WASHINGTON STATE DEPARTMENT OF ECOLOGY

Watershed Briefing Paper for the Eastern Olympic Watershed Water Quality Management Area

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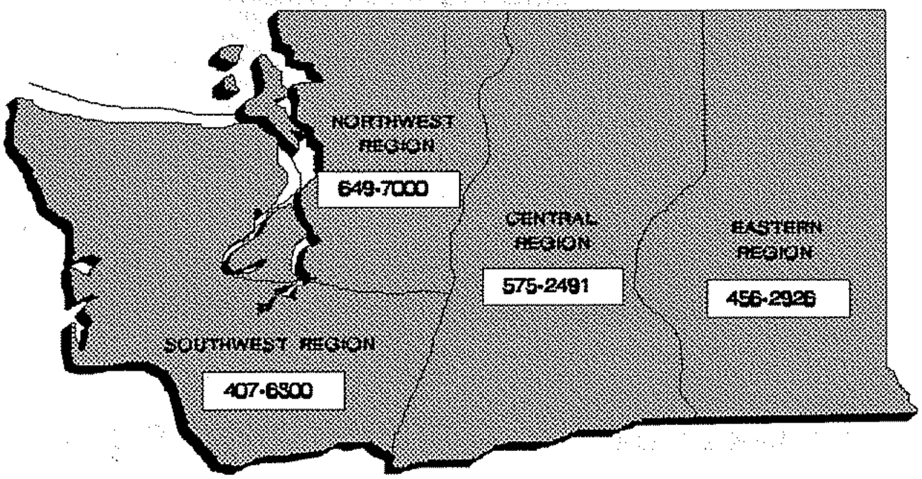

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Watershed Briefing Paper for the Eastern Olympic Watershed Water Quality Management Area

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Executive Summary

Purpose

The Department of Ecology's Environmental Investigations and Laboratory Services (EILS) Program reviewed water quality information on the Eastern Olympic Water Quality Management Area (WQMA). The Eastern Olympic WQMA, shown in Figure 1, consists of watersheds draining the eastern slopes of the Olympic Mountains into south Puget Sound and Hood Canal, the Deschutes River basin in Thurston County, and the Strait of Juan De Fuca. The marine waters of south Puget Sound approximately west of the Nisqually River are also included in this WQMA.

The purpose of this review is to describe what is known about this region and identify water quality issues that may require monitoring or intensive studies over the next two years. This evaluation is part of an agency-wide scoping and data collection effort being done for the Water Quality Program's watershed approach to water quality management. This approach is a five-year process which culminates in issuing water quality permits and implementing other pollution prevention and control actions in year five.

Content

This consolidated report contains eight individual briefing papers with information on the following subjects concerning water quality in the Eastern Olympic WQMA:

Rivers and Streams Water Quality Ambient Monitoring and Bioassessment Monitoring

Current and historical ambient water quality monitoring stations in the region are analyzed for violations of state water quality standards. Trend analysis was conducted for three basin stations (Deschutes River @ E Street Bridge, Deschutes River near Rainier, and Skokomish River near Potlatch) which had adequately long monitoring records to test for statistical trends. The results of biological monitoring conducted in 1996 on the Lyre River, South Branch Little River, Seibert Creek, Dungeness River, and Duckabush River are also presented.

Lakes Water Quality Ambient Monitoring

The results of water quality assessments of five lakes (Chambers, Crescent, Lawrence, Leland, and Macintosh) from three counties in the region are presented along with an overall assessment of lake quality.

Aquatic Plants Ambient Monitoring

Twenty lakes in the region have been surveyed for aquatic plants. Information on which lakes have known populations of noxious weeds or listed rare plants is summarized.

Marine Water Quality Ambient Monitoring

Current and historical data collected as part of the Marine Waters Ambient Monitoring Program are summarized and analyzed for water quality problems. Information is presented on fecal coliform bacteria, dissolved oxygen, nutrients, and harmful phytoplankton species. In addition, conditions conducive to creating water quality problems are discussed.

Intensive Surveys and TMDLs

The Watersheds Assessments Section reviewed watershed based studies that collected water quality data between the mid-1980s and the present. A substantial amount of information was identified in this review covering a large portion of the Eastern Olympic WQMA. Fecal coliform contamination of marine and freshwater systems, stormdrain discharges, streambank erosion and siltation, temperature violations, and nutrient enrichment were some of the water quality problems identified in the region. In addition a review of the 303(d) impaired waterbodies list is presented.

Toxics Investigations

Relatively little information has been generated on the occurrence of toxic chemicals in the Eastern Olympic GWMA. Most of the work that has been performed was associated with the major urban population centers in the region (Olympia/Lacey, Shelton, Port Townsend and Port Angeles). Screening surveys of stormdrains in several areas of Thurston County and Shelton, as well as five lakes in the region, are reviewed. In addition, the results of a comprehensive survey of Port Townsend Bay to determine the cause of high mortality in pen-reared Atlantic salmon is discussed. A limited review of ambient monitoring data on bottom sediments is also presented.

Ground Water Assessments

EILS has conducted limited ground water investigations in the region. In the last five years investigations have been conducted at three wastewater land application sites and two petroleum contamination sites. All five sites investigated are located in the northeastern part of the Olympic Peninsula.

Compliance Monitoring

There are currently 42 dischargers in the Eastern Olympic WQMA that have permits under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge Program (WAC 173-216). These include: NPDES Major Permits (3 Municipal); NPDES Minor Permits (12 Industrial, 14 Municipal); State Discharge to Publicly Owned Treatment Works Permits (1 Industrial); and State Discharge to Ground Permits (4 Industrial, 8 Municipal). The following facilities have received EILS Class II inspections during the last five years: City of Sequim, Port Townsend Paper Corporation, and Pabst Brewing Company.

Recommendations

Important recommendations from individual briefing papers are summarized below:

Rivers and Streams Water Quality Ambient Monitoring and Bioassessment Monitoring

- Fecal coliform contamination is a common water quality problem in the Eastern Olympic WQMA. Sources of contamination are cattle grazing, failing on-site septic systems, and wildlife. An inventory of potential sources and associated stream locations that are likely to be degraded by fecal coliform contamination should be prepared.

- An increase in land development has occurred along Hood Canal. The greatest concern for this development is the fate of wastewater. The pattern for future water quality problems in freshwater streams appears to be linked to the type and density of development in the Eastern Olympic WQMA. The impact of such development on water quality has already been determined by data we have analyzed. An inventory of current development and projected future development will assist in risk analysis of further water quality degradation.

- Monitoring station selection in Thurston County should consider the monitoring effort by the County and should maintain 'core' stations that would serve as a reference for future watershed monitoring projects. 'Core' station monitoring provides continuity between major watershed monitoring projects and indicates the direction of change in water quality.

- Water quantity and water quality are of concern in small streams that drain into the Strait of Juan de Fuca. Small hobby farms are emerging in large numbers. Management of these properties, particularly if keeping animals, will have some consequence on preserving water quality.

- Biological monitoring indicates that common impacts to stream channels involve erosion and possible contaminants associated with eroded materials. These types of impacts are not usually detected by surface water sampling programs. Biological monitoring should be considered where erosion of streambanks or transport of water from overland sources is suspected.

Lakes Water Quality and Aquatic Plants Ambient Monitoring

- Continued monitoring in Mason County is particularly important. Now that Island Lake has Eurasian Milfoil, it is highly likely that many of the Mason County lakes in the region will become infested with the noxious weed.

- Continued technical assistance is needed for local government officials and citizens concerning lakes with populations of noxious weeds.

- Continued lakes monitoring is needed near lakes with noxious weeds to detect any new introductions of these plants at an early stage.

- Increased public education is needed on the impacts of noxious aquatic weeds and how to prevent their spread.

Marine Water Quality Ambient Monitoring

- Any semi-enclosed bay with attributes such as freshwater input, failing septic systems, or wastewater treatment plants would be likely to have fecal contamination problems. Marine water monitoring data are lacking from many Eastern Olympic areas such as Kilsut Harbor, Port Angeles Harbor, and Oakland Bay. Un-monitored areas with the characteristics mentioned above should be considered a potential candidate for future monitoring activities.

- Within the Puget Sound Ambient Monitoring Program, better coordination between the Washington State Department of Health (Health) and the Washington State Department of Ecology (Ecology) for optimizing coverage of fecal coliform monitoring in Puget Sound is highly recommended.

- Low dissolved oxygen (DO) is of strongest concern in Hood Canal. Assessment of nutrient sources to Hood Canal (especially southern) is recommended.

- Establishing long-term monitoring to assess the DO concentration at the end of the growing season before the fall mixing events (e.g., Sept-Oct), at the heads of inlets/bays is a critical need presently not addressed.

- To assess eutrophication, it is recommended to assess nutrient trends in freshwater input, where failing septic systems may occur, and where other exogenous nutrient sources are significant. Water column measurements such as DO, nutrient concentrations, stratification intensity, phytoplankton community abundance/composition and the sensitivity of primary production to added nutrients would aid in conducting these evaluations. Comparison with historical values is highly useful. Eutrophication is of highest concern in inlets and bays within south Puget Sound and in Hood Canal.

- The degree of on-going versus historical chemical contamination and its availability in the water column and to plankton could be assessed in specific areas of high concern. New technology (semi-permeable membrane devices) and/or mussel cages with tissue analysis would yield this information readily.

- Ecology should work with Health, the University of Washington, the National Marine Fisheries Service, and the Pacific Coast Oyster Growers Association to develop a comprehensive monitoring and assessment program for harmful phytoplankton.

Intensive Surveys and TMDLs

- Review existing work in Port Angeles Harbor, and develop a Total Maximum Daily Load (TMDL) for DO with a TMDL technical study.

- Conduct a TMDL technical study for DO in Oakland Bay and Hammersley Inlet.

- Package the LOTT Budd Inlet Study into a TMDL for nutrients and DO.

- Package the Budd Inlet/Deschutes River Watershed Plan and assessment studies into TMDLs for pH, temperature, DO, and bacteria. Include the Budd Inlet listings for bacteria in this TMDL.

- Support local efforts to restore Henderson Inlet, Woodland Creek, and other tributaries, including monitoring of BMPs and water quality. Package a TMDL for Woodland Creek and the Henderson Inlet Watershed.

- Package a TMDL for nutrients in Capitol Lake from existing work, supplemented by additional monitoring and a monitoring plan. Coordinate with and support efforts to control nonpoint sources of nutrients in the Deschutes Watershed.

- Package a TMDL for fecal coliform (FC) bacteria in Oakland Bay and Hammersley Inlet, based on the work of Michaud (1987; 1988) and the Watershed Plan.

- Coordinate with Dungeness River water resources planning and allocation activities to address 303(d) listing for flow.

- Conduct monitoring of the Dungeness River for DO and temperature to determine whether summertime water quality problems occur.

- Coordinate with and support local efforts to control sediment sources in the Deschutes River Watershed.

- Coordinate issues in south Hood Canal tributaries with NWRO and local interests for the WQMA that includes Kitsap County.

- Ensure coordination with EILS staff for Port Ludlow Bay monitoring.

Toxics Investigations

- Verify toxics data that caused the following seven waterbodies (Budd Inlet-inner, Deschutes River, Ward Lake, Port Townsend, Sequim, Port Angeles Harbor, and Elwha River) to be posted on the 1996 federal Clean Water Act 303(d) list as impaired. In particular, this evaluation should focus on potential PCB sources, since five of the waterbodies have PCB contamination listed as an issue.

- Rainbow trout from Ward Lake (Thurston County) should be re-sampled to determine current PCB concentrations.

- Collect intertidal sediment samples in Oakland Bay at the outlets of storm drains which had high concentrations of metals and organics associated with in-line sediments. These data will be useful in determining the potential for sediment problems in Oakland Bay associated with storm water runoff.

Ground Water Assessments

- The large number of homes with on-site sewage systems in the Eastern Olympics Basin suggests possible areas for ground water problems, especially areas where soils are marginal for on-site sewage treatment. Such problems, if present, could have a substantial impact on shellfish and marine life.

- Ground water quality in the Sequim-Dungeness area should be tracked. Increased residential development and decreased recharge from agricultural drains can lead to ground water deterioration. The effectiveness of ground water protection measures should be evaluated based on on-going ground water monitoring.

Compliance Monitoring

- Class II inspections are recommended for facilities of concern, including those with significant changes resulting from plant modifications or plant operation.

Acknowledgments

This report draws on data collected by many EILS field staff. Most of the sample analysis were conducted by the Ecology/EPA Manchester Environmental Laboratory.

Will Kendra and Larry Goldstein reviewed the report and provided many valuable comments.

The authors would like to extend our thanks to all of these individuals and groups for their efforts in producing this document.

Abstract

Ecology's Environmental Investigations and Laboratory Services (EILS) program reviewed water quality information collected over the last ten years (primarily by EILS) in the Eastern Olympic Water Quality Management Area (WQMA). The Eastern Olympic WQMA consists of the following six water resource inventory areas:

◊ Deschutes (#13)
◊ Kennedy-Goldsbough (#14)
◊ Skokomish (#16)
◊ Quilcene-Snow (#17)
◊ Elwha-Dungeness (#18)
◊ Lyre-Hoko (#19).

This review was conducted as part of an agency-wide scoping and data collection effort being done for the Water Quality Program's watershed approach to water quality management. The primary goal of this review was to identify water quality issues in the region that may require monitoring or intensive studies during the next two years as a prelude to issuing water quality permits and implementing other pollution prevention and control actions in year five.

Water Quality information is summarized and discussed on the following eight topics: Rivers and Streams Ambient Monitoring, Lakes Water Quality, Aquatic Plants Ambient Monitoring, Marine Water Quality Ambient Monitoring, Intensive Surveys and TMDLs, Toxics Investigations, Ground Water, and Compliance Monitoring. Recommendations are also provided for work in each category.

River and Streams Ambient Water Quality Monitoring and Bioassessment Monitoring

by
Robert Plotnikoff
and
William Ehinger

Introduction

The Eastern Olympic Water Quality Management Area (WQMA) incorporates many well-known rivers and streams. Among them are those that flow into Hood Canal, the Strait of Juan de Fuca, and the Deschutes River at the southernmost point of Puget Sound. Streams in this region originate from glaciers, rain (surface runoff), and groundwater depending on the time of year.

Noteworthy problems in this WQMA are the continual flood events that occur on the Skokomish River during the winter season and fecal coliform contamination on the lower Deschutes River station. These water quality problems have been attributed to forest removal and agricultural activity, either commercial or hobby farms. Surface water temperatures are generally cool except for meandering streams that flow across areas with little topographic relief.

One of the region's high profile political issues lies with the Elwha River. Two dams currently exist that were constructed to supply inexpensive power to the area's pulp mills. Removal of these dams has been proposed and offer a unique experiment in salmon fisheries restoration of the upper Elwha River. In anticipation of this event, we have been continuously monitoring surface water on the Elwha between the two dams.

Water Quality Monitoring

Historical River and Stream Monitoring by the Ambient Monitoring Section

Freshwater Monitoring in the Eastern Olympic WQMA includes both 'core' stations and 'basin' stations which are chosen by the Southwest Regional Office. The 'core' stations represent stream types characterized by their water source (*e.g.*, glacier, rain, groundwater). Core stations were also designated where long-term historical data collection was available. Table 1 lists the stations in this WQMA and the monitoring schedule. Figure 1 provides the location of river and stream monitoring stations visited by the Ambient Monitoring Section.

Summary of Findings

Water Quality Violations

Fecal coliform contamination was evident at all of the Basin Stations in the Eastern Olympic WQMA (Hallock and Ehinger 1995). The Basin Stations were the following:

- Goldsborough Creek @ Shelton
- Big Quilcene R near Quilcene (17A070)
- Finch Creek @ Hoodsport (16E070)
- Chimacum Creek near Irondale (17B070)
- Chimacum Creek @ Chimacum (17B100)

Fecal coliform criteria were exceeded most frequently at Chimacum Creek @ Chimacum (17B100). In addition, surface water exceeded temperature criteria on one occasion and dissolved oxygen concentrations were low on several site visits. This station was situated in an area that had cattle grazing and the stream was channelized. The remaining Basin Stations were located in settings where hobby farms and rural home sites were present. Fecal bacteria contamination may have reached streams through surface water runoff or failing on-site septic systems.

Big Quilcene R near Quilcene was located below the Quilcene National Fish Hatchery. Effluent water from the hatchery, on-site septic systems further upstream, or wildlife may have contributed to this one-time bacteria violation.

Fecal coliform contamination at most stations occurred on runoff events during the wet season. Chronic fecal contamination at Chimacum Creek @ Chimacum occurred during both the wet season and when stream flow was lowest. Temperature and dissolved oxygen violations coincided with low flow periods at this station.

Water Quality Trends

Trend analysis of water quality variables was completed for three basin stations: Deschutes R @ E St. Bridge (WY '87-'97), Deschutes R near Rainier (WY '87-'93), and Skokomish R near Potlatch (WY '87-'97). Lengthy monitoring records for each of these sites provided adequate data to test for statistical trends (Table 1).

The following tables describe the results of trend analysis.

Deschutes River @ E Street Bridge (13A060)

Variable	Trend (raw data)	Trend (flow-adjusted)
Temperature	decreasing	
Dissolved Oxygen	decreasing	
% Saturation DO	decreasing	
Specific Conductivity	decreasing	
Nitrate+nitrite-N	increasing	
Suspended Solids	not significant ($p > .10$)	decreasing
Fecal Coliform	increasing	
Flow	increasing	

Trends reported from analysis of the raw data at station 13A060 (monthly observations during the wateryears 1987-1997) represented only minor changes in the direction indicated. An increase in flow was attributed to the wetter climate that occurred during the latter half of the trend period. Increased concentrations of fecal coliform bacteria and nitrate+nitrite-nitrogen may have occurred through surface runoff. Minor decreases in most variables are attributed to the flow increase.

Deschutes River near Rainier (13A150)

Variable	Trend (raw data)	Trend (seasonal)
Dissolved Oxygen	decreasing	
% Saturation DO	decreasing	
Specific Conductivity	not applicable	decreasing (Apr.-Nov.)
Nitrate+nitrite-N	increasing	
Fecal Coliform	increasing	
Flow	not applicable	increasing (Apr.-Aug.)

Trends reported from the data set 13A150 were based on a shorter monitoring interval (wateryears 1987-1993). Many of the variables had incomplete continuous records to accommodate 'raw data' trend analysis, but had consistent monitoring during portions of the year (seasonal). An increasing trend in flow records at this upper watershed station was attributed to the wetter climate pattern during the latter portion of this monitoring period. The same increasing trend for fecal coliform bacteria concentrations and nitrate+nitrite-nitrogen concentrations occurred as at the lower watershed station (13A060). Other nutrients such as total phosphorus and ammonia-nitrogen were analyzed for trends in the Deschutes River watershed. The changes were attributed to laboratory reporting procedures that took effect at mid-point of the trend intervals.

Skokomish River near Potlatch (16A070)

Variable	Trend (raw data)	Trend (flow-adjusted)
Dissolved Oxygen	decreasing	
% Saturation DO	decreasing	
Specific Conductivity	decreasing	
Nitrate+nitrite-N	decreasing	
Total Phosphorus	not applicable	decreasing

Trends reported for the data set 16A070 were based on a ten year monitoring interval (wateryears 1987-1997). Flow did not change significantly in this drainage over the length of the monitoring period. The major cause for regular flooding in this valley has been attributed to extensive logging. Water volume in the channel may now be more constant from year to year at similar time periods. Further degradation of the surrounding landscape may not transmit a response to stream conditions any longer. Trends identified for other variables represent minor changes in the direction indicated.

Bioassessment Monitoring

Collection and analysis of benthic macroinvertebrate (biological) information was completed at five sites in the Eastern Olympic WQMA (see Figure 3). Water quality conditions defined by chemical analysis can fail to protect stream biota from physical changes in the environment or from 'slugs' of pollutants that are missed in regular sampling routines. The purpose of the biological monitoring program was to screen sites for various stream quality impacts (Plotnikoff and Ehinger 1997). The following table lists the sites surveyed and the surrounding land use impacts.

Biological Monitoring Stations Sampled in 1996 in the Eastern Olympic WQMA.

Site	Surrounding Land Use
Lyre River	Minimal disturbance
South Branch Little River	Minimal disturbance
Siebert Creek	Suburban Development/water withdrawal
Dungeness River	Water withdrawal/logging
Duckabush River	Minimal disturbance

Biological condition in the Dungeness River indicates a high level of transportable sediments (*e.g.*, fine gravel, sand). The most abundant species at this site are tolerant to several types of environmental degradation. Species collected from Dungeness River and Siebert Creek indicated the large quantity of consumable organics both in the sediment and the water column. Origin of this material is usually from periodic stream bottom disturbance and erosion (*e.g.*, grazing, high flows).

The remaining sites had relatively few species that were cold-water dwellers. Minimally disturbed sites were not surrounded by suburban development or hobby farms.

Environmental variables that were related to biological condition in streams of this WQMA were: pH, dissolved oxygen, conductivity, and stream gradient. Differences in biological communities of this set of five streams were identified by surface water conductivity. Streams that were affected by surrounding land uses contain biota that may reflect impact from stormwater runoff or fine sediments entering the water column.

Recommendations

- Fecal coliform contamination is a common water quality problem in the Eastern Olympic WQMA. Sources of contamination are cattle grazing, failing on-site septic systems, and wildlife. Identification of source and stream locations that are likely to be degraded by fecal coliform contamination should be inventoried.

- An increase in land development has occurred along Hood Canal. The greatest concern for this development is the fate of wastewater. The pattern for future water quality problems in freshwater streams appears to be linked to the type and density of development in the Eastern Olympic WQMA. The impact of such development on water quality has already been determined by data we have analyzed. An inventory of current development and projected future development will assist in risk analysis of further water quality degradation.

- Monitoring station selection in Thurston County should consider the monitoring effort by the County and should maintain 'core' stations that would serve as a reference for future watershed monitoring projects. 'Core' station monitoring provides continuity between major watershed monitoring projects and indicates the direction of change in water quality.

- Water quantity and water quality are of concern in small streams that drain into the Strait of Juan de Fuca. Small hobby farms are emerging in large numbers. Management of these properties, particularly if keeping animals, will have some consequence on preserving water quality.

- Biological monitoring indicates that common impacts to stream channels involve erosion and possible contaminants associated with eroded materials. These types of impacts are not usually detected by surface water sampling programs. Biological monitoring should be considered where erosion of streambanks or transport of water from overland sources is suspected.

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Lakes Water Quality Ambient Monitoring

by
Kirk Smith

Introduction

Many lakes have been monitored for water quality within the Eastern Olympic Watershed. Mason lake should continue to receive considerable attention due to the absence of a county-funded lake's program coupled with the increased need for monitoring due to rapid population growth. Mason Lake was featured in a 1997 KOMO news clip. The significance of the report was to contrast the pristine water quality of Mason Lake to the degrading water quality of Lake Sammamish in King County.

Summary of Findings

Chambers Lake -- Thurston County

Chambers Lake is located three miles southeast of Olympia. It is also known as Big Chambers Lake, and was originally known as Russell Lake. Chambers Lake has no surface inlets, but is fed by stormwater and surface runoff. As a result, it varies in size. Chambers Lake drains via Little Chambers Lake to the Deschutes River.

Chambers Lake Characteristics	
Size (acres)	60
Maximum Depth (feet)	8
Mean Depth (feet)	5
Lake Volume (acre-feet)	270
Drainage Area (miles^2)	0.8
Altitude (feet)	194
Shoreline Length (miles)	2.2

Data from Bortleson *et al.* (1976)

Overall Assessment

Water clarity was poor in 1994, although Secchi depths were very similar in 1993 and 1994 (see graph of Secchi depth data).

Based on all measurements made in the lake in 1994, Chambers Lake was classified as eutrophic in 1994. Algae growth was heavy, as indicated by the high concentrations of chlorophyll *a* and the low Secchi depth measurements. Secchi depths, water chemistry results, and profile data are listed in tables at the end of this summary.

Because the lake is very shallow, aquatic plants can root throughout the lake bottom and much of the lake surface was covered by floating-leafed aquatic plants. Aquatic plants observed by Ecology staff during the field visits include watershield (*Brasenia schreberi*), cattails (*Typha* sp.), and a purple water lily (*Nymphaea* sp.). The latter was probably introduced into the lake. Plants observed in the lake are usually not eaten by grass carp (see other available information, below). Cattails grow along most of the shoreline, and provide habitat for a variety of birds, including swallows and blackbirds. Chambers Lake exhibits more characteristics of a wetland pond than a lake that can be used for contact recreation. Preserving the wetland characteristics of this lake should be considered if further attempts are made to restore the lake.

Other Available Information

In 1990, a four-year demonstration project on the use of grass carp was initiated by the City of Lacey, the University of Washington School of Fisheries, Ecology, and the Chambers Lake Environment and Neighborhood Association (CLEAN). Grass carp were planted in Big Chambers Lake and Little Chambers Lake to evaluate the effectiveness of grass carp on controlling floating-leafed aquatic plants, and to evaluate different stocking rates used in the two lake basins. About 3,000 fish were stocked in Little Chambers Lake, and about 12,500 were stocked in Big Chambers Lake. Two exclusion areas used to keep the fish out are still present in the wide central part of the lake. The demonstration project is still in progress.

The City of Lacey monitored several storm drains that drain into Chambers Lake. Nonpoint source controls will be implemented to reduce nutrient loading to the lake from stormwater.

Crescent Lake -- Clallam County

Crescent Lake is located 14 miles west from Port Angeles. It is 8.5 miles long. Several inlets flow into the lake, including Barnes, Smith, Aurora, Lapoel, Cross, and Eagle Creeks. Crescent Lake drains via Lyre River to the Strait of Juan de Fuca. There is a precipitous shoreline, except at both ends. It is the third largest natural lake in Western Washington. Beardslee trout are found only in Crescent Lake. This lake was monitored by Ecology staff only.

Crescent Lake Characteristics	
Size (acres)	5,127
Maximum Depth (feet)	624
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	580
Shoreline Length (miles)	*

Data from Dion *et al.* (1976)
*Information not available

Overall Assessment

Crescent Lake was sampled by Ecology staff only in 1994, by request from the Southwest Regional Office. It was last monitored for the program in 1990 (by volunteers).

Profile data were limited by the length of the cable on the profiling instrument. On both sampling dates, the profiles show the depth of the epilimnion, but depths of the metalimnion and the hypolimnion could not be determined. Also, Secchi depth could not be determined on either sampling date, because there was only 60 feet of line attached to the disk. When the lake was last monitored for the program in 1990, Secchi depths averaged around 68 feet.

Based on results from all three major trophic state parameters (total phosphorus, chlorophyll *a*, and Secchi depths), Crescent Lake was classified as oligotrophic in 1994.

Lake Lawrence -- Thurston County

Lake Lawrence is located six miles south of Yelm, and six miles southeast of Rainier. It is fed by springs, and drains to the Deschutes River. Lawrence Lake was monitored by Ecology staff only.

Lawrence Lake Characteristics	
Size (acre)	330
Maximum Depth (feet)	26
Mean Depth (feet)	13
Lake Volume (acre-feet)	4,400
Drainage Area ($miles^2$)	3.4
Altitude (feet)	421
Shoreline Length (miles)	4.0

Data from Bortleson *et al.* (1976)

Overall Assessment

Lake Lawrence was sampled by Ecology staff only in 1994, by request from Ecology's Southwest Regional Office.

Based on results from all three major trophic state parameters (total phosphorus, chlorophyll *a*, and Secchi depths), Lake Lawrence was classified as eutrophic in 1994 (see table of water chemistry data).

Whitestem pondweed (*Potamogeton praelongus*) was abundant along the shore during the September survey.

The lake was awarded a Clean Lakes Grant from Ecology to investigate sources of eutrophication and to recommend options for lake restoration. An experimental process for dredging and centrifuging dredge spoils was tested in the lake in early 1995.

Leland Lake -- Jefferson County

Leland Lake Characteristics	
Size (acres)	107
Maximum Depth (feet)	20
Mean Depth (feet)	13
Lake Volume (acre-feet)	1415
Drainage Area ($miles^2$)	5.71
Altitude (feet)	190
Shoreline Length (miles)	2.75

Data From Dion *et al.* (1976)

Leland Lake 1993 Onsite Visit Data - Water Chemistry					
Date	Station	Strata	Total Phosphorus (ug/l)	Total Nitrogen (mg/l)	Chlorophyll a (ug/l)
08/05/74[1]	-	E	61	-	-
07/02/81[2]	-	E	60	5.7	-
05/30'93	1	E	40	0.69	27.2
05/30/93	1	H	43	0.70	-

E=epilimnion composite, H=hypolimnion composite
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program
[1]= Source: Water Supply Bulletin #43
[2]= Source: Water Supply Bulletin #57

Overall Assessment

Lake Leland is of particular interest because it produces some of the best largemouth bass fishing in the state while at the same time demands attention for managing its aquatic weed problem. The overall assessment for the lake is eutrophic.

Lake McIntosh -- Thurston County

Lake McIntosh is located four miles east of Tenino. It has no surface inlets, and drains via an unnamed outlet to the Deschutes River.

Lake McIntosh Characteristics	
Size (acres)	93
Maximum Depth (feet)	11
Mean Depth (feet)	8
Lake Volume (acre-feet)	700
Drainage Area (miles^2)	2.26
Altitude (feet)	336
Shoreline Length (miles)	2.6

Data from Bortleson *et al.* (1976)

Overall Assessment

Water quality of Lake McIntosh was fair in 1994. Most water quality problems were related to algae growth, which probably resulted from high phosphorus concentrations in the water. Secchi depths and volunteer observations indicate that algal growth was most severe from late August through October. The high chlorophyll *a* concentrations in August indicates that algae were in bloom proportions at the time. An algae sample contained mainly the blue-green alga *Anabaena*, and possibly was *Anabaena circinalis*. Secchi depths and water chemistry results are listed in tables at the end of this summary.

Because the lake is shallow, it is not surprising that profile data did not change much from surface to bottom. However, it was apparent that pH in the water was somewhat high (for lake water) during the August survey. This probably resulted from the algae bloom.

Results from fecal coliform bacteria samples collected during May were very low and did not indicate any problems.

Aquatic plants observed by Ecology staff during the field visits include iris (*Iris pseudacorus*), cattails (*Typha sp.*), whitestem pondweed (*Potamogeton praelongus*), common waterweed (*Elodea candensis*), and yellow-flowering water lily (*Nuphar sp.*).

Recommendations

- Support to continue monitoring in Mason County is particularly important. Now that Island Lake has Eurasian milfoil, it is highly likely that many of the Mason County lakes in the region will become infested with the noxious weed.

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Aquatic Plants Ambient Monitoring

by
Jenifer Parsons

Introduction

This chapter of the EILS Eastern Olympic WQMA Briefing Paper provides information on waterbodies in the basin that have been surveyed for aquatic plants, have populations of noxious weeds, and listed rare plants. Recommendations for future work are also provide.

Summary of Findings

Historical Aquatic Plant Monitoring

Ecology's Ambient Monitoring Section has monitored aquatic plants in lakes and rivers of the state since 1994. Table 2 provides the names of waterbodies included in this program within the Eastern Olympics Basin.

Table 2: Waterbodies Monitored for Aquatic Plants

WRIA	County	Waterbody Name	Years Surveyed
13	Thurston	Hicks Lake	95
13	Thurston	Lawrence Lake	95
13	Thurston	Unnamed Pond (19N-02W-31)	94
14	Mason	Benson Lake	96
14	Mason	Fawn Lake	97
14	Mason	Isabella Lake	94, 95, 97
14	Mason	Island Lake	96, 97
14	Mason	Limerick Lake	94, 95, 97
14	Mason	Lost Lake	94, 97
14	Mason	Mason Lake	96
14	Mason	Spencer Lake	94, 95, 96, 97
14	Thurston	Long Lake	95
14	Thurston	Summit Lake	97
17	Jefferson	Anderson Lake	96
17	Jefferson	Crocker Lake	94, 95, 96, 97
17	Jefferson	Leland Lake	94, 95, 96, 97
17	Jefferson	Tarboo Lake	96
18	Clallam	Sutherland Lake	96
18	Clallam	Unnamed (30N-04W-17)	95
19	Clallam	Crescent Lake	96

The waterbodies listed in Table 3 are those known to contain listed noxious weeds. For reference, the aquatic plants included on the state noxious weed list are:

Cabomba caroliniana (fanwort)
Egeria densa (Brazilian elodea)
Hydrilla verticillata (hydrilla)
Lysimachia vulgaris (garden loosestrife)
Lythrum salicaria (purple loosestrife)
Lythrum virgatum (wand loosestrife)
Myriophyllum aquaticum (parrot feather)
Myriophyllum spicatum (Eurasian milfoil)

Table 3: Waterbodies with Listed Noxious Aquatic Weeds

County	Waterbody Name	Noxious Weed
Clallam	Unnamed Pond (30N-04W-17)	*Myriophyllum spicatum*
Jefferson	Leland Lake	*Egeria densa*
Mason	Island Lake	*Myriophyllum spicatum*
Mason	Limerick Lake	*Egeria densa*
Mason	Spencer Lake	*Lythrum salicaria*
Thurston	Long Lake	*Myriophyllum spicatum*

Additional Details - Waterbodies with Noxious Weeds

The unnamed pond in Clallam County with *Myriophyllum spicatum* is a private fishing pond. Grass carp were stocked for plant control several years ago. However, due to a low stocking rate the *M. spicatum* has not been eradicated from the pond (Collins, 1997).

Lake Leland is a 110 acre shallow lake in rural eastern Jefferson County. It supports a diverse community of native vegetation which appears to host much wildlife and an excellent warm water fishery (Collins, 1995). During the 1994 field season an isolated though well developed population of *Egeria densa* was discovered in the western end of the lake. Additional site visits were made in 1995 and 1996, and the *Egeria* population boundaries were recorded with a GPS unit and by visual placement on a map (Parsons, 1997). By the fall of 1996 small pioneering clumps of *Egeria* were present in much of the lake's main body, and the western end contained a dense ring of this species between depths of 1 to 3 meters. The local community and the Jefferson County Conservation District are concerned about the impacts this plant will have on the lake. They are in the process of creating an Aquatic Vegetation Management Plan (using funds from the Ecology's Aquatic Plant Management Fund). They are mapping the plant community and collecting plant biomass data during 1997 as part of this process.

Island Lake, Mason County had a relatively isolated population of *Myriophyllum spicatum* in 1996. A meeting was held with county officials and local residents to alert them to the potential problems caused by this plant, however no control efforts were made during that year. In July of 1997 the *Myriophyllum spicatum* had spread throughout much of the lake. The local community is currently organizing to decide on a plan to combat this plant.

Limerick Lake, Mason County received grant money from Ecology's Aquatic Plant Management Fund to do a whole lake treatment with the systemic herbicide Sonar® in 1996. A survey of two locations in the lake during 1997 showed re-growth of the *Egeria densa*, indicating the attempted eradication was not successful.

Spencer Lake, Mason County had a small patch of *Lythrum salicaria* which was pulled in 1994 and 1995. No regrowth has been observed in subsequent surveys (the homeowner is keeping it mowed).

Long Lake, Thurston County had a whole lake herbicide treatment in 1991. Diver surveys during subsequent years indicated the effort was successful. However, in 1995 a small patch of *Myriophyllum spicatum* was discovered in the bay near the public boat access. This is apparently a reintroduction of this plant. The county is using bottom barrier and hand pulling to control the new population.

Table 4 provides the names of waterbodies in the Eastern Olympics Basin known to contain listed rare plants. This list only includes what has been found through the surveys conducted by this program. For a more complete review of rare plant locations contact the Natural Heritage Program at the Washington Department of Natural Resources.

Table 4: Waterbodies with Listed Rare Plants

County	Waterbody	Scientific name
Clallam	Crescent Lake	*Lobelia dortmanna*
Mason	Benson Lake	*Lobelia dortmanna*
Mason	Isabella Lake	*Potamogeton obtusifolius*
Mason	Mason Lake	*Lobelia dortmanna*
Mason	Spencer Lake	*Lobelia dortmanna*

Recommendations

- Continue to offer technical assistance to local government officials and citizens concerning lakes with populations of noxious weeds
- Continue monitoring lakes near those with noxious weeds to detect any new introductions of these plants at an early stage.
- Increase public education on the impacts of noxious aquatic weeds and how to prevent their spread.

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Marine Water Quality
Ambient Monitoring

by
Jan Newton for the
Marine Waters Monitoring Team

Introduction

The Eastern Olympic basin (WRIAs #13, 14, 16, 17, 18, and 19) represents a complex area with respect to the marine systems it includes. State WRIA boundaries divide several major Puget Sound basins between two or more watershed basins. For example, Hood Canal is shared by both Kitsap and Eastern Olympic watersheds. The watershed approach makes sense for freshwater systems or for semi-enclosed marine bays receiving river water from a single watershed (e.g., Bellingham Bay); however, it is difficult to apply to the Puget Sound marine basins, which are commonly divided into: Puget Sound Main Basin, Hood Canal, South Puget Sound, Whidbey Basin, San Juan/Strait of Georgia, and Strait of Juan de Fuca. Because contamination can come from either shoreline (or any watershed) of a subdivided waterbody (e.g., Hood Canal), it is difficult to evaluate these waterbodies using the watershed approach. In this report, all adjoining waterbodies to the Eastern Olympic peninsula shoreline were considered part of the Eastern Olympic basin, not just those listed for the specified WRIAs. This means the addition of several areas with "WA-PS-xxxx" designations. The waterbody segments considered for Eastern Olympic Basin and the Marine Waters Monitoring stations located within these segments are listed in Table 5.

The Marine Waters Monitoring (MWM) program of the Ambient Monitoring Section is responsible for monitoring the marine waters of Puget Sound and the coastal estuaries Grays Harbor and Willapa Bay. Puget Sound MWM stations are shown in Figure 4. The data record for MWM stations located within the Eastern Olympic Basin and its adjoining waterbody segments are shown in Table 6. Some of the monitoring stations represent open basins whereas others represent small, enclosed bays. Stations are typically located in the central portion of the basin or bay, away from the nearshore or known point sources. Parameters monitored at MWM stations are listed in Table 7. Not all parameters are consistently available for all stations.

Two primary factors causing poor water quality are: 1) the existence of anthropogenic inputs/alterations to the environment (e.g., point and non-point contamination, nutrient loading, alteration of habitat, freshwater diversion); and 2) a long residence time (poor flushing of water). Residence times are influenced by natural bathymetry, tidal forcing and circulation. Simply stated, water quality problems become notable when input sources are significant or when removal mechanisms are slow. However, in evaluating water quality, the natural water quality for that area must be considered. Natural water quality does not always follow the WAC (1992) criteria; thus, knowledge of the environmental mechanisms affecting the various parameters is required. Because information on pre-anthropogenic influence water quality can be limited to non-existent, this evaluation can be difficult.

Marine Water Quality

Known water quality problems and concerns for the Eastern Olympic Basin MWM stations are listed in Table 8. Some of the Section 303 (d) listings were for metals or toxics and were based on data not collected by MWM. Note that water-column metals and toxics are not monitored by MWM.

In addition, there are many areas in the Eastern Olympic basin where no MWM stations exist and others where data records are scant. Areas where the physical and hydrological set-up are conducive to water quality problems, yet where no or insufficient data exist are numerous within this basin. If anthropogenic inputs are significant, the relatively constricted embayments where relatively slow circulation may occur, such as Kilsut Harbor, inner Oakland Bay, Little Skookum Inlet, and Quilcene Bay, may develop water quality problems easily. Most of these areas lack MWM stations. In addition, for areas that are monitored, the MWM stations are typically located in the central portion of the bays. However, the heads of many of the monitored bays often have been found to exhibit worse water quality than at the MWM station (e.g., Eisner *et al.*, 1994; Albertson *et al.*, 1995).

Fecal Coliform Bacteria

As shown in Table 8, fecal coliform contamination has been recorded at Henderson Inlet, Budd Inlet, Eld Inlet, Shelton Harbor, Hammersly Inlet, Oakland Bay, Dabob/Quilcene Bays, Case Inlet, South Hood Canal, Lynch Cove, and Nisqually Reach. Areas where fecal contamination could be a concern would be enclosed and poorly flushed inlets, bays and harbors with anthropogenic input and low salinity. Natural sources (harbor seals, sea lions) can also contribute to the recorded fecal coliform concentrations however, from analysis of occupation patterns (temporally and spatially) these cannot solely account for the excursions observed.

Based on MWM data, of the areas listed above, areas with chronically high (>25% of observations >14 org/100 mL) fecal coliform excursions are Oakland Bay (OAK004), where contamination has appeared chronic during the 1980's and 90's, Budd Inlet (BUD005) particularly prior to 1993, and Nisqually Reach (NSQ001), starting sharply in 1989 through last data taken in 1991.

Any semi-enclosed area with attributes such as freshwater input, failing septic systems, or wastewater treatment plants would be likely to have fecal contamination. MWM monitoring data is lacking from many Eastern Olympic areas such as Kilsut Harbor, Port Angeles Harbor, and Shelton Harbor. Evaluating the formerly mentioned attributes in the un-monitored areas is recommended in order to establish priorities for monitoring. However, the nearshore areas of many of the inlets may have fecal contamination when mid-bay monitoring stations do not. Because of the relatively short lifetime of fecal coliform bacteria in saline water (Lessard and Sieburth, 1983), mid-bay monitoring (e.g., MWM stations) is not well-suited to detecting fecal contamination. The Department of Health monitors fecal coliform at some locations with a focus on nearshore stations. Within the Puget Sound Ambient Monitoring Program, better coordination between Health and Ecology for optimizing coverage of fecal coliform monitoring in Puget Sound is highly recommended.

Dissolved Oxygen

Although the DO standard for class AA and A waters is set at 7.0 and 6.0 mg/L, respectively, (WAC, 1992) the natural DO concentrations of many Puget Sound waters will be lower. This is because the oceanic waters flowing into the region through the Strait of Juan de Fuca are upwelled Pacific Ocean waters that can have naturally low (i.e. between 5 and 7 mg/L) DO concentrations, primarily in late summer. Thus, DO excursions below 7 mg/L but above 5 mg/L are to be expected. Natural phytoplankton production also results in low near-bottom DO concentrations, through the oxidation of sunken organic material. Near-bottom DO concentrations are increased when mixed with oxygenated surface waters. Strong density stratification (e.g., in areas with freshwater input) inhibits mixing and results in maintaining low DO in near-bottom waters. Thus, areas in Puget Sound with high production and strong density stratification can naturally have DO concentrations less than 5 mg/L in late summer because of these compounding effects.

Thus, stations with DO data above 5 mg/L but below WAC standards (e.g., Oakland Bay) would be of less ecological concern that those (e.g., Budd Inlet, Lynch Cove) where values are near 3 mg/L or approach hypoxia. Other areas (e.g., Port Angeles Harbor, Port Townsend/Kilsut Harbor) lack monitoring data from the inner portions of the area.

In order to assess eutrophication and its impact on low DO concentrations, it is important to consider historical data. Of the areas on the 303 (d) listing for DO, we have historical data from the University of Washington for the period 1952-1966 (Collias et al., 1974) in both Hood Canal and Case Inlet. Both of these areas showed DO concentrations that were lower or low for longer periods of time than that observed in the Collias et al. database. Refer to Newton et al., 1997 for more thorough assessment of DO concentrations and historical values.

Low DO is of strongest concern in Hood Canal. The lowest DO recorded at a long-term MWM station was at HCB004 in Hood Canal, where anoxic concentrations were observed and where the concentrations seldom rise above 5 mg/L year round (Newton et al., 1997). Eutrophication processes and changes in circulation due to freshwater diversion are possible causes for the low DO (Newton et al., 1995). Primary productivity experiments conducted during a focused monitoring project in 1994-5 (Newton, 1995) clearly showed phytoplankton growth to be stimulated by exogenous nutrients. Assessment of nutrient sources to Hood Canal (especially southern) is highly recommended.

In another focused project, monitoring data from Sinclair Inlet showed DO to be much lower at the head of the inlet than in the centrally located long-term monitoring station (SIN001; Alberston et al., 1995). This same pattern has been found in all other areas studied by MWM (Budd Inlet, Sequim Bay, Hood Canal). Hypoxia may be a significant problem in the headwaters of many of the Eastern Olympic Basin bays/inlets that would not be revealed by the MWM monitoring stations. Henderson Inlet, Totten Inlet, Eld Inlet, Little Skookum Inlet, Discovery Bay, Shelton Harbor, Kilsut Harbor and Port Angeles Harbor are all possible candidates for this condition. Establishment of monitoring stations at the heads of inlets/bays to assess DO concentrations at the end of the growing season prior to the onset of fall mixing events (e.g., Sept-Oct), is a critical need not presently being addressed.

Nutrients

As shown in Table 8, total nitrogen concentrations were of concern in Budd Inlet. Since 1994 the LOTT (Lacey-Olympia-Thurston-Tumwater partnership) WWTP has conducted N-removal on its effluent. This action coincided with a very significant (80%) reduction in dissolved inorganic N (nitrate+nitrite+ammonium) in Budd Inlet waters in following years (Eisner and Newton, 1997). Currently a large multi-disciplinary scientific study was commissioned by LOTT to assess the capacity for Budd Inlet to handle more marine discharge of effluent in winter. The study is being conducted on all seasons and a predictive water quality model is being developed. This comprehensive study is important for Budd Inlet as well as the surrounding region.

Eutrophication will have serious impacts in areas where flushing is low and where phytoplankton growth is nutrient limited. In well-mixed areas, phytoplankton are more typically light-limited since they are mixed below the euphotic zone. Differentiating natural levels of primary production from those stimulated by exogenous nutrients is difficult. It is important to assess suspected nutrient sources and to compare DO concentrations with historical levels. Comparing nutrient concentrations is not recommended, since phytoplankton uptake is rapid; however, analysis of nutrient ratios can be insightful since ammonium-N, in short supply naturally (0.03 mg/L in Admiralty Inlet), often is indicative of anthropogenic input.

The areas where eutrophication may be problematic are those discussed in the DO section, notably Hood Canal and South Puget Sound embayments such as Budd Inlet and Case Inlet. Other smaller areas may not show low DO concentrations because their shallower waters are mixed by wind yet still experience significant nutrient input, such as Oakland Bay and Henderson Inlet. A large study, the Southern Puget Sound Nutrient Study, is presently in the scoping process at Ecology.

To assess eutrophication, it is recommended to assess nutrient trends in freshwater input, where failing septic systems may occur, and where other exogenous nutrient sources are significant. Water column measurements such as DO, nutrient concentrations, stratification intensity, phytoplankton community abundance/ composition and the sensitivity of primary production to added nutrients would aid in this evaluation. Comparison with historical values is highly useful.

Toxics/Metals

As is evident in Table 8, some of the 303(d) listings for marine areas in the Eastern Olympic Basin are from exceedances in toxics and metals. Because these analyses are expensive and because these compounds often are quite dilute in the water-column, monitoring of toxics had not been conducted by MWM. Assessment of toxics and metals is typically done by analysis of sediments, where these compounds often sequester. However, lacking is information on to what degree this contamination is historical (e.g., in sediments) or current (e.g., still mobile in water column and taken up by plankton, at the base of the pelagic food-web). New technology (semi-permeable membrane devices) and/ or mussel cages with tissue analysis would yield contamination levels in the water column readily.

Based on the 303(d) listing, notable areas in the Eastern Olympic Basin with chemical contamination are Port Angeles Harbor, Budd Inlet, Port Townsend, north Hood Canal and Sequim Bay. These areas should be evaluated based on existing data to assess the severity of the contamination. The degree of on-going versus historical chemical contamination and its availability in the water column and to plankton could be assessed in specific areas of high concern.

Harmful Phytoplankton Species

The occurrence of harmful or toxic phytoplankton in these waters is not well-documented, though outbreaks have occurred. To some extent the lack of data on harmful phytoplankton occurrence indicates a lack of outbreaks, but it also indicates a lack of monitoring.

Observations of harmful phytoplankton in the Eastern Olympic Basin includes a diatom species (*Pseudonitzschia* spp.) that causes Amnesiac Shellfish Poisoning in Hood Canal and a flagellate species (*Heterosigma carterae*) that can cause fish kills in Budd Inlet. No outbreaks have caused human death or significant loss of resources so far in this area. The stimuli for blooms of harmful phytoplankton are not understood. Monitoring of phytoplankton species, to be effective, must be done frequently and accompanied by other environmental variables.

Ecology should work with Health, the University of Washington, the National Marine Fisheries Service, and the Pacific Coast Oyster Growers Association to develop a comprehensive monitoring and assessment program for harmful phytoplankton. This work could be conducted under the auspices of PSAMP.

Recommendations

- Any semi-enclosed area with attributes such as freshwater input, failing septic systems, or wastewater treatment plants would be likely to have fecal contamination. MWM monitoring data is lacking from many Eastern Olympic areas such as Kilsut Harbor, Port Angeles Harbor, and Shelton Harbor. Un-monitored inlets/bays with the characteristics mentioned above should be considered a priority for future monitoring activities.

- Within the Puget Sound Ambient Monitoring Program, better coordination between Health and Ecology for optimizing coverage of fecal coliform monitoring in Puget Sound is highly recommended.

- Low DO is of strongest concern in Hood Canal. Assessment of nutrient sources to Hood Canal (especially southern) is recommended.

- Establishing monitoring stations at the heads of inlets/bays to assess the DO concentration at the end of the growing season prior to the onset of fall mixing events (e.g., Sept-Oct), is a critical need presently not being addressed.

- To assess eutrophication, it is recommended to assess nutrient trends in freshwater input, where failing septic systems may occur, and where other exogenous nutrient sources are significant. Water column measurements such as DO, nutrient concentrations, stratification intensity, phytoplankton community abundance/composition and the sensitivity of primary production to added nutrients would aid in conducting this evaluations. Comparison with historical values is highly useful. Eutrophication is of highest concern in inlets and bays within South Puget Sound and in Hood Canal.

- The degree of on-going versus historical chemical contamination and its availability in the water column and to plankton could be assessed in specific areas of high concern. New technology (semi-permeable membrane devices) and/ or mussel cages with tissue analysis would yield this information readily.

- Ecology should work with Health, the University of Washington, the National Marine Fisheries Service, and the Pacific Coast Oyster Growers Association to develop a comprehensive monitoring and assessment program for harmful phytoplankton.

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Intensive Surveys and TMDLs

by
Paul J. Pickett

Introduction

The Watershed Assessment Section (WAS) of EILS focuses mainly on Total Maximum Daily Load (TMDL) studies and on watershed-based intensive surveys such as REMAP, nonpoint source (NPS) identification, and Best Management Practice (BMP) evaluation. TMDL studies are conducted for water bodies that have been listed as water quality-limited on the state's 303(d) list, or as preventative TMDLs for water bodies whose beneficial characteristic uses are threatened by human activities.

This chapter reviews studies done by WAS, and also by earlier organizations and other agencies, focusing on watershed-based surveys that collected water quality data from the late 80's until present. This chapter also reviews the 303(d) list for likely candidates for WAS TMDL technical studies.

Previous Studies

Henderson Inlet, Woodland and Woodard Creeks

Harrison and Hofstad (1988) conducted sampling on four dates from June 1986 to April 1987 at 7 sites in Henderson Inlet and in 5 tributary creeks (Dobbs [East], Meyer [Snug], Goat, Woodard, and Woodland Creeks). Two Inlet stations and all 5 tributaries exceeded FC bacteria standards. Woodland Creek had the highest bacteria loading to the inlet and Woodard Creek the second highest.

Starry (1990a) analyzed DOH sampling of Henderson Inlet and conducted sampling of its tributaries from October 1987 through August 1989. Out of 28 sampling stations in Henderson Inlet, 2 exceeded state FC bacteria Class AA standards. Of 5 tributaries to the inlet (Dobbs [East], Meyer [Snug], Sleepy, Woodard, and Woodland Creeks), only Dobbs Creek met the FC bacteria water quality standards, while Woodland Creek exceeded both the geometric mean and 10% portions of the standard. Problems were associated with storm water run-off, and resulted from poor agricultural practices, on-site septic problems, and inadequately treated urban run-off. The greatest bacterial loads came from Woodard and Woodland Creeks, which drain urban run-off from Olympia and Lacey.

During the construction of the Ecology building in Lacey from January 1991 to September 1993, Woodland Creek was studied to evaluate potential impacts from construction of the building (Patterson and Dickes, 1994). The study found that BMPs used during construction were adequate to prevent any adverse impact. However, the study identified other problems in the creek: City of Lacey stormwater run-off caused high bacteria and turbidity, and contamination of sediments with metals and organic compounds; benthic macroinvertebrates were pollution tolerant species; low flows caused violations of water quality standards for temperature, DO, pH, and characteristic uses (fish migration, spawning, and rearing); and sediment problems were found at the Martin Village construction site downstream of the Ecology building.

The City of Lacey (1995) conducted volunteer monitoring of Woodland Creek on a quarterly basis at 7 stations. During 1994, results similar to the Ecology study were found. DO fell as low as 4 mg/L and temperatures rose to almost 20° C during the summer months, and portions of creek were dry almost the entire year except in the early spring. FC bacteria levels were generally highest in the summer, but maximum values were found during winter storm flows downstream of City of Lacey storm drains. Quality was generally the poorest in the reach between Pacific Avenue and Martin Way.

Deschutes River, Capitol Lake, and Budd Inlet

CH2M Hill (1978) investigated water quality problems in Capitol Lake, and concluded that bacteria and nutrient loading from the Deschutes River was the primary cause of observed problems, with wildfowl also contributing to high bacteria levels. However, the report noted that the history and management practices in the lake (a former inter-tidal area, now dammed and dredged) contribute to its problems. Prescott (1981) found patterns of FC data similar to the CH2M Hill study.

Moore and Anderson (1979) investigated sediment sources in the Deschutes River system, with their particular focus on sediment transport to Capitol Lake. About one-quarter of the river's sediment load came from 10 tributaries that were monitored, and three-quarters from erosion of the river bank on the mainstem.

The Puget Sound Cooperative River Basin Team reviewed water quality issues in the Deschutes River and Budd Inlet Watershed (PSCRBT, 1990). Timber practices were identified as the principal controllable source of sediment, and livestock operations as the principal source of bacteria requiring further controls. Additional water quality monitoring of the basin was recommended.

Collins (1994) studied the causes of channel erosion in the Deschutes River. The principal cause in bank erosion was geologic and topographic. Erosion along the banks of the Deschutes were not unusually high and have not significantly increased in 50 years. Completely eliminating erosion is not possible, or even desirable. However, opportunities exist to reduce erosion and sediment load, primarily through restoring mature trees along areas with shorter banks, and controlling timber-related erosion in the headwaters. To a large extent, erosion and channel migration in the Deschutes is a natural phenomenon. Land use planning must address property loss along the river, and sedimentation of Capitol lake can probably only be managed with dredging.

Thurston County conducted water quality monitoring as part of their Budd Inlet/ Deschutes River Watershed Characterization from December 1990 through September 1994 (Davis, *et al.*, 1993; Davis, 1995). DO in the Deschutes River was good, and pH low (probably from natural conditions), but maximum temperatures exceeded standards in some locations (associated with poor shading). FC bacteria levels were above standards at several stations and increased in the downstream direction, probably due to livestock in the upper basin, and wildfowl or leaky sewer lines in the lower basin.

In 10 tributaries of the Deschutes River and 7 tributaries of Budd Inlet, Thurston County found that 12 of 17 tributaries had FC bacteria levels that exceeded standards (Percival, Ayer, Reichel, Chambers, Spurgeon, Indian, Moxlie, Ellis, Mission, Adams, Schneider, and Butler Creeks). Land uses in the tributaries range from urban to rural residential and agricultural. Low pH levels were measured, but probably due to natural conditions. Temperatures above state standards were found only in Reichel Creek. Turbidity and TSS values were elevated in some creeks, and elevated nutrient levels were associated with urban watersheds. Thurston County considered Ayer and Reichel Creeks to have the poorest water quality of the Deschutes River tributaries, and problems were also found in Chambers, Spurgeon, and Percival Creeks. Mission and Indian/Moxlie Creeks had the poorest quality of Budd Inlet tributaries, and occasional problems were found Ellis and Schneider Creeks.

The work by Thurston County also included detailed loading calculations and intensive surveys of tributaries. A cursory review suggests that this work lays a strong foundation for a TMDL analysis of the watershed.

In 1995 Thurston County developed a plan for the Chambers basin (TCSSWP, 1995). The Chambers basin includes the Chambers Creek and Ditch; and Chambers, Ward and Hewitt Lakes. Water quality was monitored from February 1992 through April 1993. In Chambers Ditch and Creek, bacteria levels exceeded water quality standards, increasing steadily downstream. Low DO and pH were only observed during low flows, and were probably a natural condition associated with wetlands discharge. Ward Lake showed high levels of metals in the sediments, and stormwater inflows were high in nutrients. High sediment metals and nutrients inputs were also a concern in Chambers Lake, with untreated stormwater a likely source of the problems. Quality in Hewitt Lake was reported as good, although nutrient inputs are of concern.

Budd Inlet has been the subject of extensive study during the last 15 years. A discussion of Budd Inlet conditions can be found in the chapter on marine monitoring.

Totten and Eld Inlets

Harrison and Hofstad (1988) conducted sampling on four dates from June 1986 to April 1987 at 6 sites in Eld Inlet and in 8 tributary creeks (Evergreen, Houston, Madrona, McLane, Perry, Simmons, Surprise, and Tunnel Creeks). None of the inlet or tributary stations exceeded FC bacteria standards. Perry and McLane Creeks had the highest bacteria loading to the inlet.

Hofstad (1990) analyzed DOH sampling of Eld Inlet and conducted sampling of its tributaries from October 1987 through August 1989. Out of 26 sampling stations in Eld Inlet, 5 exceeded state FC bacteria Class A standards. Of 4 tributaries to the inlet (McLane, Perry, Green Cove, and Simmons Creeks), only Green Cove Creek met the FC bacteria water quality standards. Problems were associated with storm water run-off, and resulted from poor agricultural practices and on-site septic problems. The greatest bacterial loads came from McLane and Perry Creeks.

Hansen (1995) studied surface and storm water quality in Green Cove Creek. Bacteria levels exceeded standards at the mouth of the creek. DO and pH were low, but probably due to natural conditions. Out of 7 storm water drains sampled, FC bacteria exceeded standards in 4 of them. On-site septic systems and a sewer pump station were suspected as the primary sources.

Taylor (1988) conducted sampling for FC bacteria in Totten Inlet and 5 tributary creeks (Burns, Kennedy, Pierre, Schneider, and Yellowrock Creeks) from November 1984 through December 1985. All FC bacteria samples were within Class A standards in marine waters, but 4 out of 5 tributaries exceeded standards (Kennedy Creek was the exception).

Harrison and Hofstad (1988) conducted sampling on four dates from June 1986 to April 1987 at 8 sites in Totten Inlet and in 5 tributary creeks (Burns, Kennedy, Pierre, Schneider, and Yellowrock Creeks). Only one sample from the inlet stations exceeded FC bacteria standards, and that datum was questionable. Only Burns Creek exceeded FC bacteria Class A standards. Schneider Creek had the highest bacteria loading to the inlet, followed by Burns Creek.

Starry (1990b) analyzed DOH sampling of Totten and Little Skookum Inlets and conducted sampling of its tributaries from October 1987 through August 1989. Out of 26 sampling station in marine waters, all met state FC bacteria Class AA standards. Of 4 tributaries to the Totten Inlet (Burns, Kennedy, Pierre, and Schneider Creeks), only Kennedy Creek met the FC bacteria Class AA water quality standards. Problems were associated with storm water run-off, and resulted from poor agricultural practices and on-site septic problems.

Seiders and Cusimano (1996) reported on the first 4 years of a 9 year project monitoring water quality and pollution controls in the Totten and Eld Inlet watersheds. This work is part of U.S. EPA's Section 319 National Monitoring Program (NMP). Monitoring is conducted weekly during the wet season from early November through mid-April on six creeks (McLane, Perry, Schneider, Burns, Pierre, and Kennedy Creeks). Monitoring began in 1992 and is planned to continue during BMP implementation (through 1999) and will include at least 2 years of post-BMP evaluation. Data evaluated in the report indicated that water quality parameters, especially fecal coliform bacteria, were still highly variable. These results support the need for a long-term record of water quality to show improvements from BMPs.

Schuett-Hames *et al.* (1996) studied salmon habitat and water quality in 8 stream segments in the Eld Inlet watershed (McLane and Perry Creeks) and 17 stream segments in the Totten/Little Skookum Inlet watershed (Schneider, Kennedy, and Skookum Creeks). Riparian shading was inadequate to protect temperature in 19 of 25 segments. Problems were widespread with large woody debris and pool habitat ratings. Fine sediment conditions were fair to poor in 8 out of 9 segments assessed. Watershed Assessments were recommended where not completed, and management prescriptions at the county level, possibly through critical area ordinances, were recommended to address problems in agricultural and rural residential areas. Education, outreach, and economic incentives were also recommended. Temperature monitoring was recommended to directly measure the impacts of poor riparian cover.

Oakland Bay

Michaud (1987) conducted an investigation of bacterial sources in Oakland Bay. The bay was monitored from February through May 1987. Sources of FC bacteria to Oakland Bay were evaluated and loading calculated. Major sources of loading were found to be City of Shelton storm water, effluent from the ITT Rayonier research lab, and Shelton Creek. Other storm and surface water sources were suspected as contributors.

Michaud (1988) continued the bacteria study of Oakland Bay, with sampling from October 1987 through February 1988. FC levels in Oakland Bay were impacted by Shelton and Goldsborough Creeks and by city and industrial stormwater. Further monitoring and improvements in storm water collection and treatment were recommended.

The two studies are close to what are now conducted as TMDL technical studies. These two studies combined with local watershed plans could provide the core of a FC bacteria TMDL for Oakland Bay. A 10-year old study may not be acceptable to EPA, but even if it were, additional monitoring would be needed. However, building on Michaud's work could reduce the effort necessary to complete a TMDL.

Schuett-Hames *et al.* (1996) studied salmon habitat and water quality in 10 stream segments in the Oakland Bay and Hammersley Inlet watershed (Mill, Goldsborough, Johns, Cranberry, Deer, Malaney, and Cambell Creeks). Riparian shading was inadequate to protect temperatures in 9 segments. Problems were widespread with large woody debris and pool habitat ratings. Fine sediment conditions were fair to poor in all segments. Watershed Assessments were recommended where not completed, and management prescriptions at the county level, possibly through critical area ordinances, were recommended to address problems in agricultural and rural residential areas. Education, outreach, and economic incentives were also recommended. Temperature monitoring was recommended to directly measure the impacts of poor riparian cover.

North Fork Skokomish River

Kendra (1985) reported on water quality in the N.F. Skokomish. Sampling in the summer of 1985 found flows below 20 cfs and temperatures as high as 19.9 °C. The study concluded that flow enhancement would likely reduce stream temperatures, prevent de-watering and fish stranding, and increase the amount of habitat available to fish.

West Hood Canal Tributaries

As part of a project to assist DOH with identifying pollution sources contributing to shellfish bed closures, WAS will be monitoring the tributaries to Lilliwaup Bay (Sargeant, 1997). Sampling will be conducted beginning in September 1997, and results will be available in 1998.

REMAP sampling in small streams was conducted during 1994 and 1995 in the South Fork Skokomish River and its tributary Pine Creek; in the Duckabush River, and in Deadfall Creek, a tributary of the Quilcene River (Merritt, 1997). Sampling included both biological communities and physical/chemical parameters. A draft report describes regional status of the Coast Range stream populations. Three sites were in the Olympic National Forest and one in Olympic National Park, and all were classified as high quality for habitat and biology. Bull trout were found in both the South Fork Skokomish and in Pine Creek.

A cooperative study has been underway on timber practices and water quality in McDonald Creek (Dickes, 1997). Information on channel conditions should be available this fall.

Dabob and Quilcene Bays

Welch and Banks (1987) report the results of water quality monitoring in Quilcene and Dabob Bays and tributary streams from June 1986 through May 1987. Marine waters were within FC standards except for 2 stations at the head of Quilcene Bay. FC bacteria levels exceeded Class AA freshwater standards in Tarboo and Donovan Creeks and in drains in the town of Quilcene, while the standards were met in the Big and Little Quilcene Rivers. High bacteria loads were associated with agricultural and residential areas. Seals were also suspected as a major source in marine waters.

Rubida and Calambokidis (1990) continued the work of Welch and Banks (1987) by monitoring the Quilcene and Dabob Bay marine and tributary fresh water stations through February 1989. Analysis of the entire 3 year data set showed similar patterns to the earlier analysis. Marine waters were within FC standards except for the head of Quilcene Bay. FC bacteria levels exceeded Class AA freshwater standards in Tarboo Creek, Coyle Creek (a tributary of Tarboo), Leland Creek (a tributary of the Little Quilcene River), Donovan Creek, and Cemetery Drain (in the town of Quilcene), while the standards were met in the Big and Little Quilcene Rivers. Bacteria loading was primarily associated with freshwater run-off from storm events. No evidence was found that harbor seals were responsible for elevated fecal coliform levels; indeed, the analysis indicated that any contribution from seals was minimal.

Rubida (1989) sampled bacteria approximately monthly from February 1988 through February 1989 in Jackson Cove and found the water quality to be excellent.

Port Ludlow and Mats Mats Bays

Rubida (1989) sampled bacteria approximately monthly from February 1988 through February 1989 in Port Ludlow and Mats Mats Bays. FC bacteria levels were within state standards in both bays and their freshwater tributaries, although bacteria were elevated near the Port Ludlow marina.

Extensive monitoring has been conducted in Port Ludlow Bay by consultants hired by the principal developer of that area. Annual summer monitoring data is available for approximately the last 6 years on Port Ludlow. Monitoring is also conducted on a regular basis as part of the Port Ludlow NPDES permit. A report on 1990 water quality conditions (Harding Lawson Associates, 1991) found that water quality standards were met most of time. Low DO levels and the bulk of nutrient loading were attributed to inputs from Admiralty Inlet. Monitoring of Port Ludlow Bay is being managed appropriately through the NPDES permit. However, the involvement of EILS staff is recommended to ensure that the monitoring is correctly planned to collect high quality data and answer the appropriate questions.

Port Townsend

Rubida (1989) sampled bacteria approximately monthly from February 1988 through February 1989 in Port Townsend and the Chimacum Creek drainage. FC bacteria levels exceeded standards at several locations in Chimacum Creek and its tributary

Nailor Creek. FC bacteria levels in Port Townsend marine waters were within standards.

Discovery Bay

Rubida (1989) sampled bacteria approximately monthly from February 1988 through February 1989 in Discovery Bay and the Snow and Salmon Creek drainages. FC bacteria levels exceeded standards at several locations in Salmon Creek and its tributary Houck Creek; and in Snow Creek and its tributaries Andrews Creek and Zerr Ditch. FC bacteria levels in the creeks were highest in the summer, and appeared to be caused by livestock access. FC bacteria levels in Discovery Bay marine waters were within standards.

The Puget Sound Cooperative River Basin Team reviewed water quality data for Discovery Bay (PSCRBT, 1992). The marine waters of Discovery Bay typically have excellent water quality, except for some FC bacteria problems that DOH monitoring has found in the south end of the bay near the mouths of Snow and Salmon Creeks.

Sequim Bay

Determan (1986a) analyzed FC bacteria sources and distribution within Sequim Bay. Data came from surveys by Battelle Labs, the state shellfish program, and other sources. He found levels in shellfish to be highest near the bay's mouth and declining away from that area. The single largest source was found to be Bell Creek, although the exact amount of impact on the bay was uncertain. Recommendations included: continued monitoring of Bell Creek, the John Wayne marina, and Johnson Creek; and a comprehensive watershed-wide study of bacteria sources.

Determan (1986b) conducted a summertime survey of bacteria sources in Bell and Johnson Creeks. Again, Bell Creek was found to be by far the largest source, and cattle access to the creek was identified as the cause. Johnson and Jimmy-come-lately Creeks and the Highland Ditch were also found to be minor sources. Clean-up of these sources was recommended.

Clallam County monitored Sequim Bay tributary creeks from September 1986 through May 1987 (Brastad, *et al.*, 1987). Three major sub-basins (Bell, Johnson, and Jimmy-come-lately Creeks), two smaller streams (Chicken Coop and Dean Creeks), and five unnamed drainages were sampled. Bell Creek was found to be by far the largest source of bacteria to Sequim Bay, and the main causes were beef and dairy livestock operations. Johnson and Jimmy-come-lately Creeks had good water quality, except for the Highland Ditch tributary of Johnson Creek. Of the 7 small streams and drainages, 2 were found to have bacteria that exceeded standards. After livestock, on-site septic systems were believed to be a significant source of FC bacteria to the streams.

Water Quality and circulation modeling of Sequim Bay were reviewed in the Final Environmental Impact Statement for the City of Sequim wastewater treatment plant (Brown and Caldwell, 1987). Physical oceanography studies of the bay were conducted in 1967, and a water quality and flushing study was conducted in 1979. The 1979 study estimated a 5 to 140 day flushing time depending on conditions. Two models of the bay and the straits near the mouth of the bay were developed in 1983 by the University of Washington and Battelle. DO was lowest near the bottom and near the head of the bay at the south end. Low DO levels appeared to be related to productivity and settling of phytoplankton. DO was generally high near the mouth of the bay, but some low DO levels found were believed to be associated with upwelling.

In the Sequim Bay Watershed Management Plan (Sequim Bay Watershed Management Committee, 1991) concerns were raised over algal blooms and low DO. The committee cited a lack of information and recommended additional monitoring and analysis.

Dungeness River

The Puget Sound Cooperative River Basin Team reviewed water quality data for the Dungeness River watershed (PSCRBT, 1991). Very little sampling has been done in the Dungeness River watershed, except for one survey by Clallum Conservation District in 1988. That study found FC bacteria below state standards at 20 out of 27 sampling stations in the Dungeness River and in 15 tributary and neighboring streams and ditches. Agricultural activities and failing or inadequate septic systems were identified as the primary sources of nonpoint pollution.

The Water Quality Office of the Clallam County Department of Community Development conducted water quality sampling of the Dungeness River watershed during June 1992 (CCDCD, 1992). Of 36 stream or ditch stations sampled for FC bacteria, 10 met water quality standards including the 2 stations in the Dungeness River. FC bacteria levels fell below standards in the tailwaters of 4 out of 5 irrigation ditches and in 6 out of 10 streams. DO levels were high, but temperatures were over 20 °C in some locations, indicating a situation that likely grew worse later in the summer.

Port Angeles Watershed

The Port Angeles Watershed Characterization (CCPD *et al.*, 1993) reviews water quality data for marine and fresh waters in the watershed. Quality was generally excellent, with a few exceptions. High temperatures and low DO were found in the Elwha River and Dry Creek. Low DO levels were most notable in Port Angeles Harbor, with consistently low levels found in the late summer and early fall. FC bacteria standards were exceeded in Dry, Tumwater, White, and Peabody Creeks, which was attributed to livestock or urban run-off. High bacteria were also measured in Port Angeles Harbor. High turbidity was found in Peabody Creek as the result of a storm water discharge.

Review of the 303(d) List

Woodland Creek and Henderson Inlet

There are 14 303(d) listings for Woodland Creek, Henderson Inlet, and other tributaries. Thurston County is implementing the Henderson Inlet Watershed Plan prepared under the Puget Sound Early Action Watershed Program. Thurston County, the City of Olympia and the City of Lacey have adopted the Woodland and Woodard Creek Comprehensive Drainage Plan which addresses water quantity and water quality. This local work could be packaged into a TMDL with the addition of a monitoring plan and any other needed elements.

Deschutes River and Capitol Lake

Thurston County is implementing a Budd Inlet/Deschutes River Watershed Plan. The 13 listings in this area could be addressed by "packaging" the watershed plan with TMDL calculations and a monitoring plan.

Capitol Lake and Patterson Lakes have had Clean Lakes Restoration Projects conducted. TMDLs for these lakes could be completed or the lakes delisted by packaging the Clean Lakes work.

Budd Inlet

Budd Inlet is listed for 35 parameters in the Inner and Outer basins. LOTT is currently contracting a major study of pollutant capacity in Budd Inlet. This work could be packaged into a TMDL for the dissolved oxygen and nutrient listings. Bacteria listings could be addressed through a Budd/Deschutes Watershed TMDL mentioned above.

The balance of Budd Inlet listings are for toxic compounds. These listings should be evaluated to determine how to package clean-up actions into an approvable TMDL.

Squaxin, Peale, and Pickering Passages

Listings for pH in this area could be addressed through the South Puget Sound Nutrient Study currently underway.

Totten and Eld Inlets

Bacteria listings in Totten and Eld Inlets and their watersheds are being addressed through a Watershed Plan and monitored under the NMP project as described above. A TMDL for this area could be packaged from this work, or the waterbodies delisted.

Oakland Bay/Hammersley Inlet

There are 7 listings for FC bacteria and 1 for DO in Oakland Bay, Hammersley Inlet and their tributaries. There has been local work in this area in watershed planning. Sources are likely a combination of nonpoint (agriculture, on-site septic systems, urban stormwater), and point source (wastewater treatment plants). The FC bacteria listings could be packaged for a TMDL or delisted based on the work by Michaud (1987; 1988).

Little information was found regarding DO levels and circulation in Oakland Bay and Hammersley Inlet. However, the confined nature of these estuaries suggest that impacts from pollution are likely. The DO listing should be investigated further and could be a candidate for a TMDL study.

South Hood Canal Watershed

Three tributaries to South Hood Canal are listed on the 303(d) list in this WQMA. These areas should be coordinated with any efforts conducted in South Hood Canal for the Kitsap County side.

Skokomish River

The Skokomish Indian Tribe is leading the development of the Skokomish River Watershed and Ecosystem Improvement Action Plan that addresses the 6 water bodies listed in the Skokomish River basin. Ecology should coordinate with the Tribe to package their work as a TMDL or support delisting.

The North Fork Skokomish is listed for low flows due to the Cushman Dam project. Coordination with the Water Resources Program, the Skokomish Tribe, and other affected parties will be necessary to ensure delisting of this waterbody.

Quilcene and Dabob Bays

There are 4 listings for flow and fish habitat for the Big Quilcene River and other tributaries of Quilcene and Dabob Bays. These listings can probably be addressed through the TFW Watershed Analysis process and either delisted or submitted as a TMDL.

Quilcene Bay is listed for FC bacteria, and Tarboo Creek is listed for temperature. Jefferson County is implementing a Watershed plan for Quilcene and Dabob Bays. A TMDL for these listings could be packaged from existing work.

Port Townsend and Chimacum Creek

Port Townsend is listed for low DO, and is the site of a pulp mill, as well as agricultural and urban runoff. Chimacum Creek, a tributary of Port Townsend is listed for bacteria and temperature. It appears that no watershed plan has been developed for this area, or at least none has been submitted to Ecology. A TMDL technical study may be appropriate for Port Townsend, Chimacum Creek, and other tributaries. Alternatively, the DO listing could be pursued through the NPDES permit for Port Townsend Paper (the most likely non-natural cause of DO depletion in Port Townsend Bay), and the Chimacum Creek issues coordinated with Jefferson County.

Port Townsend is also listed for PCBs in fish tissue.. These data should be evaluated and possible sources investigated for clean-up activities.

Sequim Bay

Sequim Bay is listed for DO, pH, and FC bacteria, and Bell, Johnson, and Chicken Coop Creeks are listed for bacteria. The Watershed Plan could be packaged as a TMDL for bacteria. The DO and pH listing should be investigated further to see if human sources of BOD or nutrients are the cause. This may merit a TMDL technical study, or if existing work exists, the work could be packaged as a TMDL.

Sequim Bay is also listed for violation of sediment criteria. These data should be evaluated and possible sources investigated for clean-up.

Dungeness River and Sequim Area Streams

Bagley, Cassalery, and Matriotti Creeks are listed for fecal coliform violations. Ecology should work with Clallam County, tribes and other local groups to implement the Dungeness River Watershed Plan (which includes these areas). The plan should be packaged as a TMDL or used for delisting.

The Dungeness River listing for flow may be addressed through ongoing water resources management activities.

Port Angeles

Port Angeles Harbor is listed for DO. Because of the possible contributions of both point and nonpoint sources and a history of low DO, this is an appropriate area for a TMDL technical study.

Port Angeles harbor is also listed for PCBs in fish tissue. These data should be evaluated and possible sources investigated for clean-up.

Bagley and Dry Creeks are listed for FC bacteria and temperature, respectively. Both creeks are part of a watershed project conducted by Clallam County. This work could be packaged as a TMDL or used for delisting.

Strait of Juan de Fuca Rivers and Streams

The Elwha River is listed for temperature and PCBs. The data should be reviewed and possible causes investigated, in coordination with local groups and other agencies.

Deep Creek is listed for temperature and fine sediment, and the Lower Elwha Tribe is conducting a monitoring project. Existing work might be used for packaging a TMDL or delisting.

The Little Hoko, Sekiu, and Clallum Rivers are listed for temperature. These areas can probably be addressed through TFW Watershed Analysis and the results packaged for TMDL submittal or delisting.

Recommendations

Recommendations are listed below by category and prioritized in order in the best judgment of the author. High, medium and low (H, M, and L) ratings are also applied.

TMDL Technical Studies

- (H) Review existing work in Port Angeles Harbor, and develop a TMDL for DO with a TMDL technical study.
- (H) Conduct a TMDL technical study for DO in Oakland Bay and Hammersley Inlet.
- (M) Conduct a DO and nutrient study of Sequim Bay, or package existing work if available, to either develop a TMDL or support delisting.

- (M) Conduct a TMDL technical study for FC bacteria and DO in Port Townsend, Chimacum Creek, and other tributaries.

TMDL or Delisting Packaging Projects

- (H) Package the LOTT Budd Inlet Study into a TMDL for nutrients and DO.

- (H) Package the Budd Inlet/Deschutes River Watershed Plan and assessment studies into TMDLs for pH, temperature, DO, and bacteria. Include the Budd Inlet listings for bacteria in this TMDL.

- (H) Support local efforts to restore Henderson Inlet, Woodland Creek, and other tributaries, including monitoring of BMPs and water quality. Package a TMDL for Woodland Creek and the Henderson Inlet Watershed.

- (H) Package a TMDL for nutrients in Capitol Lake from existing work, supplemented by additional monitoring and a monitoring plan. Coordinate with and support efforts to control nonpoint sources of nutrients in the Deschutes watershed.

- (H) Package a TMDL for FC bacteria in Oakland Bay and Hammersley Inlet, based on the work of Michaud (1987; 1988) and the Watershed Plan.

- (H) Coordinate with Dungeness River water resources planning and allocation activities to address 303(d) listing for flow.

- (M) Package a Sequim Bay Watershed TMDL for FC bacteria from existing data and the Sequim Bay Watershed Plan. Ensure adequate monitoring of FC bacteria sources.

- (M) Complete the Totten/Eld NMP study by monitoring water quality and the installation of BMPs, and by working with Thurston Conservation District to complete farm plan implementation and determine the operation and maintenance of previously installed BMPs. Package this work as a TMDL or delisting.

- (M) Coordinate with Skokomish Tribe and other affected parties on Skokomish River watershed 303(d) listings to package a TMDL or delist the segments based on their work.

- (M) Coordinate with other agencies and local groups to support implementation of the Dungeness Basin Watershed Plan for Bagley, Cassalery, and Matriotti Creeks, with the goal of submitting the work for a TMDL or delisting.

- (M) Package the Quilcene/Dabob Bay Watershed Plan as a TMDL for Quilcene Bay FC bacteria and Tarboo Creek temperature listings.

- (L) Coordinate TFW Watershed Assessment work for Quilcene and Dabob Bays and package as TMDL or delisting.

- (L) Review status of Little Hoko, Sekiu, and Clallam River TFW Watershed Analyses and coordinate with local groups or other agencies to package work for TMDL submittal or delisting.

- (L) Package Clallam County watershed planning for Dry Creek for TMDL submittal or delisting.

- (L) Coordinate with Lower Elwha Tribe to package Deep Creek work for a TMDL or delisting.

- (L) Evaluate information on the causes of low flows in Woodland Creek, and support local efforts to restore flows. Package existing programs into a TMDL or as a basis for delisting.

- (L) Package a TMDL for Patterson Lake from existing work by developing a monitoring plan.

Monitoring or Intensive Survey Projects

- (H) Conduct monitoring of the Dungeness River for DO and temperature to determine whether summertime water quality problems occur.

- (M) Review Elwha River data for temperature and investigate causes, in coordination with local groups and other agencies.

- (L) Conduct temperature monitoring as follow-up to the salmon habitat assessment work of Schuett-Hames, *et al.* (1996) in tributaries of Eld, Totten, Little Skookum, and Hammersley Inlets and Oakland Bay.

Local Coordination and Support

- (H) Coordinate with and support local efforts to control sediment sources in the Deschutes River watershed.

- (H) Coordinate issues in South Hood Canal tributaries with NWRO and local interests for the WQMA that includes Kitsap County.

- (H) Ensure coordination with EILS staff for Port Ludlow Bay monitoring.

- (M) Begin investigation of Port Townsend low DO through the NPDES permit for Port Townsend Paper.

- (M) Coordinate and support Jefferson County to investigate high FC bacteria levels in Chimacum Creek.

- (L) Support implementation of the Discovery Bay Watershed Plan.

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Toxics Investigations

by
Dale Norton

Introduction

Relatively little information has been generated by EILS in the last ten years on toxic contamination of surface water, sediments, and tissues in the Eastern Olympic WQMA. The majority of data located has been generated in the following three Water Resource Inventory Areas (WRIA): #13- Deschutes; #17- Quilcene/Snow; and #18- Elwha/Dungeness. These WRIAs also include the major population centers in the Eastern Olympic WQMA.

Several studies by EILS and local governments were identified in a literature search which have evaluated metals and organics levels in storm drains which discharge to the following areas; Oakland Bay in Shelton, Budd Inlet from the abandoned Cascade Pole Site, Woodland Creek in Lacey and the Deschutes River Basin (Dickes, 1990; Norton, 1990; Dickes and Reed, 1992; Wilson and Norton, 1996; and Davis et. al, 1993). Several exceedances of metals and organics criteria for the protection of aquatic life were noted in each of these studies.

Five lakes in the WQMA (Cresent, Black, Ward, Chambers and Hewitt) have undergone screening surveys for toxic chemicals in fish tissue and sediments (Johnson and Norton, 1989; Serdar, et al, 1994; and Thurston County, 1995). Concentrations of most metals and organics were low in all these lakes with a few exceptions. Mercury concentrations were moderately elevated in largemouth bass from both Black and Ward compared to other Western Washington lakes. Polychlorinated biphenyls (PCBs) exceeded EPA human health criteria in rainbow trout from Ward Lake. Elevated concentrations of arsenic, copper, chromium, nickel, and lead were measured in sediments from Ward and Chambers Lakes during a study conducted by Thurston County.

The most comprehensive toxics assessment identified was in Port Townsend Bay. This study was initiated to investigate the cause(s) of high mortality observed in commercial attempts to raise pen-reared Atlantic salmon in the bay (Johnson, 1988). Chemical analysis of seawater, bottom sediments, salmon tissues and effluent from the Port Townsend Paper Mill and Naval Undersea Warfare Engineering Station on Indian Island were performed. In addition, histopathological exams of Atlantic salmon were conducted. No evidence of any unusual occurrence of toxic chemicals in the bay was identified in this investigation.

In addition to specific studies the Puget Sound Ambient Monitoring Program (PSAMP) has conducted some marine sediment sampling as part of the Marine Sediment Monitoring Task (Aasen, 1997). Between 1989 and 1995 26 stations from Southern Puget Sound, Hood Canal, Admiralty Inlet, Strait of Juan De Fuca, and Port Angles Harbor have been sampled. Metals and organics levels were low at all sites with two exceptions. Bis (2-ethyl hexyl) phthalate in Port Townsend Bay and butyl benzyl phthalate in Dabob Bay exceeded Ecology's marine sediment standards (WAC-173-204).

A total of seven waterbodies in the Eastern Olympic WQMA are listed on the 1996 federal Clean Water Act Section 303(d) list of impaired waterbodies due to toxics issues. The seven waterbodies and the associated toxic contaminant(s) of concern are listed below:

Budd Inlet (inner)	Chromium, Copper, Mercury, Zinc, PAHs, PCBs and Phthalates
Deschutes River	Mercury
Ward Lake	PCBs
Port Townsend	PCBs
Sequim Bay	PAHs
Port Angeles Harbor	PCBs
Elwha River	PCBs

Examination of this list indicates that five of the seven waterbodies have PCB contamination as an issue in their listing. The data that produced each of these listing should be re-evaluated to determine if delisting of the waterbody or further investigation is needed.

Summary of Studies

Storm Drain Monitoring

Shelton Stormdrain Evaluation (Dickes, 1990)

Sediments were collected in June 1989 from six locations in stormdrain systems that discharge to Oakland Bay in downtown Shelton (Figure 5). The primary purpose of this work was to provide baseline stormwater priority pollutant data using accumulated sediments as a surrogate. Concentration of most metals and organics measured were typical for urban runoff. Chromium, lead, zinc, polynuclear aromatic hydrocarbons (PAHs), phthalates, PCBs, and 4-methyl phenol exceeded Ecology's Marine Sediment quality standards (WAC-173-204-320) in sediments from several of the discharges. The investigator recommended screening sediments at the drain outlets to see if metals and organics concentrations were at problem levels in Oakland Bay intertidal sediments.

Cascade Pole Stormwater Evaluation (Norton, 1990)

Surface runoff from the abandoned Cascade Pole Company wood treatment plant in Olympia was sampled in the spring of 1990 and analyzed for several metals and organics. In addition, stormwater was subjected to toxicity testing. Results of this testing indicated that copper in all discharges and pentachlorophenol in two of the discharges exceeded EPA criteria for the protection of saltwater aquatic life. Concentration of most other contaminates were generally low. The data also indicated that a high potential existed that chlorinated dioxins and furans were accumulating in marine sediments and benthic organisms adjacent to the site. Subsequent sediment investigations confirmed the presence of these compounds in intertidal sediments. The site is currently undergoing remediation on both the uplands and intertidal area. Remediation is tentatively scheduled to be completed by the end of 1999 (Pitz, 1997).

Lacey Stormdrains and Woodland Creek (Dickes and Reed, 1992; Wilson and Norton, 1996)

Particulates from several stormdrains which ultimately discharge to Woodland Creek, in the vicinity of Lacey, were sampled in 1995 as part of a pilot study to test in-line sediment traps as a monitoring tool (Wilson and Norton, 1996). Concentrations of most constituents were low with the exception of zinc which exceeded recommended freshwater sediment quality values. Additional stormwater sediment data collected by Thurston County are also summarized in the report.

Results of sediment sampling in Woodland Creek as part of construction monitoring activities for the Ecology headquarters building tended to support the finding that metals are the major stormdrain contaminant in this area (Dickes and Reed, 1992).

Eld, Henderson, and Totten Watershed Implementation Plan (Hansen, 1992)

Sediments from nine sites (5 streams and 4 stormdrains) in the Eld, Henderson, and Totten Inlet Watersheds were collected and analyzed for a variety of metals and organics during dry weather conditions in 1990. Mercury at one site, and PAHs and phthalates at two sites, exceeded applicable sediment standards.

Toxics in Lakes

1989 Lakes and Reservoir Water Quality Assessment: Survey of Ten Washington Lakes (Johnson and Norton, 1989)

Sportfish tissue (fillet) and bottom sediment samples were collected from two lakes (Black and Crescent) in the Eastern Olympic WQMA during this 1989 survey. Analysis included EPA priority pollutants, herbicides, and organophosphorus pesticides. Contaminant levels in fish and sediments were low in both lakes with the exception of a moderate mercury elevation (0.54 mg/kg, wet) in Black Lake largemouth bass. This elevation was attributed to the older age of the fish analyzed.

Survey of Chemical Contaminants in Ten Washington Lakes (Serdar *et al.*, 1994)

Whole-bottom feeding fish, predator fish muscle, and bottom sediments were sampled in 1992 from Ward Lake in Thurston County in this screening survey. The suite of analytes were similar to the 1989 survey discussed above. Moderately elevated mercury concentrations (0.35 mg/kg, wet) were measured in Ward Lake bass. In addition, PCB levels in rainbow trout (8 ug/kg) exceeded EPA's human health criteria from the National Toxics Rule. PCB levels detected were sufficient to cause the lake to be listed as "water quality limited" under section 303(d) of the Clean Water Act.

Following the listing of Ward Lake on the 303(d) list concern was raised by the Thurston County Health Department that the listing was inappropriate since rainbow trout in the lake are planted hatchery fish and no PCBs were detected in bass from the lake. The Washington Department of Fish and Wildlife (WDFW) sampled food and broodstock fish at the Eells Springs hatchery and analyzed the samples for PCBs as a follow-up to the listing. No PCBs were detected during this investigation (Michael, 1997). The source of PCB contamination in Ward Lake remains unresolved.

Elevated arsenic concentrations (34-41 mg/kg) were also measured in bottom sediments from Ward Lake during the ten lakes survey. Based on comparisons to the Ontario Provincial Guidelines for sediment quality these levels would be sufficient to produce impacts to benthic communities.

Chambers/Ward/Hewitt Comprehensive Drainage Basin Plan (Thurston County, 1995)

The Chambers/Ward/Hewitt Comprehensive Drainage Basin Plan was developed to address growing concerns over the impacts of urban development on natural resources in the basin. Part of this effort involved collection and analysis (metals and organics) of sediment samples from these three lakes. In Chambers and Ward Lakes, arsenic concentrations were above levels considered deleterious to benthic communities. In addition cadmium, chromium, copper, and nickel were elevated in Ward Lake compared to other lakes in the basin. Organic contaminant levels were low in all three lakes.

Port Townsend Bay

Screening Surveys of Port Townsend Bay (Johnson, 1988, 1989)

Commercial attempts to pen-rear Atlantic salmon in Port Townsend Bay in 1986 and 1987 experience cumulative moralities of over 90%. Extensive examinations by pathologists at the Battelle Sequim Laboratory led to the conclusion the fish died from liver disease caused by chronic exposure to a water-borne toxic chemical. In response Ecology conducted chemical analysis of salmon tissues, bottom sediments, seawater from Port Townsend Bay, and effluent from Port Townsend Paper Corporation and the Naval Undersea Warfare Engineering Station Sewage Treatment Plant.

Results of these tests did not identify the cause of Atlantic salmon mortality. Concentrations of metals, other trace elements, and chlorinated compounds in the tissues of affected fish were similar to concentrations in fish from un-affected areas. Contaminant levels in Port Townsend Bay were also low.

Additional seawater samples were collected from Port Townsend Bay in August 1988 and analyzed for EPA priority pollutants, 61 trace elements, herbicides, and nitrogen and -phosphorus containing compounds in an effort to identify the water borne toxicant thought responsible for the liver disease. Again contaminant levels were low and consistent with the previous sampling in October - December 1987. It was recommended that further follow-up work into the cause of liver disease should focus on the occurrence of natural toxins (Johnson, 1989).

Recommendations

With the exception of Port Townsend Bay, little comprehensive information has been generated on the occurrence of toxics in the Eastern Olympic WQMA. Most of toxics data located has been collected in small geographical areas around the major urban centers (Olympia, Shelton, Port Townsend, and Port Angeles) in the region.

Based on the studies examined the following recommendations are made:

- Verify toxics data that caused the following seven waterbodies (Budd Inlet-inner, Deschutes River, Ward Lake, Port Townsend, Sequim, Port Angeles Harbor, and Elwha River) to be posted on the 1996 federal Clean Water Act 303(d) list as impaired. In particular, this evaluation should focus on potential PCB sources, since five of the waterbodies have PCB contamination listed as an issue.

- Rainbow trout from Ward Lake (Thurston County) should be re-sampled to determine current PCB concentrations.

- Collect intertidal sediment samples in Oakland Bay at the outlets of storm drains which had high concentrations of metals and organics associated with in-line sediments. These data will be useful in determining the potential for sediment problems in Oakland Bay associated with storm water runoff.

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Ground Water Investigations

by
Barbara Carey
and
Pam Marti

Introduction

EILS has conducted limited ground water studies in the Eastern Olympics Watershed. In the last five years investigations have been conducted at three wastewater land application sites and two petroleum contamination sites. All five sites are in the northeastern part of the Olympic Peninsula. These investigations are summarized below.

Land Application Surveys

Three sites were investigated during 1994 to evaluate the potential for ground water contamination related to land application of wastewater. The facilities were located at Fort Flagler State Park on Marrowstone Island near Port Townsend, Sequim Bay State Park five miles southeast of Sequim, and Sunland Wastewater Treatment Plant near Sequim (Erickson, 1995 and Carey, 1995). Soil borings were drilled at the state park sites. Effluent samples were collected at all three facilities. The information was needed to update the wastewater discharge permits for the facilities.

At Fort Flagler State Park, Erickson (1995) found a high potential for ground water contamination due to the shallow depth to water below the three treatment ponds. A soil boring drilled near the infiltration/evaporation pond indicated permeable sand and silty sand to a depth of 3.6 feet. The water table was at 3.7 feet. Constituents of concern are nitrogen (ammonia and nitrate), organics (total organic carbon and biochemical oxygen demand), and arsenic. Contaminants reaching the shallow upper aquifer would eventually discharge to Admiralty Inlet. However, no effects were observed during the July 1994 site visit. Erickson (1995) also provided guidelines for a ground water monitoring plan at Fort Flagler.

The potential for ground water contamination at Sequim Bay State Park was low. However, Erickson (1995) made recommendations for fine-tuning the application rate to address the infiltration capability of the soil and nutrient uptake of the forested area. He also recommended that effluent application be limited to the months of May through September. The constituents of concern are the same as for Fort Flagler. In addition, however, surface runoff of coliform and fecal coliform bacteria could be a problem if effluent is applied in excess of the evapotranspiration rate.

The potential for ground water contamination at the Sunland wastewater treatment site was judged to be high for the following reasons: (Carey, 1995)

- the land application site overlies a shallow aquifer,
- the effluent application rate exceeded recommended fertilizer rates,
- over one-half of the effluent was applied during the non-growing season when plant uptake of nitrogen is low, and
- nitrogen in the form of grass was not removed from the field.

Recommendations were provided to redesign the nutrient and hydraulic loading rates for the land application site to correspond with agronomic rates. Carey (1995) also suggested that the hydrogeologic characterization of the site be completed and that the ground water monitoring network be upgraded.

Sequim-Dungeness Area

Ground water studies conducted by the USGS (Drost, 1983) and Clallam County Department of Community Development (Soule, 1991) indicate localized areas of nitrate concentrations of 2.5 to 10 mg/L compared to a background concentration of about 1.3 mg/L (Soule, 1997).

Drost (1983) sampled 138 wells for ammonia and nitrate+nitrite, as well as pH, specific conductance, and chloride. The median nitrate+nitrite concentration was 0.35 mg/L. The maximum was 2.5 mg/L.

The Clallam County Department of Community Development sampled 36 wells in 1990-91, most of which had also been sampled in 1980 (Soule, 1991). Soule (1991) shows that although the nitrate concentrations increased in most of the wells, they also decreased in almost one-third of the wells. The average nitrate+nitrite value increased between 0.6 and 1.1 mg/L over the decade.

Many of the elevated nitrate values were found in areas with excessively drained soils, although transport pathways may be complex. Contaminants may travel laterally as well as vertically depending on the hydrostratigraphy of the local area.

Drost (1983) also analyzed ground water flow using a model. He found that most of the ground water recharge was from leakage in the irrigation systems. He predicted that decreasing or eliminating the irrigation system could lead to declines in water-table aquifer elevations of about 20 feet.

A hydrogeologic study of the area is being conducted by the USGS and is scheduled for completion in 1998.

Petroleum Contamination Investigations

EILS has conducted two soil gas investigations in the Eastern Olympic Basin. Both studies were conducted to identify the source of petroleum contamination to ground water.

In 1993, samples were collected for soil gas, soil, and water in the vicinity of Lincoln Apartments, Port Angeles, Washington as part of a leaking underground storage tank (LUST) system investigation. Two potential source areas of petroleum contamination were identified (Marti, 1993).

In 1994, soil gas samples were collected in Quilcene, Washington in response to petroleum contamination of five private drinking water wells. Two potential source areas of petroleum contamination were identified (Marti, 1995).

Recommendations

- The large number of homes with on-site sewage systems in the Eastern Olympics Basin suggests possible areas for ground water problems, especially areas where soils are marginal for on-site sewage treatment. Such problems, if present, could have a substantial impact on shellfish and marine life.

- Ground water quality in the Sequim-Dungeness area should be tracked. Increased residential development and decreased recharge from agricultural drains can lead to ground water deterioration. The effectiveness of ground water protection measures should be evaluated based on on-going ground water monitoring.

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Compliance Monitoring

by
Steven Golding

Introduction

There are currently 42 dischargers in the Eastern Olympic WQMA that have permits under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge Program (WAC 173-216). These include:

NPDES Major Permits - 3 Municipal
NPDES Minor Permits - 12 Industrial, 14 Municipal
State Discharge to Publicly Owned Treatment Works (POTW) Permits - 1 Industrial
State Discharge to Ground Permits - 4 Industrial, 8 Municipal

The following facilities have received EILS Class II Inspections during the last five years: City of Sequim, Port Townsend Paper Corporation, and Pabst Brewing Company.

Summary of Inspections

Following are summaries of EILS Class II inspections conducted in the Eastern Olympic WQMA during the last ten years:

Sequim Class II Inspection, August 1990 (Zinner, L., 1991)

A Class II Inspection was conducted at the City of Sequim Wastewater Treatment Plant (WTP) on August 6-8, 1990. The effluent flume was properly configured but comparison of Ecology instantaneous flow measurements to WTP influent flowmeter records could not confirm its accuracy. The WTP effluent V-notch weir needed recalibration. The WTP was performing well during the inspection; the effluent was within all NPDES permit limits. The WTP may be approaching 85 percent of design capacity for BOD_5 and TSS mass loadings; loadings should be recalculated after the weir is recalibrated. No acute toxicity was indicated in the WTP effluent by rainbow trout or *Ceriodaphnia dubia*. No chronic toxicity was indicated by the *Ceriodaphnia dubia*, but some chronic toxicity was indicated by the echinoderm sperm fertilization bioassay. Further calculations to determine if sludge stabilization is adequate are suggested. Priority pollutants were at low concentrations in the digested sludge. The automatic chlorine addition system was not functioning properly during the inspection.

WTP and Ecology lab results from sample splits for permit parameter analysis compared well.

Port Townsend Paper Corporation, November/December 1993 Class II Inspection (Golding, S., 1994)

A Class II Inspection was conducted at the Port Townsend Paper Company pulp and paper mill just south of Port Townsend, Washington, on November 15-17, 1993. Related sediment sampling was conducted December 15. The combined process water and sanitary discharge met all NPDES permit requirements. The sanitary effluent was also well within all permit requirements. All VOA and BNA compounds found were within applicable EPA water quality criteria. No pesticide/PCB compounds were found in the influent or effluent. Five priority pollutant metals were detected in the effluent. Copper was found in an estimated concentration of over four times Ecology water quality criteria. The fathead minnow chronic test and bivalve larvae test demonstrated sensitivity to the pulp mill effluent.

No VOA compounds were detected in the sediment samples. All BNA compounds and metals detected were below Ecology Marine Sediment Quality Standards. No toxicity was found in the Microtox test. Amphipod test results found one sample equal to 25 percent toxicity.

Pabst Brewing Company Basin Class II Inspection Summary (Das, T., 1994)

An announced Class II inspection was conducted at the Pabst Brewing Company facility on October 13-14, 1992. The following points are summarized:

- Outfall 008, which discharges process and sanitary wastewater to LOTT, met permit limitations for flow, BOD_5, TSS, and pH.

- Effluent from four outfalls discharging to the river (001 through 004) met permit requirements for flow, temperature, and pH. Outfall 003 had a total residual chlorine of 0.20 mg/L, but the permit in effect at the time had no chlorine limits for this particular discharge.

- Total phosphorus loading to the Deschutes River from the four Pabst outfalls was about 1.75 lbs/day, compared to 7.88 lbs/day in the river upstream of the outfalls. A more detailed evaluation of nutrient loading to the river and Capitol Lake was completed in 1992 by Thurston County.

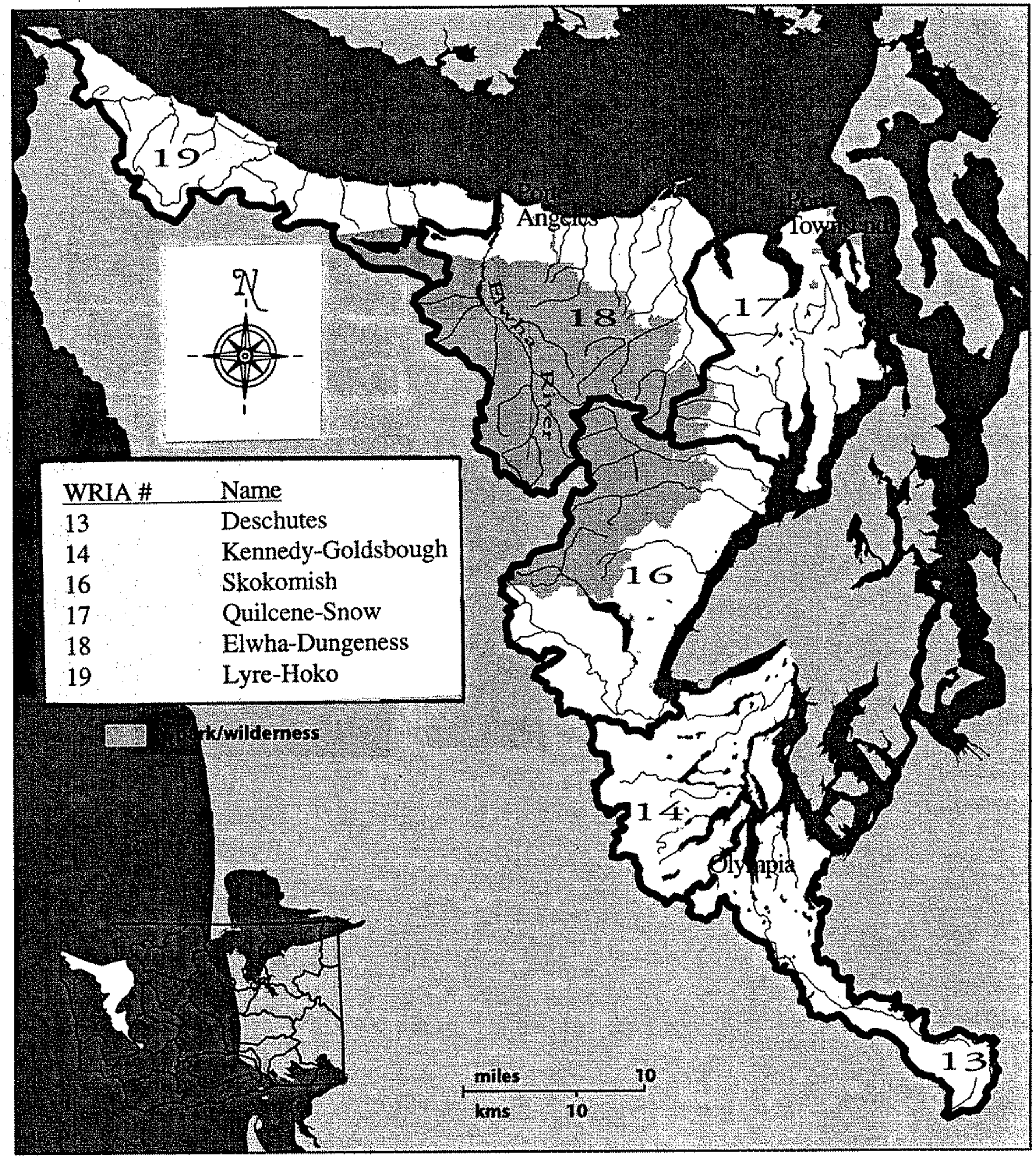

Figure 1: Eastern Olympic Water Quality Management Area.

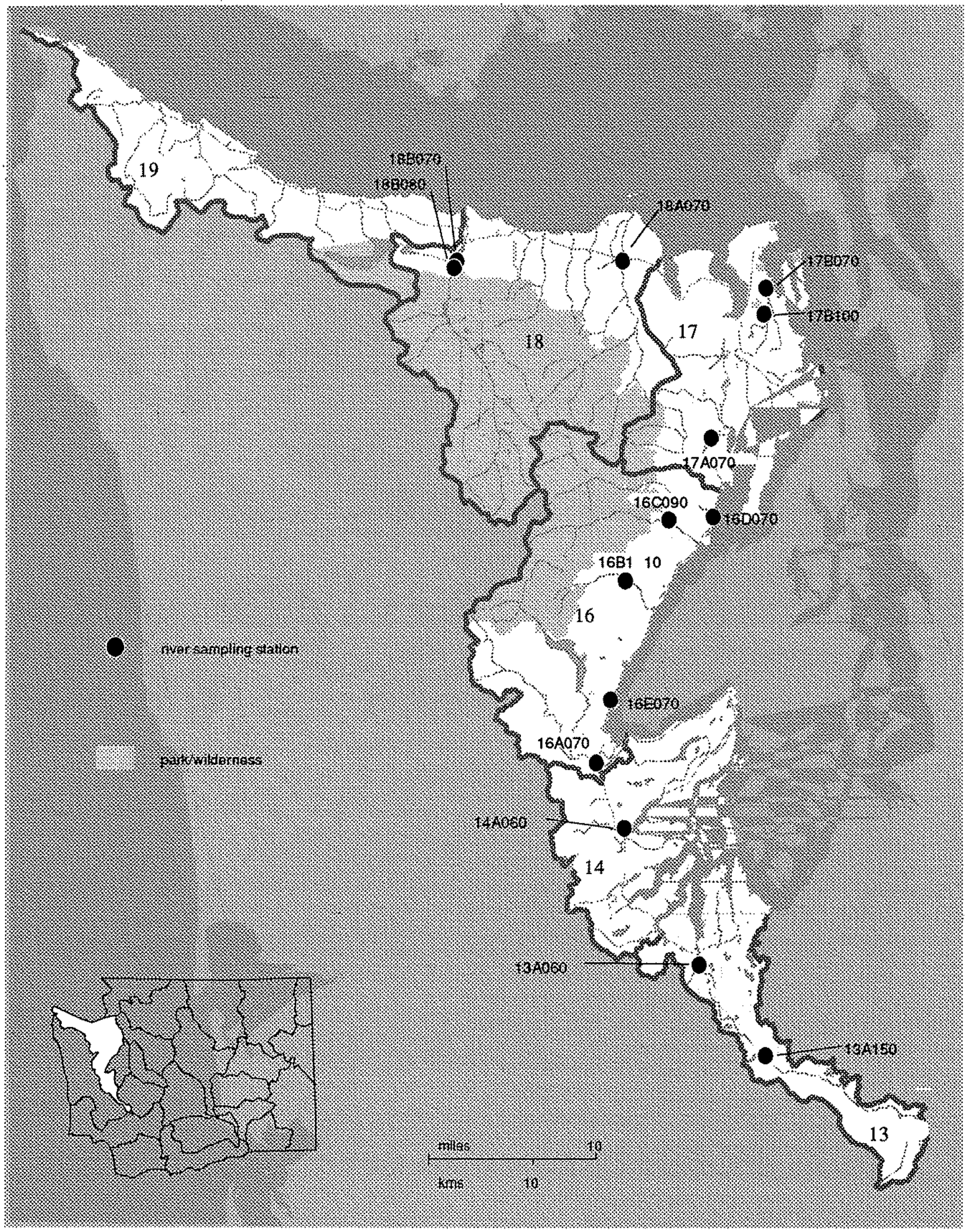

Figure 2: Freshwater Ambient Monitoring Stations.

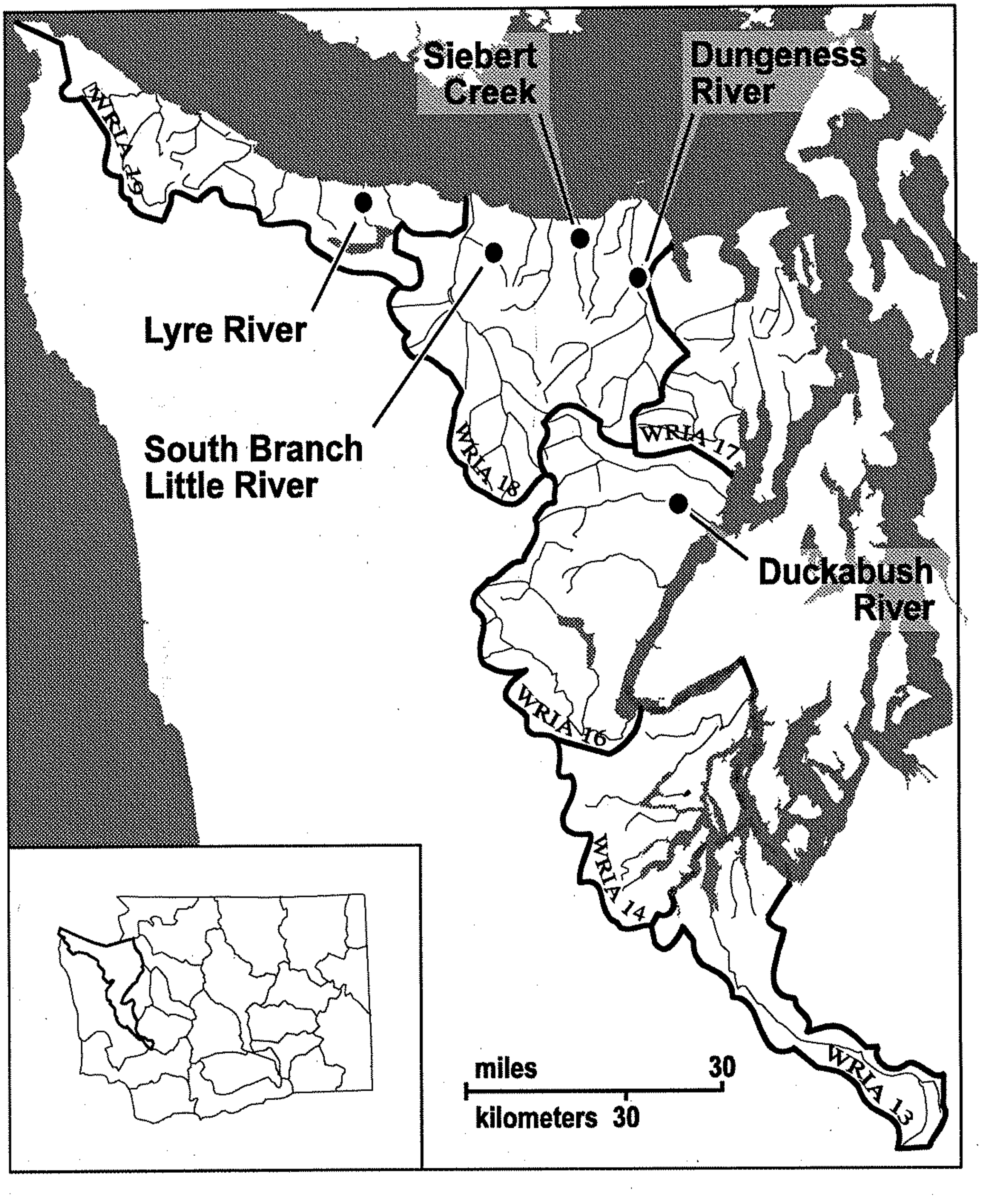

Figure 3. Eastern Olympic Water Quality Management Area. Summer 1994 biological monitoring sites.

Stations by waterbody

Waterbody	Station	Type
Admiralty Inlet	ADM001	C
	ADM002	C
	ADM003	C
Bellingham Bay	BLL009	C
	BLL011	R
Budd Inlet	BUD005	C
	BUD002	R
Burley-Minter Lagoon	BML001	R
Carr Inlet	CRR001	R
Case Inlet	CSE001	R
Commencement Bay	CMB003	C
	CMB006	R
Dana Passage	DNA001	C
Discovery Bay	DIS001	R
Drayton Harbor	DRA002	R
Dyes Inlet	DYE004	R
East Passage	EAP001	R
East Sound	EAS001	R
Eld Inlet	ELD001	R
Elliott Bay	ELB015	C
Fidalgo Bay	FID001	R
Fisherman Bay	FSH001	R
Friday Harbor	FRI001	R
Georgia Strait	GRG002	C
Gordon Point	GOR001	C
Henderson Inlet	HND001	R
Holmes Harbor	HLM001	R
Hood Canal	HCB004	C
	HCB006	C
	HCB008	C
	HCB002	R
	HCB003	R
	HCB007	R
Juan de Fuca (Strait of)	JDF005	R
Lopez Sound	LOP001	R
Nisqually Reach	NSQ002	C
Oakland Bay	OAK004	C
Penn Cove	PNN001	R
Pickering Passage	PCK001	R
Port Angeles Harbor	PAH008	R
Port Madison	PMA001	R
Port Orchard	POD006	R
Port Susan	SUZ001	R
Port Townsend Harbor	PTH005	C
Possession Sound	PSS019	C
	PSS008	R
Puget Sound Main Basin	PSB003	C
Quartermaster Harbor	QMH001	R
Saratoga Passage	SAR003	C
Sinclair Inlet	SIN001	C
Skagit Bay	SKG001	R
	SKG003	R
Totten Inlet	TOT001	R

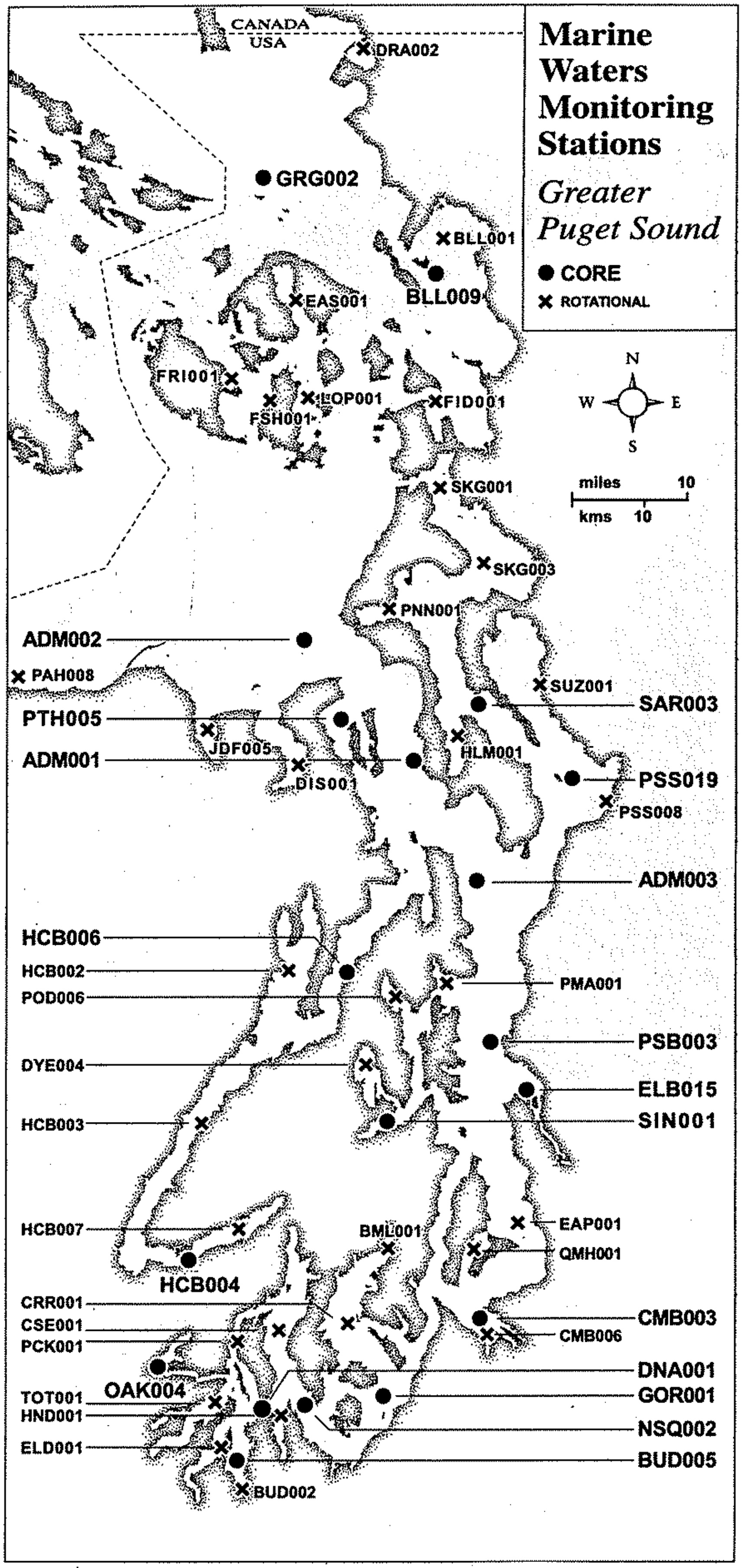

Figure 4: Long-Term Marine Waters Monitoring Stations in Puget Sound.

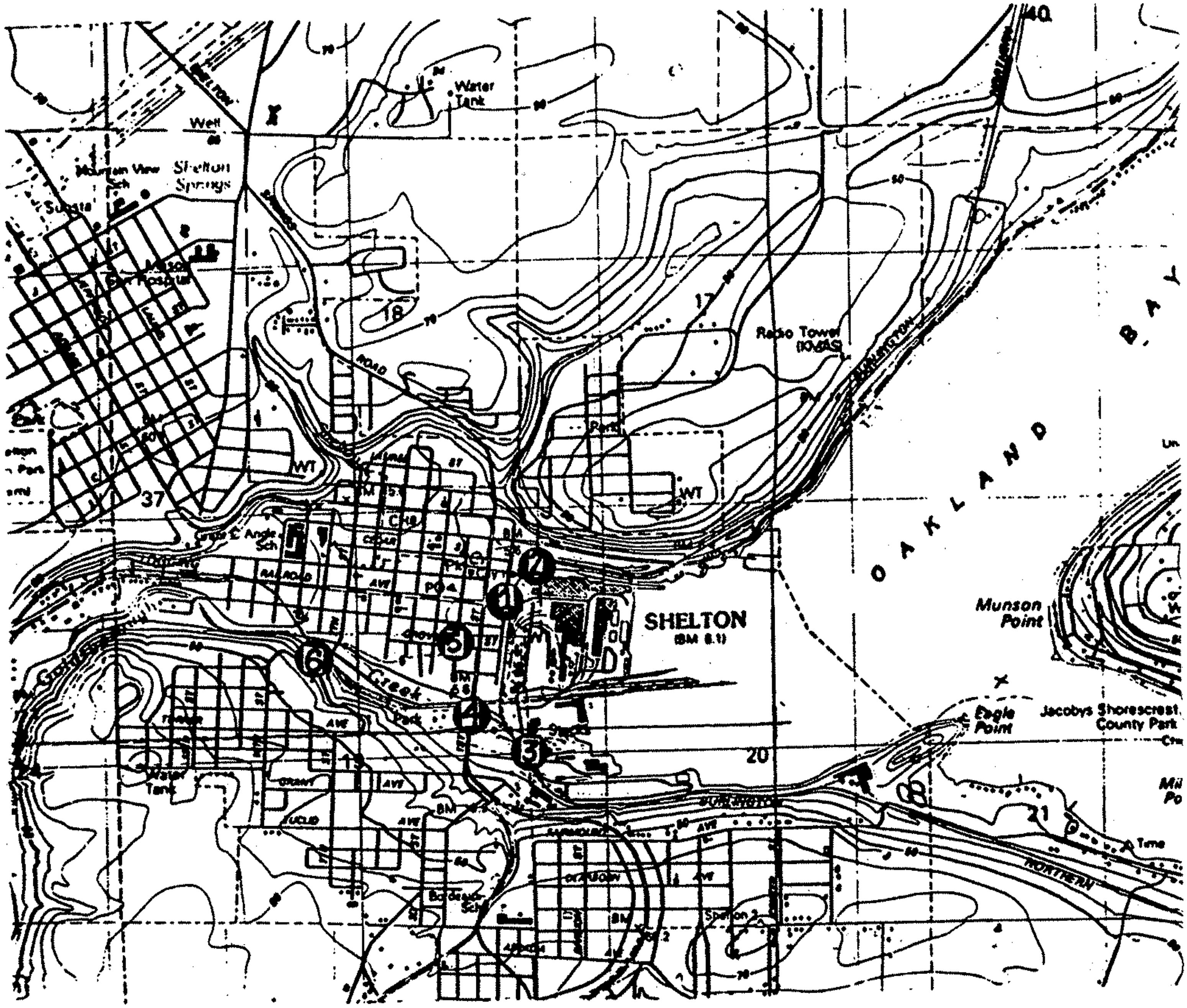

Figure 5: Shelton Stormdrain Sampling Locations.

Table 1. Summary of ambient monitoring stations in the Eastern Olympic Water Quality Management Area. 'Core' stations are underlined and monitoring activity is projected into Water Year 1998.

Station no.	Station Name					59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	9596
13A050	Deschutes R @ Tumwater					X	X	X	X	X		X	X							X																						
13A060	Deschutes R @ E St. Bridge																				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
13A080	Deschutes R nr Olympia														X			X		X																						
13A150	Deschutes R nr Rainier														X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X						
14A060	Goldsborough Cr @ Shelton																																				X					
14A070	Goldsborough Cr nr Shelton							X	X	X		X	X																													
16A070	Skokomish R nr Potlatch		X	X	X	X	X	X	X	X		X	X		X	X	X				X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
16B070	Hamma Hamma R nr Mouth				X	X	X	X	X	X		X	X			X																										
16B110	Hamma Hamma R nr Eldon															X	X																				X					
16C070	Duckabush R @ Mouth		X	X	X	X	X	X	X	X		X	X			X																										
16C090	Duckabush R nr Brinnon														X	X	X																				X	X	X	X	X	
16D070	Dosewallips R @ Brinnon	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X																				X					
16E070	Finch Cr @ Hoodsport																																				X					
17A070	Big Quilcene R nr Quilcene	X	X	X	X	X	X	X	X			X			X	X	X																				X					
17B070	Chimacum Cr nr Irondale																																				X					
17B090	Chimacum Cr @ Hadlock															X																										
17B100	Chimacum Cr @ Chimacum																																				X					
17B110	Chimacum Cr nr Chimacum															X																										
18A070	Dungeness R nr Sequim	X	X	X	X	X	X	X	X						X	X	X																				X					
18B070	Elwha R nr Port Angeles	X	X	X	X	X	X	X	X			X			X	X	X																				X	X	X	X	X	
18B080	Elwha R @ McDonald Br.																	X	X	X	X	X	X	X	X	X	X	X														
19A070	Pysht R nr Pysht														X	X	X																									
19B070	Hoko R nr Mouth														X																											
19B090	Hoko R nr Sekiu															X	X																									

Table 5. Waterbodies Relevant to the Eastern Olympic WQMA. (Also shown are the Marine Waters Monitoring stations located within the waterbody)

Segment #	Waterbody Name	Class	MWM Station (current)	MWM Station (historical[1])
WA-13-	Henderson Inlet	AA	HND001	
WA-13-	Budd Inlet (Outer)	A	BUD005	*BUD003,*
WA-13-	Budd Inlet (Inner)	B	BUD002	*BUD001*
WA-14-	Squaxin, Peale, and Pickering	AA	*none*	PCK001
WA-14-	Eld Inlet	A	ELD001	ELD002
WA-14-	Shelton Harbor (Inner)	B	*none*	
WA-14-	Hammersly Inlet	A	*none*	
WA-14-	Oakland Bay	A	OAK004	*OAK001*
WA-14-	Little Skookum Inlet	AA	*none*	
WA-14-	Totten Inlet	AA	TOT001	
WA-17-	Dabob Bay and Quilcene Bay	AA	*none*	HCB002
WA-17-	Port Townsend and Kilsut Harbor	A	*none*	*PTH002,*
WA-17-	Port Townsend	A	PTH005	
WA-17-	Discovery Bay	AA	DIS001	
WA-17-	Sequim Bay	AA	JDF005	JDF007
WA-18-	Strait of Juan de Fuca (East)	AA	PAH008	
WA-18-	Port Angeles Harbor	A	*none*	PAH003,-006,-
WA-19-	Strait of Juan de Fuca (West)	AA	*none*	
WA-PS-	Case Inlet and Dana Passage	AA	CSE001,	*CSE002*
WA-PS-	Hood Canal (North)	AA	HCB006	
WA-PS-	Admiralty Inlet (Outer)	AA	ADM002	
WA-PS-	Admiralty Inlet (Inner)	AA	ADM001	
WA-PS-	Hood Canal (South)	AA	HCB003	
WA-PS-	Great Bend/Lynch Cove	AA	HCB004,	
WA-PS-0290	Nisqually Reach/Drayton Passage	AA	NSQ002	NSQ001

[1] Italicized stations have few data

Table 7. Data parameters available for Marine Waters Monitoring stations. The database field name, US EPA STORET parameter code, units, and parameter name are listed below. Not all parameters are sampled at every station. Typically, parameter values are available at 0.5, 10, and 30 m (exceptions are fecal (0.1 m), pigments (0.5, 10 m), Secchi disk depth, and stations shallower than 30 m).

Dbase Field	P Code	Units	Parameter Name
Physical parameters:			
TEMP	P10	°C	temperature* (also contains stn #, date, time, and depth)
SALIN1	P480	ppt	salinity* (Oct 1986 - present)
SALIN2	P70305	mg/L	salinity (1973 - Sep 1986)
COND	P95	μmhos	specific conductivity
light:			
SECCHI	P78	m	Secchi disk depth
TRANSMIS	P74	%	percent light transmission (via transmissometer)
Chemical parameters:			
OXYGEN	P300	mg/L	dissolved oxygen*
PCTSAT	P301	%	percent oxygen saturation
PH	P400	units	pH*
nutrients :			
NH3_DIS	P608	mg/L	dissolved ammonium-N (Oct 1990 - present)
NH3_N	P610	mg/L	total ammonium-N (1973 - Sep 1990)
NO2_DIS	P613	mg/L	dissolved nitrite-N (Oct 1990 - present)
NO2_N	P615	mg/L	total nitrite-N (1973 - Sep 1990)
NO23_DIS	P631	mg/L	dissolved nitrate + nitrite-N (Oct 1990 - present)
NO2_NO3	P630	mg/L	total nitrate + nitrite-N (1973 - Sep 1990)
NO3_N	P620	mg/L	total nitrate-N (1973 - Sep 1990)
OP_DIS	P671	mg/L	dissolved ortho-P (Oct 1990 - present)
OP_TOT	P70507	mg/L	total ortho-P (1973 - Sep 1990)
TP_P	P665	mg/L	total P (1973 - Sep 1990)
pigments:			
CHL	P32211	μg/L	chlorophyll *a* (extracted fluorescence)
PHEO	P32218	μg/L	phaeopigment " "
Biological parameters:			
FC	P31616	#/100 mL	fecal coliform bacteria (membrane filter method)

<u>NOTES:</u>

*Since Nov 1989, *in situ* CTD sensors have been used to obtain depth, temperature, salinity, light transmission, DO, and pH data. Prior to Nov 1989, these data were obtained using a variety of methods, except for light transmission which was not measured. Information on sensors and methods used is available upon request.

Salinity was measured: via conductance using a CTD from Nov 1989 - present; via refractometer from 1987 - Oct 1989; and via titration from 1973 - 1987.

Nutrients were sampled for dissolved rather than total concentrations beginning in Oct 1990. Samples for dissolved nutrient concentrations are filtered through 0.45 μm pore size cellulose filters. As of June 1992, dissolved nitrite-N has been determined in three urban embayments only (Bellingham Bay, Budd Inlet, Commencement Bay).

Table 8. Summary of marine water quality issues in Eastern Olympic Basin. Includes WRIA #13-14, 16-19 and relevant PS segments.

Segment #	Area Name	Water Quality Issues: 1996 Section 303 (d) listing	Water Quality Issues: Other water quality concerns/observations
WA-13-0010	Henderson Inlet	Fecal Coliform	Data collected at HND001 during WY 93 and 96 showed no FC exceedences. All concentrations below 14 org/100 mL.
WA-13-0020	Budd Inlet (Outer)	DO Fecal Coliform pH Total Nitrogen	At mid-bay station BUD005, DO only occasionally is below 5 mg/L. Fecal coliform frequently is above 14 org/100 mL. The pH appears to be within marine water expectations at this station. Since 1994, LOTT underwent N-removal for WWTP effluent and this has correlated with a significant reduction in the nitrate and ammonium concentrations in the water column.
WA-13-0030	Budd Inlet (Inner)	DO Fecal Coliform pH Total Nitrogen Toxics (PAHs, PCBs, Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, 2-Methylnapthalene, Fluoranthene, Pyrene, PCB-1254, Benzo (a) pyrene, Benz (a) anthracene, Chrysene, Benzo (b,k) fluoranthenes, Dibenzo (a,h) anthracene, Indeno (1,2,3-cd) pyrene, Benzo (g,h,i) perylene, Butyl Benzyl Phthaleate, Bis(2-ethyl hexyl Phthalate, Dibenzofuran, Sediment Bioassay, Benzo(b)fluorene, Benzo(k)fluorene) Metals (Chromium, Copper, Mercury, Zinc)	At inner-bay station BUD002, DO drops below 5.0 mg/L regularly (i.e. during most but not all seasonal cycles). Fecal coliform levels are typically even higher than those at BUD005. Likely this is aided by the lower salinity in the inner bay. Particularly in the recent data, the pH appears to be within normal marine waters range. Since 1994, LOTT underwent N-removal for WWTP effluent and this has correlated with a significant reduction in the nitrate and ammonium concentrations in the water column.
WA-14-0040	Squaxin, Peale, and Pickering Passages	pH	No recent MWM data on which to evaluate. The pH range observed during WY 92 at PCK001 was 7.5 to 8.4.
WA-14-0020	Eld Inlet	Fecal Coliform	Fecal coliform only occasionally above 14 orgs/100 mL at ELD001 and ELD002, but may be higher nearshore.
WA-14-0050	Shelton Harbor (Inner)	Fecal Coliform	No MWM data on which to evaluate.
WA-14-0100	Hammersly Inlet	Fecal Coliform	No MWM data on which to evaluate.
WA-14-0110	Oakland Bay	Fecal Coliform DO	Long-term record at OAK004 shows no occurrence of DO below 5 mg/L. May be significant variation depending on location in area. Fecal coliform frequently above 14 org/100 mL at OAK004.
WA-17-0010	Dabob Bay and Quilcene Bay	Fecal Coliform	No MWM data on which to evaluate.

Table 8 (continued.): Summary of Marine Water Quality Issues for the Eastern Olympic WQMA.

Segment #	Area Name	Water Quality Issues	
		1996 Section 303 (d) listing	Other water quality concerns/observations
WA-17-0020	Port Townsend and Kilsut Harbor	DO	No data from this inner area. Data at PTH005 (WA-17-0030) shows no occurrence of DO below 5 mg/L. May be significant variation depending on location in area.
WA-17-0030	Port Townsend	PCBs	
WA-17-0050	Sequim Bay	Toxics (PCBs, Dieldrin)	DO at JDF005 above 5 mg/L, but variation evident in bay with lowest DO in southern tip. Flushing during 1993 study showed DO did not persist. Fecal coliform was consistently below 14 org/100 mL during all WYs monitored at JDF005. The pH was within marine ranges, with slight elevations historically (WY 86).
WA-18-0020	Port Angeles Harbor	DO Toxics (PCBs)	Monitoring data from this waterbody is old and less reliable. Recent DO data from nearby PAH008, which is much more well-flushed., shows concentrations around 5 mg/L which is likely natural, influenced by upwelling in Strait of Juan de Fuca.
WA-PS-0090	Case Inlet	DO @ *CSE001* pH Fecal Coliform	Low DO also noted in 1959 (Collias et al., 1975), however, values not as low as current values at CSE001.
WA-PS-0100	Hood Canal (North)	Toxics (Acenaphthalene, Anthracene, Benz (a) anthracene, Benzo (a) pyrene, Total Benzo fluoranthenes, Benzo (g, h, I) perylene, Chrysene, Fluoranthene, Indeno (1,2,3-c,d) pyrene, Phenanthrene, Pyrene, 4-Methylphenol, Pentachlorophenol, Dibenzo (a, h) anthracene, Bis (2-ethylhexyl) phthalate) Metals (Copper, Lead, Mercury, Zinc)	Naturally low DO (4-5 mg/L) seen at HCB006 in late summer due to high productivity and upwelling.
WA-PS-0250	Hood Canal (South)	Fecal Coliform	Naturally very low DO (2-3 mg/L) seen at HCB003 in late summer due to high productivity, upwelling, and reduced circulation but some suggestion of worsening..
WA-PS-0260	Great Bend/Lynch Cove	DO @ *HCB004, HCB007* pH @ *HCB004, HCB007* Fecal Coliform	Naturally low DO's, as above, but anthropogenic influence apparent. Similar conditions noted in 1954 (Collias et al., 1975) but seasonal extent longer now (includes Jan-Apr). DO's <2 mg/L observed July-Sep; <1 mg/L in July '96. Low pH cause not known but also observed by Mason County.
WA-PS-0290	Nisqually Reach/ Drayton Passage	Fecal Coliform @ *NSQ001*	Onset of high fecals (15-60 org./100 mL) during 1988-1991; not monitored since 1991.

Recommendations

- Class II inspections are recommended for facilities of concern, including those with significant changes resulting from plant modifications or plant operation.

References

Das, T., 1994. Pabst Brewing Company Basin Class II Inspection Summary. Memorandum to Backous and Greg Cloud, 13 pp.

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