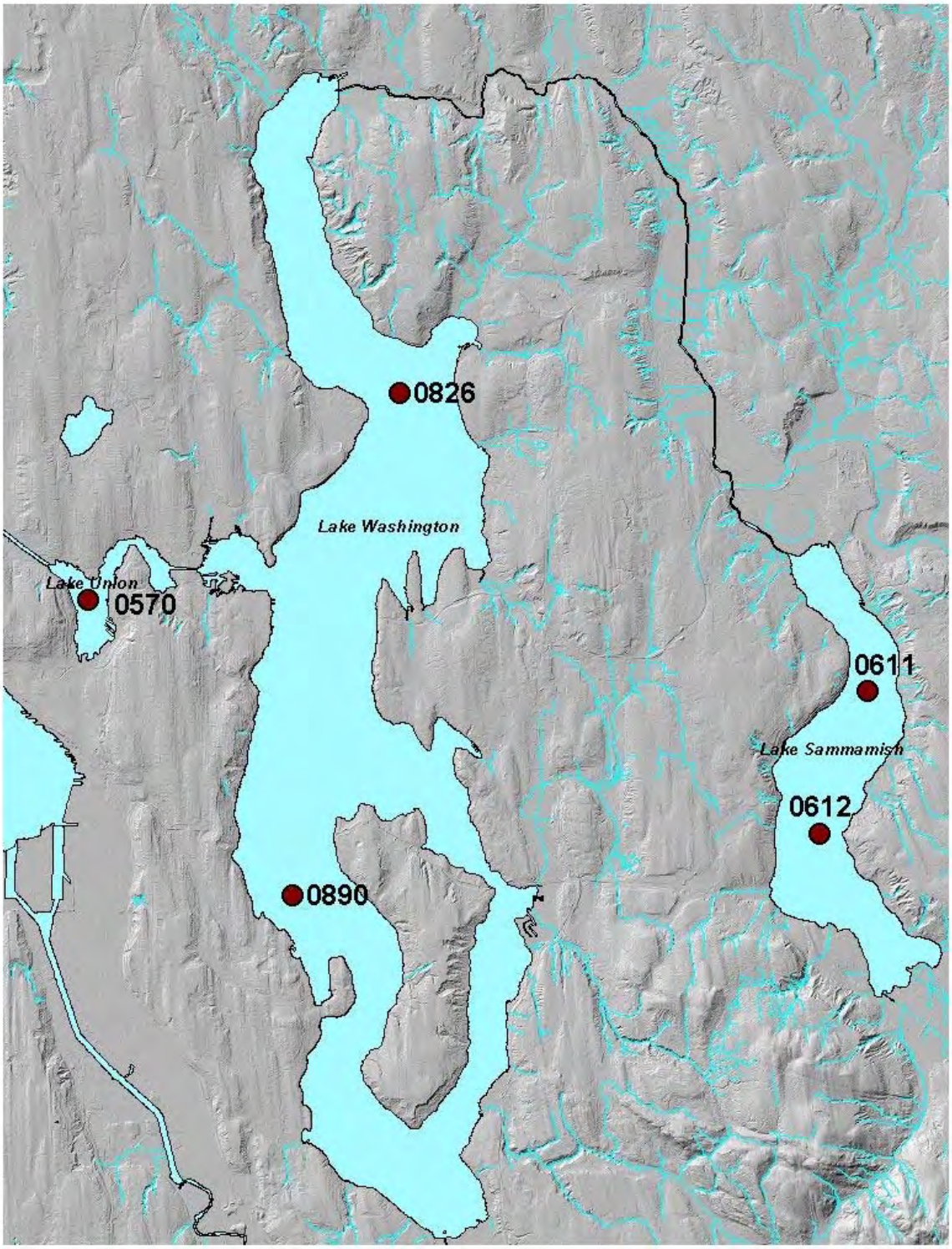

Figure C-13. Long-Term Sediment Monitoring Stations in Lakes Washington, Sammamish, and Union

Water Temperature—Effects of Climate Change

Global climate change is having an impact on our local weather patterns and subsequently on county aquatic resources. On average, ambient air temperatures in the Pacific Northwest have increased over the twentieth century by roughly 1.5ºF.[16] Air temperatures in the region are expected to continue to increase by another 2 to 9ºF over the next 80 years.

Warmer temperatures have reduced the snow pack levels in Washington and, thus, the timing and quantity of flows in regional rivers and streams. Higher air temperatures and changes in wind patterns also increase lake temperatures through surface heat exchange processes. January water temperatures are taken at a 1-meter depth from the mid-lake monitoring stations in Lakes Washington, Sammamish, and Union (Figure C-14). Because the lakes are well mixed during January, temperatures at the surface reflect the temperatures throughout the water column.

The University of Washington has routinely measured temperatures in Lake Washington since 1957. King County (then Metro) began monitoring temperatures in Lakes Washington, Sammamish, and Union in 1979. Additional Lake Washington data were collected in 1913, 1933, and 1950–1952. Lake temperatures vary annually, depending on seasonal weather conditions (wind, precipitation, cloudiness, and ambient air temperatures). Overall, winter water temperatures have increased about 0.25^{o}C (0.45^{o}F) per decade since 1960 in Lake Washington and about 1^{o}C (1.8^{o}F) per decade since 1979 in Lakes Sammamish and Union. The smaller increase in Lake Washington is likely due to its larger volume, which is roughly 8 times greater than Lake Sammamish and 118 times greater than Lake Union.

[16] For more information on climate in the Pacific Northwest, see the University of Washington's Climate Impacts Group Web site at http://www.cses.washington.edu/cig/pnwc/pnwc.shtml.

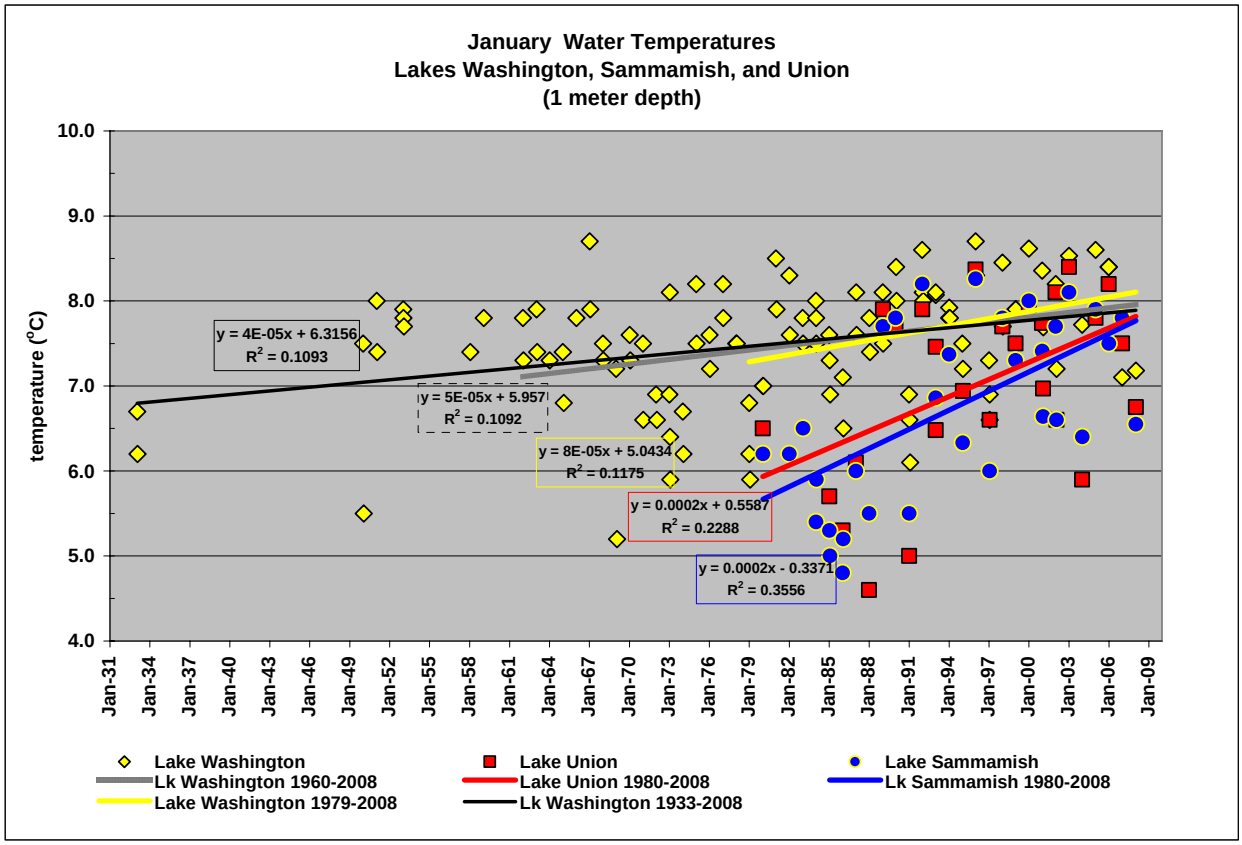

Figure C-14. January Water Temperatures in Lakes Washington, Sammamish, and Union, 1933-2008

River and Stream Monitoring Results

This section describes the quality of water in King County rivers and streams in terms of overall water quality (water quality index) and normative streamflows.

Monitoring Locations

Fifty-six sites along rivers and streams in Water Resource Inventory Areas (WRIAs) 8 and 9 (Cedar-Sammamish and Duwamish-Green watersheds) have been sampled monthly, some for over 30 years. Numerous water quality parameters are monitored, including those used to determine the water quality index (Figure C-15). Samples are collected monthly under base flow conditions and three to six times each year at the mouth of streams under storm conditions.

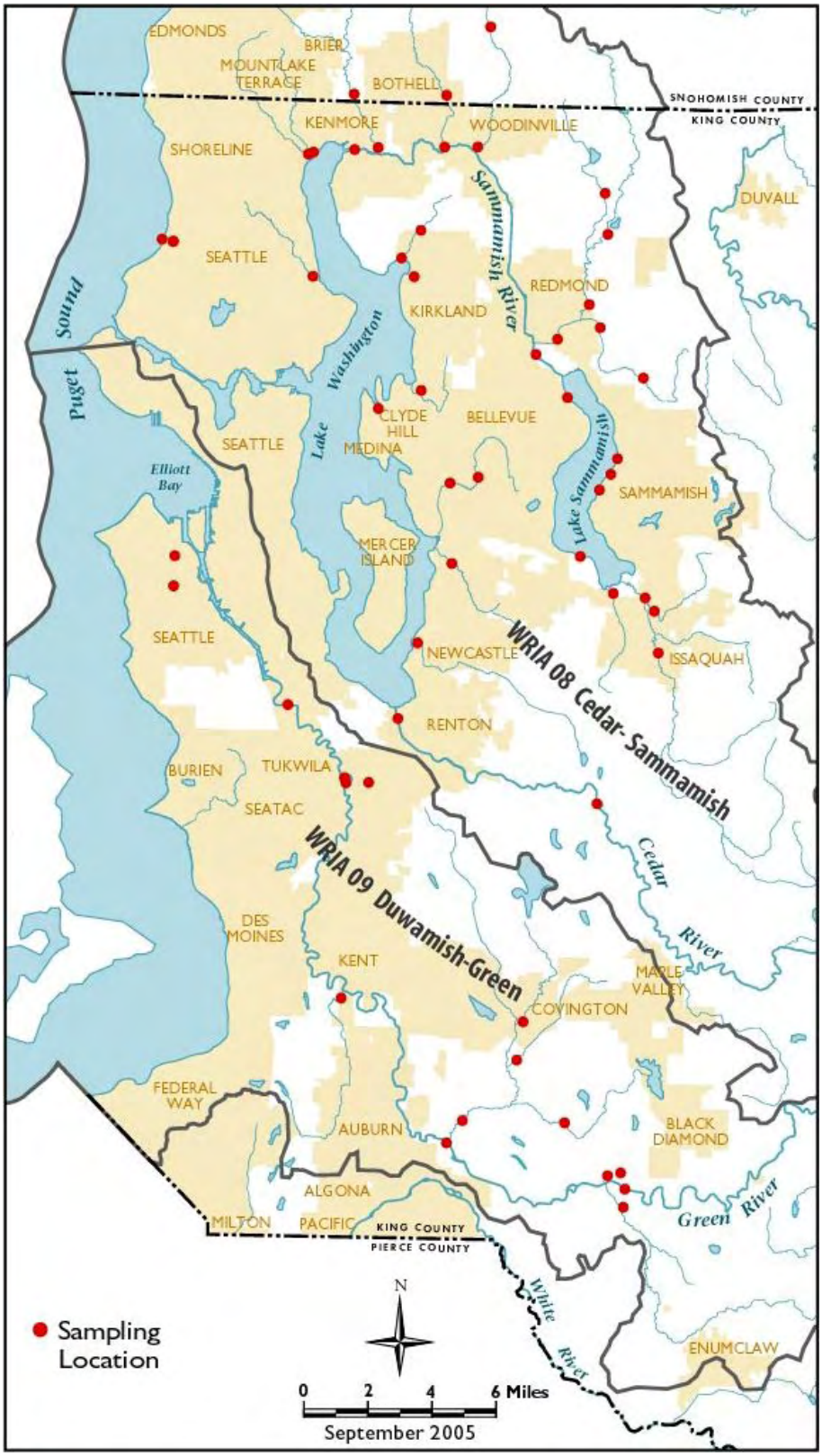

Figure C-15. Monitoring Locations in Rivers and Streams

Overall River and Stream Water Quality—Water Quality Index

The water quality index (WQI) for rivers and streams attempts to integrate a series of key water quality indicators into a single number that can be used for comparison over time and among locations. The WQI is based on a version proposed by Ecology and originally derived from the Oregon water quality index. The WQI is a number ranging from 1 to 100—the higher the number, the better the water quality. For temperature, pH, fecal coliform bacteria, and dissolved oxygen (DO), the index expresses results relative to state standards required to maintain beneficial uses. For nutrient and sediment measures, where the state standards are not specific, results are expressed relative to expected conditions in a given eco-region. Multiple constituents are combined, results are aggregated over time to produce a single score, and a rating of low, moderate, or high concern is assigned for each sampling station.

Overall water quality in King County streams varies between and within streams, reflecting the effects of a population of almost two million residents and intense urbanization. Increased development and greater volumes of stormwater runoff have impacted and continue to impact the water quality of rivers and streams. Increased stormwater runoff is most likely the reason why overall WQI values dropped in 2007. Weather in the 2006–2007 water year (October 1 through September 30) was particularly wet. Cumulative rainfall was well above historical averages, and record-breaking precipitation occurred in November and December 2006.

In the 2006–2007 water year, 45 percent of the fifty-six sampling sites (twenty-five sites)—compared to 63 percent in 2006—were considered moderate or high water quality (moderate or low concern) and 55 percent (thirty-one sites) were rated to be of low water quality (high concern) (Figure C-16). Of the sixteen sites in WRIA 9, six sites were rated of low concern, six sites were of moderate concern, and four sites were of high concern (Figure C-17). Of the forty sites in the WRIA 8, one site was rated of low concern, twelve sites were of moderate concern, and twenty-seven sites were of high concern (Figure C-18).

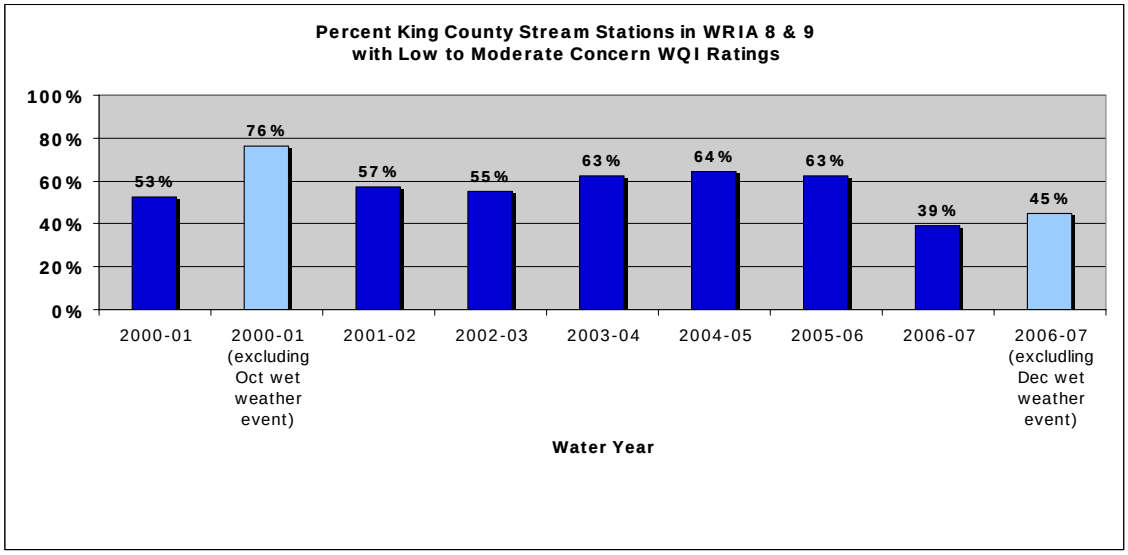

Figure C-16. Percentage of Streams in WRIAs 8 and 9 with Low or Moderate Concerns Based on Water Quality Index, 2000–2007

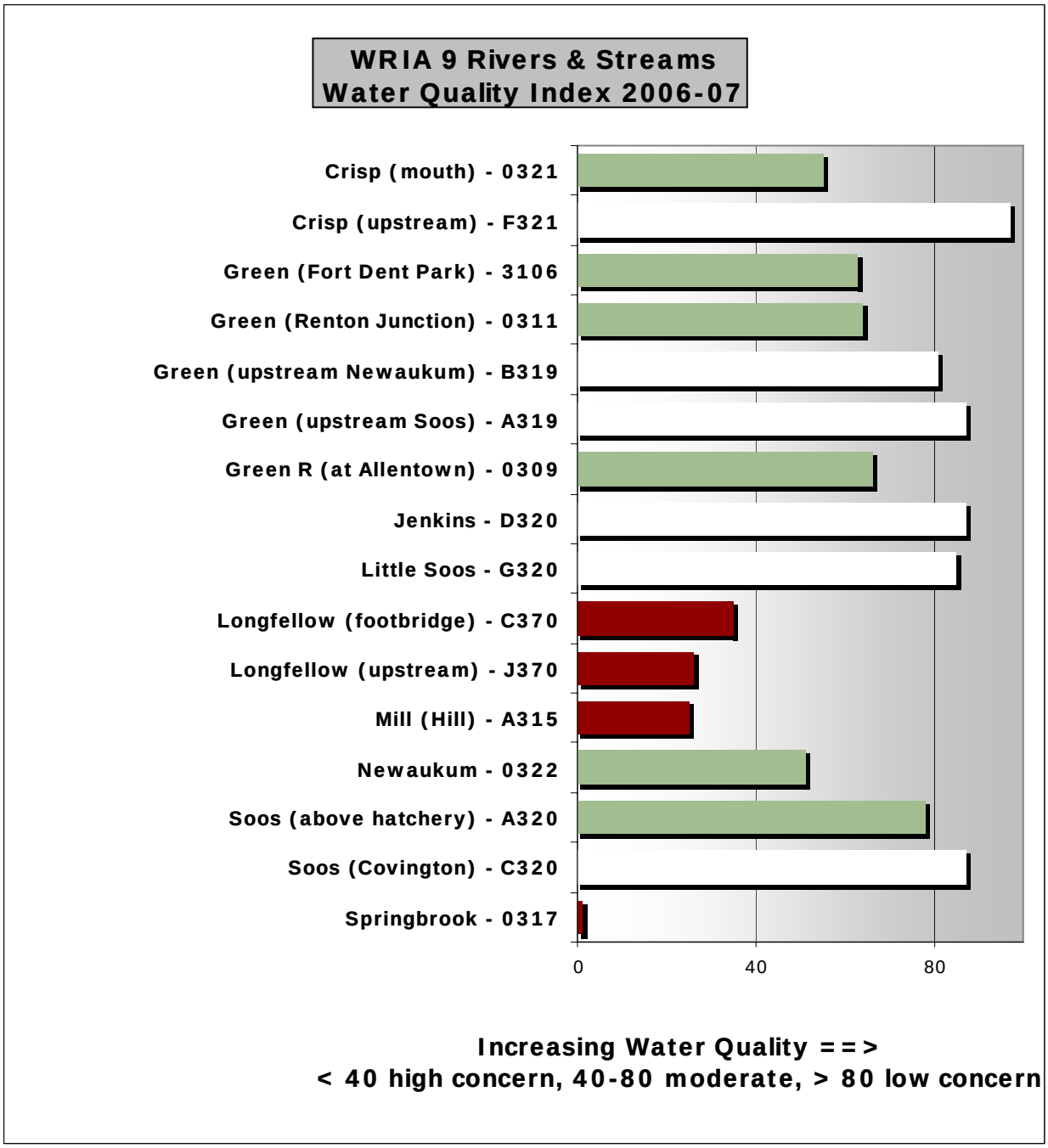

Figure C-17. Water Quality Index Rankings for Rivers and Streams in WRIA 9, 2006–2007

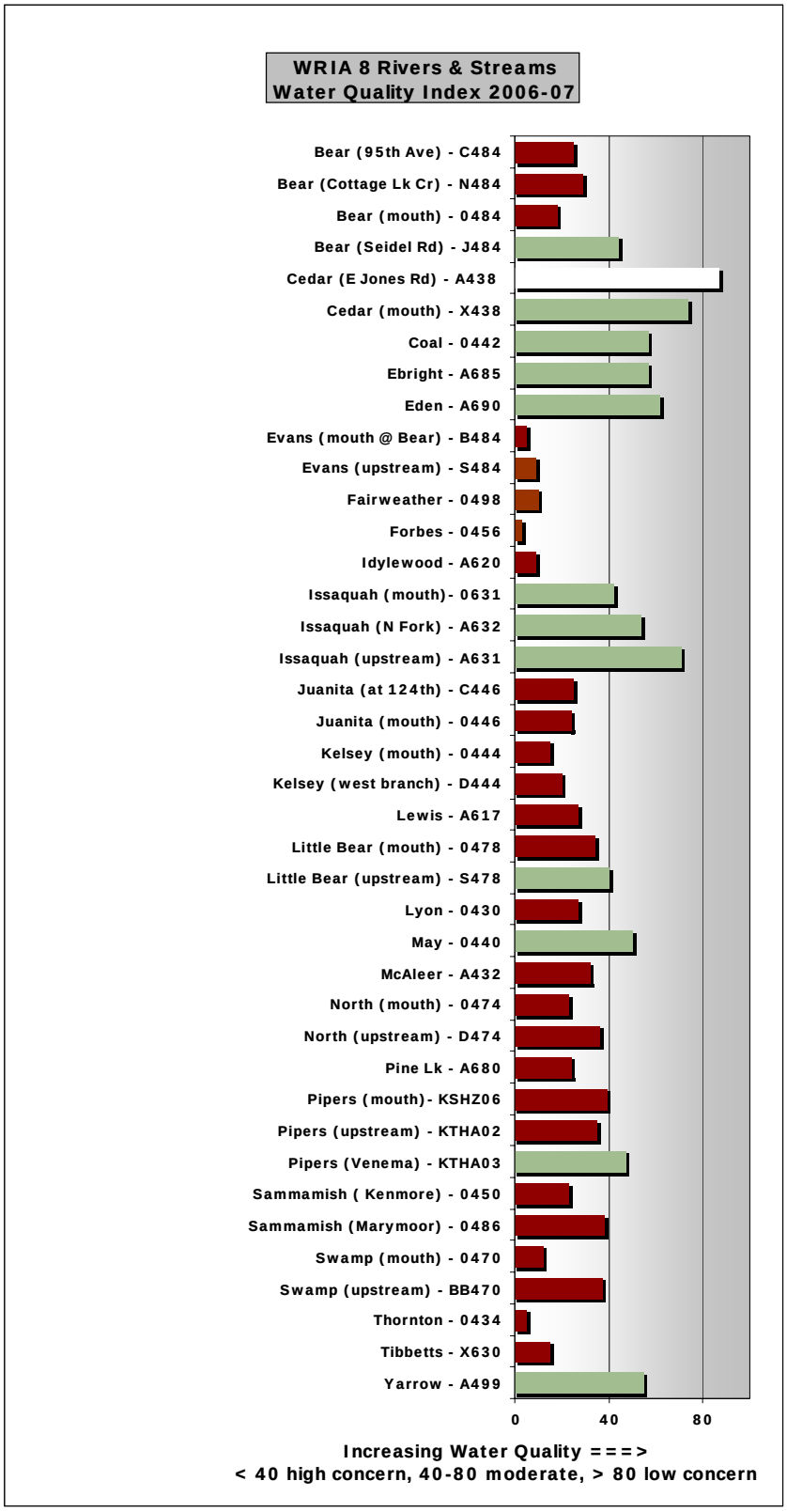

Figure C-18. Water Quality Index Rankings for Rivers and Streams in WRIA 8, 2006–2007

These percentages do not include routine samples taken in December 2006 during an extreme wet-weather event. If these samples had been included, only 39 percent of the samples would have been rated as low or moderate concern for 2006–2007. Excluding this event allows for year-to-year comparison of routine events. Figure C-16 shows the percentages for 2006–2007 both with and without the extreme wet-weather event to illustrate the impact that one wet-weather event can have on water quality. (Two percentages are also given for 2000–2001.)

All samples that were rated of high concern in 2007 showed excessive nitrogen and/or phosphorus concentrations. Almost all of these samples also showed high fecal coliform bacteria (97 percent), low DO (74 percent), high temperatures (58 percent), and high-suspended solids/turbidity (32 percent).

Stormwater and waterfowl and pet wastes are the most likely sources of bacteria in urban streams. Poor livestock manure management and failing septic systems can be a potential source of bacteria in agricultural and suburban areas. In wetlands, wildlife excrement and stagnant water conditions can lead to elevated bacteria counts. High phosphorus concentrations are found in fecal material and elevated concentrations of phosphorus are often linked to similar sources as bacteria. Elevated phosphorus concentrations are also linked to areas undergoing development. Low DO concentrations can be associated with low flows, wetlands, high temperatures (colder water holds more oxygen), and high levels of organic matter (bacteria use oxygen in the process of decomposing).

Stream Sediment

The Stream Sediment Monitoring Program began in 1987. Monitoring between 1987 and 2002 in WRIAs 8 and 9 found concentrations of several metals, including arsenic, cadmium, copper, nickel, and zinc, above available sediment quality guidelines. The data also showed elevated concentrations of petroleum hydrocarbons.

Using these data and new information, the county began an updated 10-year stream sediment monitoring program in 2004. The updated program was designed to address data gaps identified during the original program, monitor the effects of pollutant sources (point sources, stormwater, and other urban discharges), achieve a better understanding of sediment quality in entire stream basins, and determine long-term trends.

Additional parameters were added to those monitored in the original program. Samples collected through the updated program are analyzed for metals, organics, and physical parameters. All parameters are compared to sediment quality guidelines, including Ecology's floating percentile guidelines and guidelines developed as part of the International Association for Great Lakes Research, to understand their effect on aquatic life.[17]

[17] Smith, S. S., D.D. MacDonald, K.A. Keenleyside, C.G. Ingersoll, and L.J. Field. 1996. A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. *J. Great Lakes Res.* 22(3): 624-638. Internat. Assoc. Great Lakes Res.
Washington State Department of Ecology and Avocet Consulting. 2003. *Development of freshwater sediment*

For trend analysis, 10 small wadeable streams in WRIAs 8 and 9 were selected from the original program, allowing for use of historical metal and conventional data. Samples are collected yearly. Trends will be evaluated when sufficient data have been collected over time.

For stream basin analysis, one-time samples are collected along each mile of a stream to monitor the processes that affect sediment quality in WRIAs 8 and 9. Three streams are monitored each year. All 30 streams in the program will be monitored by the end of the 10-year program. So far, Thornton, McAleer, Lyon, Swamp, North, Little Bear, Juanita, Forbes, Bear, Evans, Cottage, Kelsey, and Coal Creeks have been monitored.

Results from the preliminary analysis of stream basin data collected between 2004 and 2006 show that about half of the samples exceeded at least one sediment quality guideline (Figure C-19).[18] Chemicals that exceeded guidelines include metals, PAHs, and bis(2-ethyhexyl)phthalate. Other chemicals that exceeded guidelines were organochlorines, including PCBs and banned insecticides such as DDT, DDD, DDE (DDD and DDE are byproducts of DDT), chlordane, and dieldrin. The presence of these organochlorines shows that chemicals can persist in the environment decades after being banned. These types of chemicals can accumulate in aquatic organisms and be taken up by organisms that are higher in the food chain (larger fish). A current advisory suggests limiting the consumption of some types of fish from Lake Washington because of high levels of some of these contaminants.

Data from this program along with data from lake sediment and fish tissue samples are beginning to form a picture of the fate and transport pathway of these persistent chemicals.

Normative Streamflows

Streams in urban areas respond more quickly to rainfall than streams in forested areas. Because less rainfall is being absorbed by vegetation and soil, more surface runoff occurs. Higher, more rapid, and frequent pulses of runoff ("flashiness") lead to flooding and channel erosion. From a biological perspective, streams with more frequent peak flows are disturbed more often. Organisms that survive in these conditions are those that have adapted to more frequent and severe disturbances.

Flows from 17 stream sites, including 4 sites monitored by the U.S. Geological Survey, were measured and their flashiness calculated during the 2007 water year (October 2006–September 2007) (Figure C-20). The "flashiness index" is based on the reciprocal of the fraction of days during the year that the flow rises above the annual mean daily flow ($1/T_{Qmean}$). The stream flashiness index was also calculated for previous years using historical data. The number of streams where data were available ranges from one stream in 1941 to twenty-one streams in 2001. The median flashiness declined between 2006 and 2007, primarily from interannual variation resulting from variation in rainfall. In general, the median of the flashiness index scores

quality values for use in Washington State. Phase II Report: Development and recommendation of SQVs for freshwater sediments in Washington State. Washington State Department of Ecology, Olympia, WA.

[18] Data from 2007 are still being analyzed.

across streams measured in King County has increased between 1945 and 2007 (Figure C-21). These data suggest that increased urbanization has resulted in faster surface runoff and peak streamflow rise and fall (increased flashiness) than previously occurred for at least some streams.

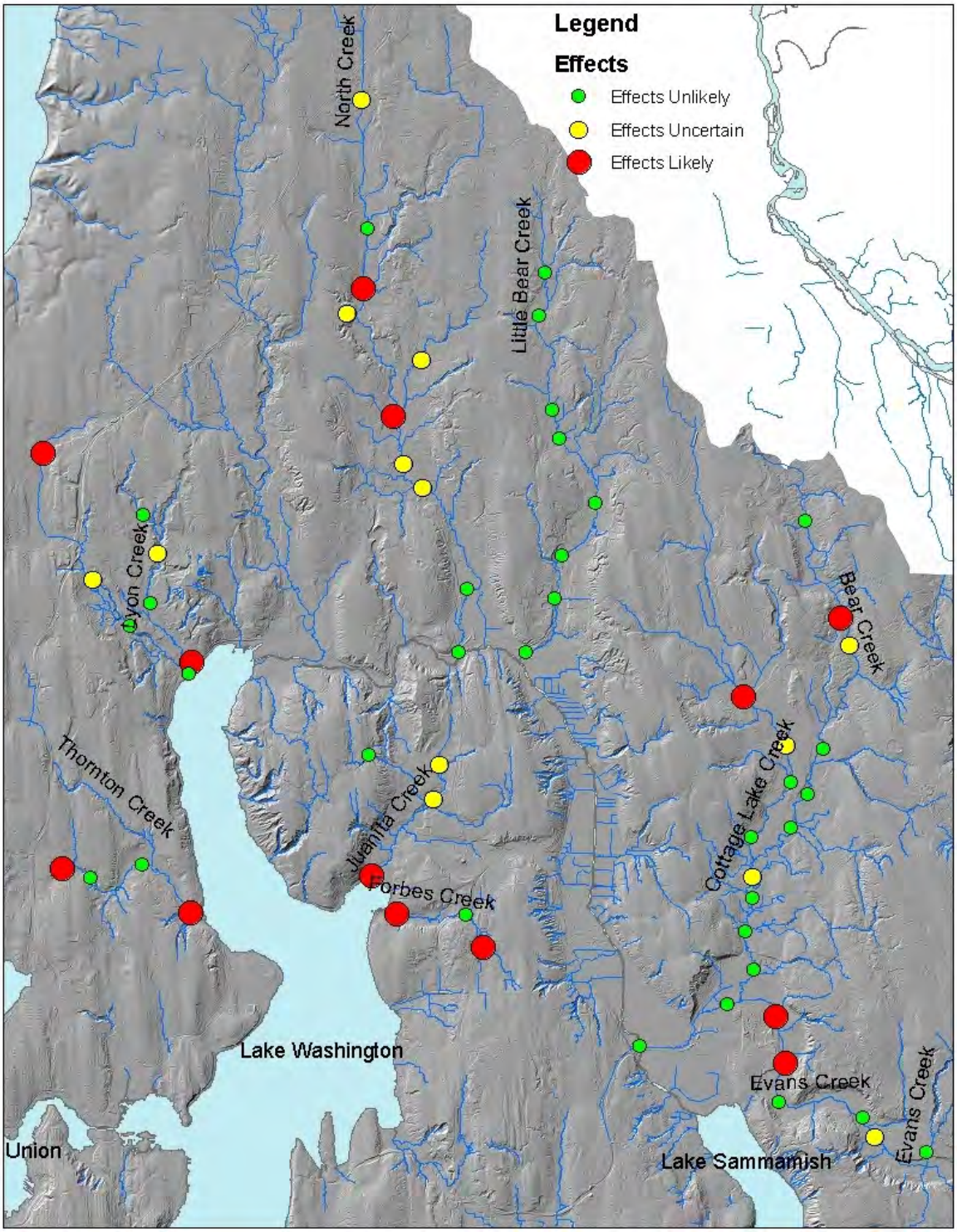

Figure C-19. Stream Basin Sediment Sampling Results, 2004–2006

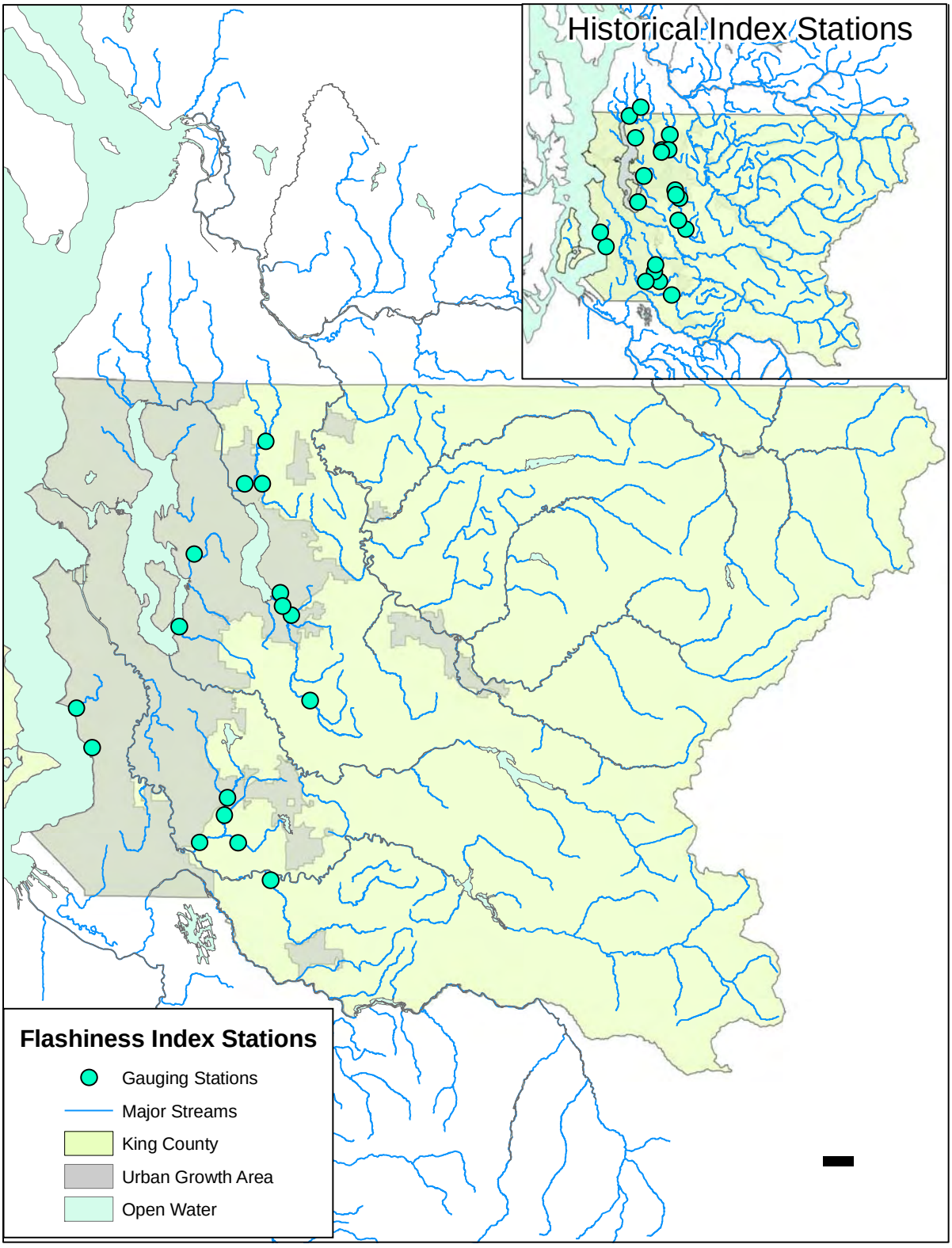

Figure C-20. Hydrologic Monitoring Stations Used to Calculate the Stream Flashiness Index, 1945–2007

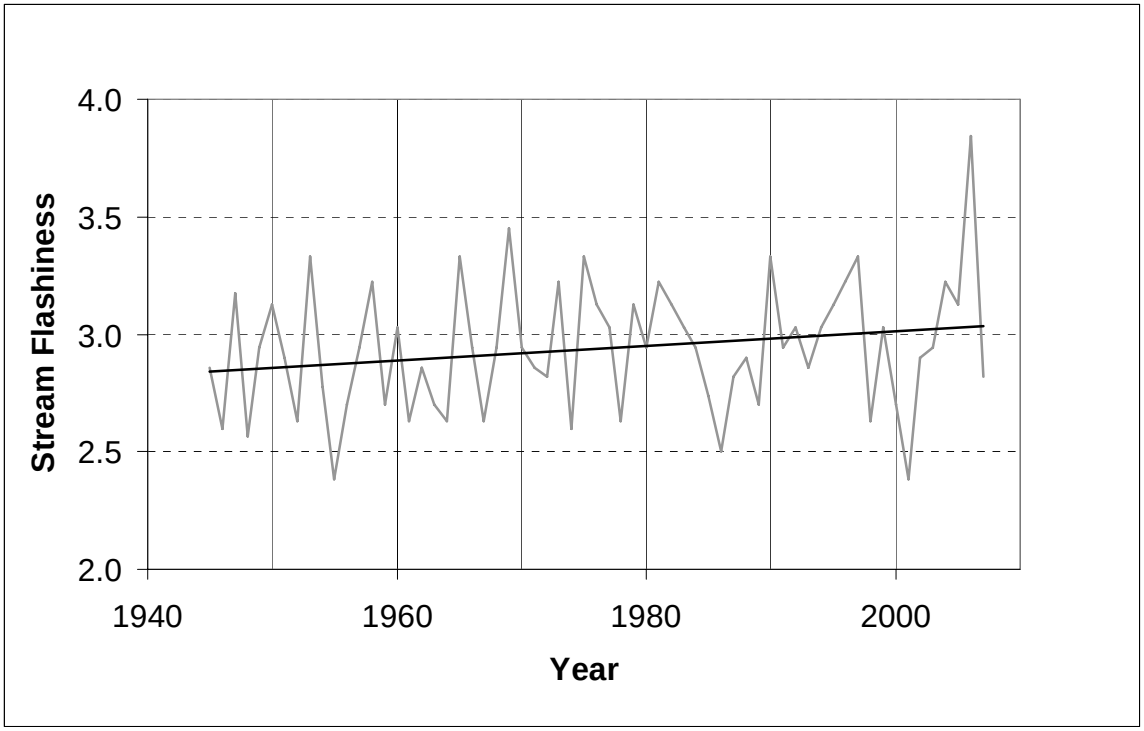

Figure C-21. Annual Median Stream Flashiness Index Scores, 1945–2007

Wetland Monitoring for Carnation Treatment Plant Discharge

The City of Carnation and King County are designing and building a wastewater collection and treatment system to serve the City of Carnation. The wastewater treatment plant, scheduled to begin operating in 2008, will use membrane bioreactor (MBR) technology to produce reclaimed-quality water. During startup, the plant will discharge effluent to the Snoqualmie River. After startup, the effluent will be discharged to a wetland at the Chinook Bend Natural Area just North of Carnation.

Enhancements were made to the wetland in preparation for discharge. As part of its reclaimed water use permit application to the Washington State Departments of Ecology and Health, the county collected samples in 2006 to establish water and sediment quality at the wetland site before the enhancements. Data analysis results were reported in 2007. Post-enhancement monitoring will be conducted in 2008 and post-discharge monitoring in 2009–2010. The monitoring is investigating the quality of the pond water, inflow source water, outflow water, and sediment.

Water samples were collected twice during 2006, once during the summer dry season and once during the winter wet season at three locations: where surface water enters the wetland, in the middle of the open-water pond, and where water flows out of the wetland. Sediment samples were collected during the summer from the central area of the open-water pond, the shoreline of

the pond, and the wet soils where groundwater is seeping into the pond. All samples were analyzed for organics, metals, and physical parameters.

Water quality data indicate that aluminum exceeded the chronic water quality criteria in the pond and in the outflow stream during both the wet and dry seasons. Maximum concentrations of metals were most often found in the pond water. Few maximum concentrations were found in the inlet water stream. These findings indicate that metals in inflow are probably not the source of metals to the pond.

The nutrient balance in the pond during the dry season indicates that the pond may be nitrate limited, which is unusual in freshwater systems. Samples from the pond indicate very eutrophic conditions with high phosphorus levels. Normally, these conditions would contribute to unsightly anaerobic conditions. However, dissolved oxygen levels were good and the aquatic ecosystem appeared to be functioning well.

Only a few organic chemicals were detected out of the 128 organic compounds that were analyzed in water samples. Estrone and estrodiol were found at all sites at least once during both the wet and dry seasons. Estrone was the most often detected of the hormones that were analyzed.[19]

Preliminary statistical comparisons indicated significant differences between the summer and winter results, including lower phosphorus, higher nitrogen, and higher metals in the winter. These differences are likely to be at least partly the result of flooding that occurred just prior to winter sampling. The higher metal results in the winter indicate that metals concentrations in the pond may increase from periodic inundation by flood waters.

The sediment analysis found that copper in the pond center exceeds the draft Washington State sediment quality guidelines.[20] However, application of a bioavailability indicator and measurement of total organic carbon concentrations indicate that such metals are not likely to cause toxicity in the pond sediments even with additional inputs.

These concentrations and indicators will be followed in the coming years during post-enhancement and post-discharge monitoirng.

[19] These natural hormones are classified as endocrine-disrupting chemicals (EDCs). See the definition earlier in this report under "Sediment Quality in the Duwamish Waterway."

[20] Washington State Department of Ecology and Avocet Consulting. 2003. *Development of freshwater sediment quality values for use in Washington State. Phase II Report: Development and recommendation of SQVs for freshwater sediments in Washington State.* Washington State Department of Ecology, Olympia, WA.