Quality Assurance Project Plan

Deschutes River, Capitol Lake, and Budd Inlet Temperature, Fecal Coliform Bacteria, Dissolved Oxygen, pH, and Fine Sediment Total Maximum Daily Load Study

by
Mindy Roberts, Brian Zalewsky, Trevor Swanson, Lawrence Sullivan,
Kirk Sinclair, and Mike LeMoine

Washington State Department of Ecology
Environmental Assessment Program
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1996 and 1998 303(d) listings addressed in this study:

Deschutes River (WA-13-1010; TM40PW): Temperature, Fecal Coliform, pH
Deschutes River (WA-13-1020; TM40PW): Temperature, Fine Sediment
Mission Creek (WA-13-1380; no ID): Fecal Coliform
Ayer (Elwanger) Creek (WA-13-1015; XR83PB): Fecal Coliform, Dissolved Oxygen, pH
Indian Creek (WA-13-1300; KX91JE): Fecal Coliform
Reichel Creek (WA-13-1022; PN25TO): Fecal Coliform
Capitol Lake (WA-13-9020; 601ADB): Fecal Coliform, Total Phosphorus
Moxlie Creek (WA-13-1350; HN77NY): Fecal Coliform
Budd Inlet (inner) (WA-13-0030; 390KRD): Dissolved Oxygen, pH, Total Nitrogen (1996)
Budd Inlet (outer) (WA-13-0020; 390KRD): Dissolved Oxygen, pH, Total Nitrogen (1996)
Huckleberry Creek (WA-13-1024; RX35HU): Temperature, Fecal Coliform

Additional waterbody numbers addressed in this study:

Adams Creek (no ID): Fecal Coliform, pH
Black Lake Ditch (no ID): Temperature, Fecal Coliform
Butler Creek (no ID): Fecal Coliform, pH
Chambers Creek (no ID): Fecal Coliform, pH
Ellis Creek (no ID): Fecal Coliform, pH
Hard Creek (no ID): pH
Huckleberry Creek (WA-13-1024; RX35HU): Dissolved Oxygen
Lincoln Creek (no ID): pH
Little Deschutes (no ID): pH
Percival Creek (no ID): Temperature, Fecal Coliform, pH
Schneider Creek (no ID): Fecal Coliform, pH
Spurgeon Creek (no ID): Fecal Coliform, pH
Thurston Creek (no ID): pH

Ecology EIM Number: KSIN0009

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Approvals

Approved by:	February 5, 2004
Chris Hempleman, TMDL Lead, SWRO	Date
Approved by:	February 5, 2004
Kim McKee, Unit Supervisor, SWRO	Date
Approved by:	February 10, 2004
Kelly Susewind, Section Manager, SWRO	Date
Approved by:	January 29, 2004
Mindy Roberts, Project Manager, Watershed Ecology Section	Date
Approved by:	February 5, 2004
Brian Zalewsky, Temperature Project Manager, Nonpoint Studies Unit	Date
Approved by:	February 4, 2004
Mike LeMoine, Principal Investigator, Nonpoint Studies Unit	Date
Approved by:	February 2, 2004
Trevor Swanson, Principal Investigator, Water Quality Studies Unit	Date
Approved by:	February 5, 2004
Kirk Sinclair, Hydrogeologist, Nonpoint Studies Unit	Date
Approved by:	February 1, 2004
Karol Erickson, Unit Supervisor, Water Quality Studies Unit	Date
Approved by:	February 2, 2004
Darrel Anderson, Unit Supervisor, Nonpoint Studies Unit	Date
Approved by:	February 4, 2004
Will Kendra, Section Manager, Watershed Ecology Section	Date
Approved by:	February 4, 2004
Stuart Magoon, Director, Manchester Environmental Laboratory	Date
Approved by:	February 9, 2004
Cliff Kirchmer, Ecology Quality Assurance Officer	Date

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Abstract

Section 303(d) of the federal Clean Water Act requires the state of Washington to prepare a list of all surface waters in the state for which beneficial uses of the water are impaired by pollutants. Waterbodies placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs) to identify and quantify sources of the impairments and to recommend implementation strategies for reducing point and nonpoint source loads.

The Deschutes River, Capitol Lake, Budd Inlet, and some of their tributaries are on the 303(d) list for at least one of the following parameters: temperature, fecal coliform bacteria, dissolved oxygen, or pH. This Quality Assurance (QA) Project Plan describes the technical study that will evaluate pollutants in those impaired waterbodies, building from previous data collection efforts conducted by a variety of governmental, tribal, and private organizations. The study will be conducted by the Washington State Department of Ecology (Ecology) Environmental Assessment (EA) Program in cooperation with the Squaxin Island Tribe, Thurston County, and the city of Olympia.

Introduction

The Deschutes River, Capitol Lake, Budd Inlet, and their tributaries lie within Water Resource Inventory Area (WRIA) 13 in South Puget Sound. The study area extends north from the Deschutes River headwaters in Gifford Pinchot National Forest in Lewis County through Thurston County to Capitol Lake and Budd Inlet (Figure 1). The study area includes 11 freshwater and marine waterbody segments impaired by fecal coliform, heat, nutrients, and fine sediment, as listed in the 1996 or 1998 Clean Water Act Section 303(d) lists. The impairments were identified based on sampling conducted by Thurston County, Ecology, Squaxin Island Tribe, and other entities.

Ecology is required by the federal Clean Water Act to conduct a TMDL study for all waterbodies on the 303(d) list. Studies begin with a technical evaluation of the current condition of the waterbodies including the capacity to absorb pollutants and still meet water quality standards. The study identifies and quantifies the likely sources of pollutants and determines how much pollution from point sources and nonpoint sources can contribute to a waterbody without exceeding standards. The outcome is a recommendation for point source wasteload allocations and nonpoint source load allocations, the sum of which cannot exceed the capacity of the waterbodies minus a margin of safety for each parameter of concern. The results of the technical study will be incorporated into a TMDL submittal report compiled by the Ecology regional office for approval by the U.S. Environmental Protection Agency (EPA). The subsequent report includes plans for implementing load and wasteload reductions developed in conjunction with other governments and agencies, as well as local citizens.

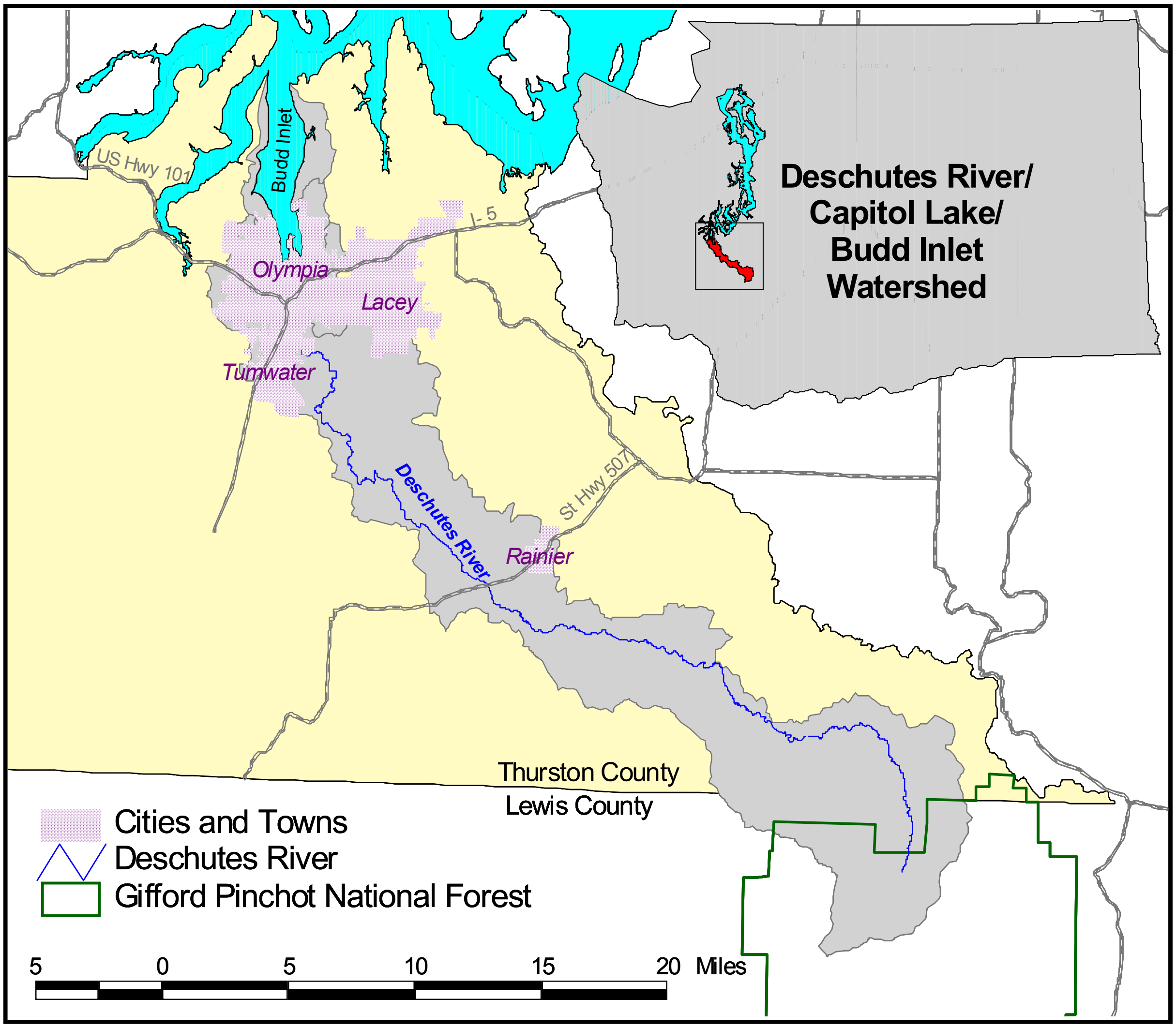

Figure 1. Deschutes River, Capitol Lake, and Budd Inlet TMDL Study Area.

The Deschutes River, Capitol Lake, and Budd Inlet TMDL study data collection program began in summer 2003 with reconnaissance monitoring intended to update historical data and to generate information with which to design the 2004 monitoring program. Appendix A contains the technical memorandum outlining the reconnaissance monitoring. This QA Project Plan covers monitoring to be conducted in calendar year 2004. Table 1 presents the 303(d) listings addressed in this study while Table 2 summarizes additional waterbodies for which historical data, collected by Thurston County, do not meet limits set in the water quality standards. The waterbodies and parameters listed in Table 2 will be evaluated further in the present study to determine whether impairments exist. If data indicate impairments, the study will include allocations. If the waterbodies meet standards under the current study, the waterbodies will not receive allocations but may be recommended for additional monitoring. In total, 24 streams or rivers are impaired by temperature, fecal coliform bacteria, dissolved oxygen (DO), and/or pH.

Table 1. Waterbodies on the 1996 and/or 1998 Clean Water Act Section 303(d) Lists Addressed in the Present Study.

Waterbody	New ID	Old Water Body ID (WBID)	Township, Range, Section	Parameter	On 303(d) list?
Deschutes River	TM40PW	WA-13-1010	18N 02W 60 17N 01W 33	Temperature	1996, 1998
Deschutes River	TM40PW	WA-13-1010	18N 02W 60	Fecal Coliform	1996, 1998
Deschutes River	TM40PW	WA-13-1010	18N 02W 60	pH	1996, 1998
Deschutes River	TM40PW	WA-13-1020	15N 03E 07 16N 02E 34 16N 02E 30 16N 01E 18	Temperature	1996, 1998
Deschutes River	TM40PW	WA-13-1020	16N 02E 30	Fine Sediment	1996, 1998
Mission Creek	(none)	WA-13-1380	18N 02W 11	Fecal Coliform	1996, 1998
Ayer (Elwanger) Creek	XR83PB	WA-13-1015	17N 01W 07	Fecal Coliform	1996, 1998
Ayer (Elwanger) Creek	XR83PB	WA-13-1015	17N 01W 07	Dissolved Oxygen	1996, 1998
Ayer (Elwanger) Creek	XR83PB	WA-13-1015	17N 01W 07	pH	1996, 1998
Indian Creek	KX91JE	WA-13-1300	18N 01W 18 18N 02W 41	Fecal Coliform	1996, 1998
Reichel Creek	PN25TO	WA-13-1022	16N 01E 27	Fecal Coliform	1996, 1998
Capitol Lake	601ADB	WA-13-9020	18N 02W 15	Fecal Coliform	1998
Capitol Lake	601ADB	WA-13-9020	18N 02W 15	Total Phosphorus	1996, 1998
Moxlie Creek	HN77NY	WA-13-1350	18N 02W 27	Fecal Coliform	1998
Huckleberry Creek	RX35HU	WA-13-1024	15N 03E 27	Temperature	1996, 1998
Budd Inlet (inner)	390KRD	WA-13-0030	N/A	Dissolved Oxygen	1998
Budd Inlet (inner)	390KRD	WA-13-0030	N/A	pH	1998
Budd Inlet (inner)	390KRD	WA-13-0030	N/A	Total Nitrogen	1996
Budd Inlet (outer)	390KRD	WA-13-0020	N/A	Dissolved Oxygen	1998
Budd Inlet (outer)	390KRD	WA-13-0020	N/A	pH	1998
Budd Inlet (outer)	390KRD	WA-13-0020	N/A	Total Nitrogen	1996

Table 2. Additional Waterbodies Where Historical Data Do Not Meet Water Quality Standards but the Waterbodies Are Not Currently On the Clean Water Act Section 303(d) List.

Waterbody	New ID	Old Water Body ID (WBID)	Township, Range, Section	Parameter	On 303(d) list?
Adams Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Black Lake Ditch	N/A	N/A	N/A	Temperature, Fecal Coliform	Not Listed
Butler Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Chambers Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Ellis Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Hard Creek	N/A	N/A	N/A	pH	Not Listed
Huckleberry Creek	RX35HU	WA-13-1024	15N 03E 27	Dissolved Oxygen	Not Listed
Lincoln Creek	N/A	N/A	N/A	pH	Not Listed
Little Deschutes	N/A	N/A	N/A	pH	Not Listed
Percival Creek	N/A	N/A	N/A	Temperature, Fecal Coliform, pH	Not Listed
Schneider Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Spurgeon Creek	N/A	N/A	N/A	Fecal Coliform, pH	Not Listed
Thurston Creek	N/A	N/A	N/A	pH	Not Listed

The 1996 and 1998 303(d) lists also include parameters and waterbodies that are not being addressed by the present study. Ward Lake and Budd Inlet are listed for PCBs but source identification and reduction must be part of a future regional study rather than a watershed-specific study. Inner Budd Inlet is also listed for a number of toxic contaminants. The majority of these listings are associated with remediation activities already underway. Consequently, they do not require source identification and load allocations. The Deschutes River is also listed for large woody debris and instream flow. These parameters are not considered "pollutants" under the Clean Water Act and, therefore, are not candidates for TMDL allocations as per Ecology policy. However, large woody debris is likely to be improved indirectly through allocations for fine sediment and temperature. Instream flow is currently being addressed through watershed planning under the Watershed Planning Act (90.82).

Project Description

Study Area

The study area extends from the headwaters of the Deschutes River northward through Capitol Lake and Budd Inlet. The watershed occupies a total of 186 mi^2 (480 km^2) including the 8.3-mi^2 (22-km^2) surface area of Budd Inlet. Elevations range from 3870 ft (1180 m) at Cougar Mountain in the Bald Hills to sea level.

Precipitation varies from over 90 in (230 cm) at the headwaters to 45 in (115 cm) between Tumwater and Rainier (Miller et al., 1973). Precipitation gages are located at the Olympia Airport, near Vail, and near the Port of Olympia. The U.S. Geological Survey (USGS) has gaged discharge on the mainstem of the Deschutes River at Rainier and near the mouth at the E Street Bridge since 1949 and 1945, respectively. Historically, USGS also monitored the Deschutes River at Olympia but the location was discontinued in 1964. Average annual flows are 263 cfs (7.5 cms) and 406 (11.5 cms) cfs at Rainer and E Street, based on the period from 1950 to 2001 and 1946 to 2001, respectively. USGS estimates the seven-day average low flow with a ten-year recurrence interval (7Q10) at Rainer as 24.0 cfs (0.68 cms), based on the period 1949 to 2001. The estimated 7Q10 at E Street Bridge, based on the period 1946 to 2002, is 64.1 cfs (1.8 cms) (D. Kresch, Personal Communication).

The geology and groundwater resources of the study area were initially inventoried in the early 1950s to mid 1960s (Snavely et al., 1951a, 1951b, 1958; Wallace and Molenaar, 1961; Noble and Wallace, 1966). The Bald Hills, including the uplands of the southern study area, are composed largely of Tertiary age bedrock consisting of basalt, andesite flows, and volcaniclastic deposits/rocks of the Northcraft Formation. These rocks are typically compact and yield little water to wells except where jointed or deeply weathered. The northern study area (north and west of Lake Lawrence) is underlain largely by Vashon Age deposits of outwash gravel and sand with interspersed deposits of Vashon till. The outwash gravels and sands are both capable of yielding significant volumes of water to wells and area streams.

Land cover includes forest lands, agricultural, rural residential, and urban lands as summarized in Table 3. Developed areas dominate in the northern watershed, while grass, shrubs, and forests dominate the southern part of the watershed. Most of Olympia and Tumwater, a portion of Lacey, and the town of Rainier are the largest population centers within the watershed. The population of Olympia has nearly doubled since 1970 to 42,530 people as of April 2001 (Municipal Research and Services Center of Washington, 2003). Over 50,000 people live in the study area.

Table 3. Land Use Distribution in the Study Area (1998 LandSat Image).

Land Use	Overall Study Area
Developed Land	10%
Grass/Shrub	60%
Marsh/Water	6%
Forested	24%

The city of Olympia relies on groundwater and surface water, including McAllister Springs located outside of the project study area, for its drinking water supply and discharges wastewater through the Lacey, Olympia, Tumwater, and Thurston County Wastewater Alliance (LOTT) facility to Budd Inlet. A portion of the downtown Olympia area is served by a combined sewer system where stormwater and municipal wastewater are conveyed to the LOTT wastewater treatment plant. Combined sewer overflows occur when the system hydraulic capacity is exceeded.

Tumwater and Lacey operate separate groundwater systems for drinking water supplies. Most of Tumwater and Lacey are served by the LOTT wastewater facility with the remaining population served by septic systems. The town of Rainier relies on groundwater for drinking water with wastewater treated by septic systems.

Olympia, Tumwater, Lacey, Rainier, and a portion of unincorporated Thurston County have been identified tentatively as entities that must receive coverage under the National Pollutant Discharge Elimination System (NPDES) Phase II municipal stormwater permit program. Ecology expects to develop the Phase II general municipal stormwater permit by the end of 2004. The permit will apply to stormwater discharges from all conveyances owned or operated by the named municipalities. In addition, discharges from conveyances owned or operated by special districts (such as drainage districts and ports) and located in these municipalities also fall under the federal permit requirement. Stormwater conveyances include enclosed pipes, ditches, roads with drainage systems, municipal streets, catch basins, curbs, gutters, and man-made channels that discharge to the Deschutes River, Percival Creek, Capitol Lake, Budd Inlet, or their tributaries. Currently, stormwater requirements vary by jurisdiction; however, most new developments since the mid-1990s must infiltrate stormwater on site or implement other control.

Weyerhaeuser Company is the largest private forest lands owner and largest landowner, with 49,480 acres (20,024 ha) or 39% of Deschutes-Budd Inlet Watershed, while the Department of Natural Resources (DNR) and the U.S. Forest Service own and manage public timberlands. Practices involving private forestlands were the subject of the 1987 Timber Fish and Wildlife (TFW) Agreement. The goals of the agreement are to provide compliance with the Endangered Species Act for aquatic- and riparian-dependent species on non-federal forest lands, restore and maintain riparian habitat to support a harvestable fish supply, meet the requirements of the Clean Water Act, and keep the timber industry economically viable. Load allocations are established in this TMDL in accordance with Schedule M-2 of the Forests and Fish report.

Commercial and non-commercial agriculture occur primarily in the central Deschutes River Watershed. Animal facilities include one commercial dairy, sheep, and non-commercial livestock.

The watershed is traversed by three major highways. Interstate 5 crosses northeast-southwest near Olympia, Tumwater, and Lacey dividing Capitol Lake into the middle and south basins. Highway 101 connects with Interstate 5 near Heritage Park along Capitol Lake. Highway 507 crosses the watershed east-west through the town of Rainier. The Washington State Department of Transportation (WSDOT) also is subject to the NPDES municipal stormwater permit requirement. While WSDOT has a permit under the NPDES Phase I municipal stormwater program, conditions apply only to those municipalities with populations over 100,000, none of which occur within the project study area. However, WSDOT has applied for a state-wide municipal stormwater NPDES permit that will cover stormwater discharges from all state highways and WSDOT facilities such as maintenance yards and park-and-ride lots. Ecology will work with WSDOT and the public to develop this permit in 2004.

Capitol Lake, located adjacent to the State Capitol complex in Olympia, Washington, is an artificial impoundment of the waters of the Deschutes River formed in 1951 with the construction of the Fifth Avenue /Dam over the tidal flats where the Deschutes River empties into Budd Inlet. The primary objectives were to eliminate odors and aesthetic problems associated with tidal estuaries, remove the blight of a shanty development in close confines to the State Capitol, and develop a scenic lake environment which would serve as a showcase for the Capitol and a centerpiece for recreation. Originally, the lake had a surface area of 320 ac (130 ha) but that has been reduced to 267 ac (108 ha) (CH2MHill, 2001) due to sedimentation. The Washington Department of General Administration (GA) operates and maintains the outlet structure of Capitol Lake which consists of two radial gates, a fish gate (weir), and a siphon to stabilize the lake level, maintain freshwater conditions, and control flooding. An automated system opens the radial gates, while GA personnel manually adjust the fish weir seasonally and adjust the radial gates in the event of expected high Deschutes River discharge (URS Group, Inc. and Dewberry, 2003). GA expects to install water level recorders in winter 2003-04, but no long-term historical records of lake level exist. The lake had been flushed to control macrophyte growth and dredged to remove excess sediments but the dredging was discontinued in 1986.

Capitol Lake has trapped sands, silts, and clays eroded from stream banks and slopes within the watershed. Annual accumulations range from 30,000 to 50,000 cubic yards (20,000 to 30,000 cubic meters) (Clingman, Personal Communication). This accumulation of sediment has become a problem of increasing concern, affecting many uses of the lake and surrounding area.

The sedimentation problem in Capitol Lake had previously required the implementation of an expensive dredging program to protect the recreational and fish rearing uses of the lake. Identified as the major source of sediment to the lake, the Deschutes River has become the subject of numerous investigations aimed at (1) identifying those natural and anthropogenic processes contributing to erosion and sedimentation within the basin, (2) quantifying the relative importance of each process, and (3) developing a strategy to alleviate and monitor reaches of the river with severe erosion problems.

The Washington Department of Fish and Wildlife (WDFW) has operated a chinook hatchery in Percival Cove within Capitol Lake for over 50 years. The WDFW believes that lake and watershed conditions have degraded and is seeking to develop or upgrade upstream facilities at Tumwater Falls and Pioneer Park (Eltrich, Personal Communication).

The region’s glacial geology profoundly influences erosion and sedimentation in the Deschutes River. From its mouth at Capitol Lake to Tumwater Falls, the river flows through unconsolidated silt, sand, and gravel deposited by the last continental glaciation which ended about 12,000 years ago (Schasse, 1987). Previous studies have identified bank erosion of these glacial sediments in the reach between Capitol Lake and Deschutes Falls as the dominant source of sediment in the watershed (Moore and Anderson, 1978; Sullivan et al., 1987).

The Capitol Lake Adaptive Management Plan (CLAMP) Committee, composed of representatives from GA, Ecology, WDFW, DNR, Squaxin Island Tribe, city of Olympia, city of Tumwater, Thurston County, and the Port of Olympia was convened by GA to advise on issues related to Capitol Lake. With input from the committee, GA developed and is implementing a ten-year management plan (GA, 2002). The committee currently is evaluating funding options to investigate the feasibility of returning the lake to an estuary.

Budd Inlet is one of several terminal inlets in South Puget Sound. Depths range from 100 ft (30 m) in the north to mudflats in the shallow East and West Bays; much of the inlet varies from 5 to 15 m (15 to 50 ft) in depth. The tide range is 14.6 ft (4.5 m), based on the difference between mean higher high water and mean lower low water; however, spring tides can exceed 18 ft (5.5 m). Historically, the inlet was used for shellfish harvesting, but the Department of Health has closed the beds due to contamination.

Black Lake, part of WRIA 23, sits at the drainage divide with WRIA 13 and contributes flow to both WRIA 23 via the Black River and WRIA 13 via Black Lake Ditch to Percival Creek and Capitol Lake. Black Lake Ditch, approximately two miles (3.2 km) long, flows from the north end of Black Lake and joins Percival Creek between Mottman Road and Highway 101.

Black Lake Ditch was excavated in 1922 to drain potential agricultural land. In 1976, the abandonment of the Consolidated Drainage Improvement District #101 led to the county acquiring ownership of the ditch and the adjacent easement. The easement varies from 25 feet (7.6 m) to 50 feet (15.2 m) on both sides. In 1993, local jurisdictions adopted the Percival Creek Comprehensive Drainage Basin Plan (City of Olympia et al., 1993). Two recommendations have since been implemented by the city of Olympia. The city of Olympia constructed a stormwater pond (Black Lake Meadows) adjacent to the ditch to detain stormwater from the Capital Mall commercial area, and the city also replaced the culvert under R.W. Johnson Boulevard to allow juvenile salmon access to upstream rearing habitat. Thurston County intends to continue habitat enhancement and protect the ditch's drainage function by establishing native vegetation along the length of the watercourse.

The Deschutes and Budd Inlet Watersheds support important shellfish and anadromous fish populations. Five salmonid species use the Deschutes Basin and other drainages into Budd Inlet for spawning and rearing: steelhead trout, searun and resident cutthroat trout, coho, hatchery chinook, and chum salmon (Haring and Konovsky, 1999), although historically Tumwater Falls presented a natural barrier to fish passage. Washington Department of Fisheries constructed a fish ladder in 1954 (GA, 2002). The distribution of chum salmon is restricted primarily to small, low-gradient streams feeding directly into Budd Inlet. Chinook salmon use of the basin is limited mainly to the lower and middle mainstem of the Deschutes River and Percival Creek. The middle and upper reaches of most of the accessible drainages are used by coho salmon, steelhead trout, and searun and resident cutthroat trout. Resident trout are common in the tributaries above barriers to anadromous salmonids.

Salmonids from the Deschutes River now constitute a substantial portion of the southern Puget Sound sport and Native American fishery. Several synoptic surveys of the fish species and habitat distribution in the Deschutes Basin have been performed by the Washington Department of Fisheries (Williams et al. 1975) and Weyerhaeuser Company (Dinicola, 1979; Bisson et al., 1985; and Sullivan et al., 1987). These studies, along with research studies in the headwaters, have provided some understanding of fish utilization of the basin. Haring and Konovsky (1999) provide a recent summary of the distribution and condition of natural spawning populations of salmonids in the Deschutes Watershed.

Other fish species that occur within the drainages of Budd Inlet include the Pacific lamprey, largescale suckers, speckled dace, longnose dace, redside shiners, torrent sculpin, and shorthead sculpin (Sullivan et al., 1987).

Species of shellfish known to occur within Budd Inlet important to recreational and commercial harvesters are geoducks, manila, native littleneck, butter clams, cockles, mussels, squid, red rock crabs, and oysters (Zulauf et al., 1990).

Project Objectives

Temperature

- Characterize stream temperatures and processes governing the thermal regime in the Deschutes River, Percival Creek, and Black Lake Ditch including the influence of lakes and wetlands on the heat budget.
- Develop predictive models of the Deschutes River and the Percival Creek/Black Lake Ditch systems under critical conditions. Apply the models to determine load allocations for effective shade and other surrogate measures to meet temperature water quality standards, identify the areas influenced by lakes and wetlands; and, if necessary, determine the natural temperature regime.

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

- Characterize fecal coliform bacteria concentrations and identify major sources (geographically or by land use) to the Lower Deschutes River, Mission Creek, Ayer (Elwanger) Creek, Indian Creek, Reichel Creek, Capitol Lake, Moxlie Creek, Adams Creek, Black Lake Ditch, Butler Creek, Chambers Creek, Ellis Creek, Percival Creek, Schneider Creek, and Spurgeon Creek.
- Conduct surveys for physical, chemical, and biological measures relevant to dissolved oxygen in Ayer (Elwanger) Creek and Huckleberry Creek.
- Characterize current pH and relevant physical, chemical, and biological measures in the Deschutes River, Ayer (Elwanger) Creek, Adams Creek, Butler Creek, Chambers Creek, Ellis Creek, Hard Creek, Lincoln Creek, Little Deschutes River, Percival Creek, Schneider Creek, Spurgeon Creek, and Thurston Creek. If streams are impaired by anthropogenic activities, assess or model productivity.
- Determine fecal coliform, DO, nutrient, and pH TMDL targets for the Deschutes River and its tributaries, tributaries to Capitol Lake, and tributaries to Budd Inlet, achieved through point source wasteload allocations and nonpoint source load allocations.
- Monitor dissolved oxygen, nutrients, pH, and parameters related to productivity in Capitol Lake.
- Model productivity in Capitol Lake and use the results to establish TMDL targets, point source wasteload allocations, and nonpoint source load allocations for Capitol Lake and all inflows to the lake.
- Utilize existing data and refined model of Budd Inlet to establish TMDL targets, point source wasteload allocations, and nonpoint source load allocations for dissolved oxygen and related parameters including nutrients.

Fine Sediment

- Identify and quantify the processes governing the generation, transport, and deposition of fine sediment in the Deschutes River Watershed.
- Evaluate the relative contributions of natural and anthropogenic sources of fine sediment in the Deschutes River Watershed and its tributaries, and use the results to establish TMDL targets and nonpoint source load allocations.

Water Quality Standards and Beneficial Uses

The Washington State water quality standards, set forth in Chapter 173-201A of the Washington Administrative Code, include designated beneficial uses, waterbody classifications, and numeric and narrative water quality criteria for surface waters of the state.

This study includes both marine and freshwater bodies that represent a combination of Class AA, A, and B waters. The headwaters of the Deschutes River lie within the Gifford Pinchot National Forest and are Class AA waterbodies, based on WAC 173-201A-130 (31). Downstream of the National Forest, the mainstem of the Deschutes River and all of its tributaries are Class A waterbodies per WAC 173-201A-130 (30). Capitol Lake is considered lake class, as described in Appendix B based on WAC 173-201A-120 (3) and WAC 173-201A-030 (5). Percival Creek, tributary to Capitol Lake, is a Class AA waterbody, based on WAC 173-201A-120 (2) for feeder streams to lake-class waterbodies. Inner Budd Inlet, identified by WAC 173-201A-140 (1) as south of latitude 47° 04' N (south of Priest Point Park) is a Class B waterbody. Freshwater tributaries to the Class B marine waterbody are considered Class A waters, based on WAC 173-201A-120 (6). The remainder of Budd Inlet is a Class A waterbody, based on WAC 173-201A-140 (23).

Characteristic uses for both Class AA and Class A waterbodies include water supply (domestic, industrial, agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, and harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, aesthetic enjoyment), and commerce and navigation. Characteristic uses for Class B waterbodies include water supply (industrial and agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, and harvesting), wildlife habitat, recreation (secondary contact recreation, sport fishing, boating, aesthetic enjoyment), and commerce and navigation.

Numeric criteria for specific water quality parameters are intended to protect designated uses. However, criteria are more stringent in Class AA waters such that the water shall markedly and uniformly exceed the requirements for all, or substantially all, uses.

Ecology revised the state water quality standards in July 2003, although the revisions have not been evaluated and approved by EPA to date. Until the new standards are approved, the previous version remains in effect for TMDLs and other programs administered under the federal Clean Water Act. Under the revised water quality standards, while the waterbody classification system will change, the numeric target for each of the waterbodies included in the present study will not, with the exception of the Class A temperature target, as described below. Current freshwater and marine standards are listed below for each parameter of concern in the Deschutes River, Capitol Lake, and Budd Inlet Watersheds.

Temperature

- *Class AA.* Freshwater temperature shall not exceed 16.0°C due to human activities. When natural conditions exceed 16.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Incremental temperature increases resulting from point source activities shall not, at any time, exceed $t=23/(T+5)$[1]. Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C when the temperatures are less than the standard.

[1] T represents the background waterbody temperature, while t is maximum permissible temperature increase measured at the edge of the mixing zone; both are in °C.

- *Class A*. Water temperature shall not exceed 18.0°C due to human activities. When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/(T+7)[1]. Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.
- *Lake Class*. The water quality standards do not include numeric temperature targets, but lakes must maintain no measurable change from natural conditions.

The July 2003 temperature standards do not use the Class AA and A distinction but depend on whether streams are, or could be, salmonid or trout core-rearing or non-core-rearing waterbodies. However, streams that were previously identified as Class AA are designated as salmonid or trout spawning, core rearing, and migration streams which must not exceed a seven-day average maximum temperature threshold of 16°C (the previous standard also used 16°C but as the instantaneous maximum temperature). Streams that were previously identified as Class A are designated as salmonid or trout spawning, non-core rearing, and migration and must not exceed a seven-day average maximum temperature threshold of 17.5°C. The project will evaluate the ability to meet the standards in effect at the time the report is written.

Dissolved Oxygen and Nutrients

- *Class AA*. Freshwater dissolved oxygen shall exceed 9.5 mg/L. No Class AA marine waters are included in the study.
- *Class A*. Freshwater dissolved oxygen shall exceed 8.0 mg/L, and marine dissolved oxygen shall exceed 6.0 mg/L.
- *Class B*. Marine dissolved oxygen shall exceed 5.0 mg/L.

When natural conditions, such as upwelling, occur causing the dissolved oxygen to be depressed near or below the levels described above by class, natural dissolved oxygen levels may be degraded by no more than 0.2 mg/L by the combined effect of all human-caused activities.

- Lake Class: The water quality standards do not include a minimum target for DO, but lakes must have no measurable change in DO from natural conditions.

Fecal Coliform Bacteria

- *Class AA*. Freshwater fecal coliform organism levels shall both not exceed a geometric mean[2] value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
- *Class A*. Freshwater fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.

[2] The geometric mean is calculated as the n^{th} root of the product of n numbers.

- *Lake Class*. Freshwater fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.

Budd Inlet is not listed for fecal coliform bacteria, and no marine waters will be evaluated for fecal coliform bacteria.

pH

- *Class AA*. The pH shall be within the range of 6.5 to 8.5 for freshwater with a human-caused variation within the above range of less than 0.2 units.
- *Class A*. The pH shall be within the range of 6.5 to 8.5 for freshwater or 7.0 to 8.5 for marine water with a human-caused variation within the above range of less than 0.5 units.
- *Class B*. The pH shall be within the range of 7.0 to 8.5 for marine water with a human-caused variation within the above range of less than 0.5 units.
- *Lake Class*. The water quality standards do not include a target range for pH, but lakes must have no measurable change in pH from natural conditions.

Fine Sediment

Fine sediment is governed by the narrative standards without numeric targets established in the water quality regulations. The characteristic use to be protected is wildlife habitat which must be protected from harmful fine sediment levels.

WAC 173-201A-030 (1) (vii) includes protection from fine sediment levels that would be construed as deleterious. Deleterious material concentrations shall be those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health as determined by the department (see WAC 173-201A-040 and WAC 173-201A-050).

In addition, WAC 173-201A-070 states that existing uses shall be maintained and protected and no further degradation which would interfere with, or become injurious to, existing beneficial uses shall be allowed. The section also states that whenever the natural conditions of a system are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

Historical Data Review

Several organizations have collected water quality, streamflow, geomorphology, and other data within the Deschutes River Watershed (including Capitol Lake and Budd Inlet). This section contains a brief review of prior studies by Ecology, Thurston County, Squaxin Island Tribe, USGS, city of Olympia, Weyerhaeuser Company, DNR, Natural Resources Conservation Service (NRCS), LOTT, Miller Brewing Company, and consultants that were reviewed and used to develop the 2003 and 2004 TMDL monitoring programs for the watershed.

Department of Ecology

2003 Reconnaissance Study

Ecology began a reconnaissance-level survey in summer 2003 to update older data sets and to evaluate the temperature regime and associated parameters during a low-flow year. Appendix C provides the preliminary results of the 2003 monitoring program, which are summarized below.

In the Deschutes River Watershed, the seven-day averages of daily maximum water temperature exceeded 18°C at 16 of 25 monitored locations at least once from June through September 2003. The mainstem met the standard at the Upper Deschutes Falls but exceeded the standard from 1000 Road downstream. Reichel Creek, Tempo Lake outflow, Spurgeon Creek, and Ayer Creek also exceeded standards. Most sites exhibited peak temperatures at the end of July, although the Tempo Lake outflow and one spring peaked in September and June, respectively. Discharge fell below 7Q10 levels at the USGS gage. In the Percival Creek system, water temperature exceeded 18°C except in Percival Creek upstream of the Black Lake Ditch confluence.

A seepage run, where discharge is measured at several locations along the mainstem and in tributaries by several teams over a short time period, was conducted August 5, 2003, in the Deschutes system and August 6, 2003, in the Percival system. Zones of losses and gains were identified and quantified. The data will be used in model calibration and verification.

In addition, observations of vegetation were made to ground-truth the draft vegetation datalayer, originally developed from aerial photo interpretation. Hemispherical photographs were taken of representative vegetation polygons to provide a statistically-based estimate of effective shade by vegetation type.

Ecology contracted with a consultant to provide thermal infrared (TIR) and color videography of the Mainstem Deschutes and the adjacent riparian vegetation. The helicopter-mounted equipment recorded conditions on August 20, 2003. Results will not be available until March 2004.

Ecology installed thirteen piezometers in the mainstem of the Deschutes River and recorded piezometric head and temperature at various depths below the substrate. Temperature recorders were downloaded monthly from June through October 2003.

Ecology has collected grab samples for fecal coliform bacteria analysis from six stations along the Mainstem Deschutes River, nine tributaries, Capitol Lake and four tributaries, and eight tributaries of Budd Inlet since July 2003 and will continue through December 2003. Based on six rounds of sampling analyzed as of September 2003, Spurgeon, Percival, Ellis, Indian, Mission, and two sites along Moxlie Creek exceeded the geometric mean water quality standard. Capitol Lake experienced one high value at the beginning of the program but has had low levels through September 2003. Grab samples analyzed for dissolved oxygen were below the 8.0 mg/L water quality standard at Reichel and Ayer Creeks, while pH was less than 6.5 at Ayer Creek. A subset of sites was monitored for nutrients and related parameters.

Capitol Lake fecal coliform, conductivity, nutrients, temperature, and dissolved oxygen were recorded in September 2003 along the thalweg, or deepest part of the lake (up to 4 m or 12 ft). The survey found very low fecal coliform levels. Dissolved oxygen varied from 9 to 13 mg/L, but the sites were not monitored in early morning when values would be expected to be lowest. No significant stratification was noted. In addition, dissolved oxygen will be recorded from October 13 through November 3, 2003, at the outlet from Capitol Lake to establish the daily variability of DO during the fall vegetation senescence period.

Twelve stormwater outfalls were identified with the assistance of the city of Olympia, city of Tumwater, GA, and Thurston County and visited once during dry weather conditions. Sites were selected to represent a variety of catchment land uses and to include larger tributary areas. Three pipes carried dry weather flow, and fecal coliform levels were low to moderate. Wet weather monitoring will occur from November through December 2003 when two events will be monitored two to four times over the hydrograph and analyzed for fecal coliform bacteria and nutrients.

Ambient Monitoring Program

As shown in Table 4, Ecology's EA Program has monitored water quality monthly at various sites in the Deschutes River from 1959 to present (Ecology, 2003c). Continuous temperature logging using Onset StowAway TidBits started in summer 2001 and is ongoing. Water quality parameters include: flow, conductivity, DO, pH, barometric pressure, suspended solids, temperature, turbidity, ammonia, orthophosphate, total phosphorus, total persulfate nitrogen, and turbidity. Various metals were sampled at the E Street station as well.

Table 4. Ecology Ambient Water Quality Monitoring Sites in the Deschutes River.

Station Code	Station Name	Class	Last Year Sampled	Sampling History 1960 1970 1980 1990 2000
13A050	Deschutes R @ Tumwater	A	1977	XXXXX XX X
13A060	Deschutes R @ E St Bridge	A	2003	XXXXXXXXXXXXXXXX XXXXXXXXX
13A080	Deschutes R nr Olympia	A	1977	X X X
13A150	Deschutes R nr Rainier	A	1993	XXXX X X XXXXXXXXXXXXXX X

Salmon Recovery Index Watershed Monitoring

Ecology monitors flow, water quality, and surface water temperatures in numerous watersheds as part of the Salmon Recovery Index Watershed (SRIW) program. The monitoring program supports a salmon strategy, adopted by the state of Washington, to address four major factors affecting salmon (habitat, hatcheries, harvest, and hydropower) and utilizes a science-based approach to assess the effectiveness and validity of strategy elements. One such approach is a statewide system of index watersheds to monitor long-term watershed responses.

One of the watersheds selected for index monitoring is the Deschutes River. Year-round in-situ measurements, grab samples, and stream temperature monitoring began in 2001 at three stations along the mainstem (Table 5).

Table 5. Ecology SRIW Temperature Monitoring Stations in the Deschutes River.

Station	Location	Class	River Mile	Period of Record (May-Sept)
SRIW 1302	Deschutes River at E Street Bridge	A	0.6	2001-2003
SRIW 1304	Deschutes River at Waldrick Road	A	18.0	2001-2003
SRIW 1307	Deschutes River at Woodbrook Lane	A	26.7	2001-2003

Table 6 summarizes the yearly instream temperature data for each station from 2001 to 2003 including the highest daily maximum temperatures, maximum seven-day averages, and percentage of days exceeding the 18°C temperature standard.

Table 6. SRIW Temperature Summary for the Deschutes River (2001 to 2003).

Station	Location	Year	Highest Daily Maximum Temp (°C)	Maximum 7-day Avg. of Maximum Temp (°C)	% of Days Exceeding 18°C
SRIW 1302	E Street Bridge	2001	19.9	19.2	23
		2002	19.9	19.1	17
		2003	20.9	19.9	34
SRIW 1304	Waldrick Road	2001	20.9	20.5	29
		2002	19.8	18.8	13
		2003	22.7	21.6	52
SRIW 1307	Woodbrook Lane	2001	17.7	17.2	0
		2002	20.3	19.1	17
		2003	21.0	19.9	26

In 2001 (Summers 2001), two Deschutes River stations had a relatively high percentage of days exceeding the Class A temperature standard: the E Street Bridge (23%) and Waldrick Road (30%). State officials declared water year 2001 a drought year in Washington State which likely exacerbated elevated stream temperatures within the basin.

In 2002 (Seiler et al., 2002), all three stations exceeded the Class A temperature standard of 18°C at least 13% of the time. Stations located at E Street Bridge and Woodbrook Lane exceeded the Class A temperature standard approximately 17% of the time.

The hottest instream temperatures were recorded in 2003 (unpublished data). All three stations along the Deschutes Mainstem exceeded the Class A temperature standard at least 25% of the time. The Waldrick Road station recorded a maximum daily value approaching 23°C. Flows in the Deschutes River during the 2003 summer period were less than the 7Q10 values established at the USGS stations at E Street Bridge and Vail Loop Road.

Ecology conducted monthly water quality surveys from May 2001 to September 2002 at river mile 21.6 (SRIW 1305). Sampling parameters included turbidity, total suspended solids, fecal coliform bacteria, ammonia, nitrate + nitrite, total nitrogen, total phosphorus, and orthophosphate. Hardness and dissolved metals (copper and zinc) were analyzed at each site for several months when sampling was initiated but were discontinued when the concentrations were found to be low (Seiler et al., 2002). Field measurements included dissolved oxygen, temperature, pH, and conductivity.

From May 2001 to September 2002, the Deschutes River at SRIW 1305 did not exceed Class A fecal coliform or dissolved oxygen standards. Six percent of the pH samples taken by Ecology at SRIW 1305 were below Class A standards (Seiler et al., 2002).

Suspended Sediment Transport

The goals of the Ecology study (Moore and Anderson, 1979) were to identify sources of sediment transported by the Deschutes River and to determine the quantity and significance of sediments contributed by each of the sources identified. Suspended sediment samples were collected from both automatic samplers and grab samples at approximately 13 mainstem and tributary locations, with two of the tributaries (Little Deschutes and Mitchell Creek) selected for intensive monitoring. Visual survey field techniques were used to estimate the amount of material entering the river from eroding river banks.

The results indicated that the majority of suspended sediment reaching Capitol Lake was transported over a two-month period during which a series of storms passed through the watershed. Measured flows during this storm period were found to have a recurrence interval of two years. Overall, approximately 25% of the yearly suspended sediment loads could be attributed to the eleven headwater streams, with the remainder originating either from the stream bed or the banks of the Mainstem Deschutes River.

Stream bank erosion from approximately 12 major areas within the mainstem accounted for the majority of sediment in the Deschutes River Basin. Stream bank erosion appeared to occur throughout the year with natural forces such as wind, alternating cycles of wetting and drying, and freezing and thawing contributing to erosion rates.

Thurston County

Two divisions have collected flow and water quality data within the study area.

Environmental Health Division

The Thurston County Environmental Health Division has conducted ambient monitoring of lakes and streams since 1991 including many sites within the Deschutes River, Capitol Lake, and Budd Inlet Watersheds. *In situ* and laboratory analyses include temperature, fecal coliform bacteria, DO, pH, and nutrients in various waterbodies as well as chlorophyll a, phaeophytin, and Secchi depth within Capitol Lake.

The Thurston County Environmental Health Division has measured surface water temperatures in selected locations within the Percival Creek and Deschutes River Watersheds since 1991. In-situ measurements of temperature were generally taken twice during the summer months. Table 7 summarizes surface water temperatures at 17 locations (Thurston County, 2003). The Deschutes River, Percival Creek, and Spurgeon Creek exceeded 18°C.

Table 7. Thurston County Environmental Health Division Stream Temperature Data.

Waterbody	Location	Class	Period of Record	# of Samples	Highest Daily Maximum Temp (°C) *
Ayer Creek	Off Sienna Court	A	1993-1998	11	14.7
Chambers Creek	Off Henderson Blvd	A	1991-2002	22	13.5
Deschutes River	At Weyerhaeuser 1000 Road	A	1991-1994	8	15.5
Deschutes River	At E Street Bridge	A	1992-2002	21	17.3
Deschutes River	At Henderson Blvd	A	1991-1994	8	18.0
Deschutes River	At Route 507	A	1991-1994	8	**19.0**
Deschutes River	At Rich Road	A	1991-1994	8	**19.2**
Deschutes River	At Vail Road	A	1991-1994	8	**20.5**
Hard Creek	Above confluence w/Deschutes R.	A	1991-1994	8	13.5
Huckleberry Creek	At Weyerhaeuser 1000 Road	A	1991-1994	8	16.5
Lincoln Creek	Above confluence w/Deschutes R.	A	1991-1994	8	14.2
Little Deschutes River	Above confluence w/Deschutes R.	A	1991-1994	8	16.0
Percival Creek	At footbridge	A	1991-2002	24	**18.6**
Percival Creek	At Mottman Road	A	1996-1998	6	15.9
Reichel Creek	At Vail Loop Road	A	1991-1994	8	**20.0**
Spurgeon Creek	At Rich Road	A	1991-1998	16	17.8
Thurston Creek	At Weyerhaeuser 1000 Road	A	1991-1994	8	13.5

* Bold indicates temperatures above the Class A criterion of 18°C

The Thurston County Environmental Health Division has also sampled conventional water quality parameters at selected locations within the Deschutes River, Capitol Lake, and Budd Inlet Watersheds. On average, six grab samples were taken per year since 1991. Table 8 summarizes the parameters sampled at stations relevant to the present study and the years sampling occurred (Thurston County, 2003). In addition to the samples taken at the railroad trestle on Capitol Lake, chlorophyll *a*, and phaeophytin were sampled and Secchi depth and bottom depth were measured. Thurston County Environmental Health Division has conducted additional monitoring in Capitol Lake since 1999 in cooperation with GA including conductivity, temperature, and DO profiles.

Table 8. Thurston County Environmental Health Division Water Quality Data.

Station	Period of Record	Estimated Number of Samples	Flow	Temperature	DO	Conductivity	pH	Turbidity	Fecal Coliform	Total Phosphorus	Nitrate/ Nitrite	Total Nitrogen	Ammonia
Deschutes River @ E Street	1992-2002	64	x	x	x	x	x	x	x	x	x		x
Deschutes River @ 1000 Rd	1991-1994	24	x	x	x	x	x	x	x	x	x		x
Deschutes River @ Henderson Ave	1991-1994	28	x	x	x	x	x	x	x	x	x		x
Deschutes River @ Hwy 507	1991-1994	24	x	x	x	x	x	x	x	x	x		x
Deschutes River @ Rich Rd	1991-1994	26	x	x	x	x	x	x	x	x	x		x
Deschutes River @ Vail Rd	1991-1994	22	x	x	x	x	x	x	x	x	x		x
Reichel Creek @ Vail Loop Rd	1991-1994	24	x	x	x	x	x	x	x	x	x		x
Ayer (Elwanger) Creek off Sienna Ct	1993-1998	30	x	x	x	x	x	x	x	x	x		x
Mission Creek @ East Bay Drive	1993-1998	36	x	x	x	x	x	x	x	x	x		x
Indian Creek @ Quince Ave	1993-1998	32	x	x	x	x	x	x	x	x	x		x
Capitol Lake @ Railroad Trestle	1996, 1999-2003	NA	NA	x	x	x	x		x	x		x	
Moxlie Creek @ Plum St & Henderson	1991-1998	48	x	x	x	x	x	x	x	x	x		x
Moxlie Creek @ East Bay Drive	not monitored												
Adams Creek @ Boston Harbor Rd	1993-1994	11	x	x	x	x	x	x	x	x	x		x
Butler Creek @ French Loop Rd	1993-1998	36	x	x	x	x	x	x	x	x	x		x
Chambers Creek off Henderson Blvd	1991-2002	71	x	x	x	x	x	x	x	x	x		x
Ellis Creek @ East Bay Dr	1993-1998	36	x	x	x	x	x	x	x	x	x		x
Percival Creek @ Foot Br	1991-2002	71	x	x	x	x	x	x	x	x	x		x
Percival Creek @ Mottman	1996-1998	18	x	x	x	x	x	x	x	x	x		x
Huckleberry Ck @ 1000 Rd	1991-1994	24	x	x	x	x	x	x	x	x	x		x
Black Lake outlet at Belmore Rd	1993	1	x							x			
Black Lake Ditch nr Percival Confluence	not monitored												
Schneider Creek @ West Bay Dr	1993-1998	35	x	x	x	x	x	x	x	x	x		x
Spurgeon Creek off Rich Road	1991-1998	48	x	x	x	x	x	x	x	x	x		x

Department of Water and Waste Management

The Department of Water and Waste Management has collected continuous stream temperature data in Percival Creek, Black Lake Ditch, and Chambers Creek since 2002 (Table 9). The highest daily maximum stream temperatures in Percival Creek and Black Lake Ditch were 21.9°C and 24.9°C, respectively. No violations of the Class A temperature standard were recorded in Chambers Creek.

Table 9. Thurston County Department of Water and Waste Management Stream Temperature Data.

Waterbody	Location	Class	Period of Record	Highest Daily Maximum Temp (°C)	Maximum 7-Day Avg of Daily Maximum Temperature (°C)
Percival Creek	Jones Quarry Bridge	A	7/02-9/03	21.9	21.7
Chambers Creek	At Rich Road	A	8/02-9/03	17.6	17.6
Black Lake Ditch	Near confluence with Percival Creek	A	1/03-8/03	24.9	24.7

The Department of Water and Waste Management currently operates three stream gaging stations within the WRIA 13 study area. Flow data for Chambers Creek, Black Lake Ditch, and Percival Creek are available for years 2002-2003 (Thurston County, 2003b).

In 2001, the Department of Water and Waste Management conducted a groundwater inflow study in the mainstem of the Deschutes River (Thurston County 2002). The study area encompassed approximately 39 miles (63 km) of the mainstem from Tumwater Falls to Deschutes Falls. Study methods included the short-term placement of several piezometers, a seepage run which included discharge measurements at 22 locations along the river and its tributaries, and a stream survey to identify seeps, springs, and losing reaches of the mainstem.

The study found that although some spring concentrations are well correlated with geological features, gains and losses of flow from the Deschutes River varies greatly and sometimes over a short distance. The three major areas of groundwater inputs to the river included the area just north of State Highway 507, the area just north of Offutt Lake, and in the vicinity of Rich Road and Henderson Boulevard.

Stream Corridor Management Plan for the Deschutes River

The Thurston County Conservation District commissioned a riparian stream corridor study to investigate water quality in the Deschutes River as it related to erosion and sedimentation (McNicholas, 1984). The study sought to identify and quantify the sources of sediment filling Capitol Lake and to develop a comprehensive stream corridor management plan which would outline economically and environmentally feasible management techniques for treatment of the sediment source sites.

Direct observation of erosion sites was accomplished by floating and hiking approximately 40 miles (60 km) of the Mainstem Deschutes River from Tumwater Falls to the headwater section just downstream of Deschutes Falls. Approximately 140 eroding banks were recorded totaling 53,375 ft (16,269 m). Field estimates were made for dimensional data, including length, height, annual lateral recession, and soil composition of the streambank. An estimated 34,791 cubic yards (26,600 m^3) were eroding from these 140 sites annually, with 78% of the material consisting of fine sands, silts, and clays.

The study hypothesized at the outset that increased overall streamflow in the Deschutes Basin was the result of extensive clearcut logging which in turn contributed to increased streambank erosion and sedimentation in Capitol Lake. A hydrologic model of ten-year peak flows was constructed for twelve subwatersheds within the Deschutes Basin using the Runoff Curve Number (RCN) methodology. At the time, RCN was a commonly used method for determining runoff volumes in small basins by incorporating soil type, slope, land use, and land treatment. The ten-year peak flows were calculated for past (1966), present (1981), and future basin conditions. These predicted flows were combined with the historical sediment load characteristics (Nelson, 1974) to generate sedimentation rates for the basin in tons/yr. The model predicted ten-year peak flows of 6,092 cfs (173 cms), 6,592 cfs (187 cms), and 7,593 cfs (215 cms) for past, present, and future scenarios and concomitant sedimentation rates of 38,000 tons/yr (21,216 m^3/yr), 50,000 tons/yr (27,906 m^3/yr), and 65,000 tons/yr (36,507 m^3/yr).

Samples of Capitol Lake sediments were analyzed to determine if sedimentation patterns would indicate a change in river discharge and confirm the study hypothesis. In the upper basin, near the outlet of the Deschutes, sediments were found to be composed of sands and coarse gravels. Since the presence of coarse gravels at this location had not been mentioned in any previous survey, the study concluded that the appearance of these coarse gravels indicated an increase in stream energy (flow) at the time of the study.

Squaxin Island Tribe

1995 Summer Temperatures

The Squaxin Island Tribe monitored stream temperatures at six locations along the Mainstem Deschutes River during the summer and fall of 1995 (Table 10) (Schuett-Hames and Child, 1996). Continuous stream and air temperature data was recorded using HOBO XT digital temperature loggers. Data on stream temperature were collected using standard TFW protocols (Rashin et al., 1994).

Table 10. Stream Temperature Data for Deschutes River Monitoring Stations (Summer 1995).

Location	Sampling Period	Total Days Standard Exceeded	Longest Continuous Period Exceeding 18°C	Maximum Water Temperature (°C)
E Street Bridge	June 20 -Sept 18	54	14.5 hrs	22.6
Waldrick Road SE	June 22 - Sept 20	32	44.5 hrs	22.1
Near Western Junction	June 22 - Sept 20	27	69.5 hrs	21.6
Route 507	July 17 - Sept 26	20	18 hrs	22.0
Vail Loop Road	June 23 - Sept 21	38	42 hrs	23.1
Driftwood Valley Road	June 23 - Sept 21	25	18 hrs	20.9

Water temperatures at all six stations frequently exceeded the Class A temperature standard of 18°C during the summer period. The maximum temperatures observed were above the optimal range of salmonids (12 to 14°C) and were approaching the lethal range of 23 to 29°C (Bjornn and Reiser, 1991).

Mean monthly discharge for the Deschutes River at Vail Loop Road was 44 cfs (1.3 cms) in July 1995, compared to a mean July discharge of 55 cfs (1.6 cms) from 1949 to 1994. Mean monthly discharge was 34 cfs (0.96 cms) for August 1995 at Vail Loop Road compared with a mean of 40 cfs (1.1 cms) from 1949 to 1994. The authors speculated that the somewhat lower flows (approximately 80% of the mean) observed in the summer of 1995 could have contributed to the large number of temperature exceedences observed through reductions in water depth and volume of water to be heated.

Monitoring of the Upper Deschutes Watershed

During 1989 and 1991, the Squaxin Island Tribe's Natural Resources Department and the Northwest Indian Fisheries Commission collected information on the condition of stream channels and salmon habitat in the Upper Deschutes River Watershed (Schuett-Hames et al., 1991). The study included portions of the Deschutes River and many tributaries including Buck, Fall, Hard, Huckleberry, Johnson, Lewis, Lincoln, Mine, Mitchell, Thurston, and Ware Creeks, and the West Fork Deschutes River. Information on the length of active streambank erosion and the area of active streamside mass wasting features (landslides) was collected.

High rates of active streambank erosion were observed in many of the stream reaches surveyed. Bank cutting rates of over 500 meters of bank per 1,000 meters of stream were observed in segments of Fall Creek, Huckleberry Creek, Johnson Creek, Mitchell Creek, Thurston Creek, and the Mainstem Deschutes River. Natural factors, including the geomorphic setting of the stream, the composition of bank materials and their relatively low resistance to the cutting action of the stream, and the recent scouring of streambanks by debris flows appeared to have contributed to the high rate of bank cutting.

Channel Erosion along the Deschutes River

The goal of the study, prepared in 1994 for the Squaxin Island Tribe Natural Resources Department, was to improve the understanding of sediment sources and delivery in the Deschutes River by looking at the geological and geomorphic processes at work in the basin and to examine land-use patterns contributing to sediment mobility (Collins, 1984). The study set out to conduct a historical analysis of bank erosion, channel widening, and channel migration, evaluate the sensitivity of bank materials and streamside landforms to erosion, evaluate variation in coarse sediment supply from mass wasting, and to prepare an integrated analysis of bank erosion in the Deschutes River.

The study found that tributaries contributing sediment to the Deschutes River are upstream of RM 35 and that they contribute an estimated 1,000 yd^3/yr of sediment to the system. Thirty-nine major landslides were found to have introduced an estimated 38,000 yd^3 of sediment since 1966. Suspended sediment transport from all tributaries was estimated to contribute 11,000 t/yr between 1976 and 1987. Sediment from the headwaters accounts for roughly 20% of the river's suspended sediment load.

The report also found that the mainstem channel had not widened systematically since 1941; however, localized erosion did exist. There were 127 eroding banks found for the 1981 to 1991 time period which accounted for 53% of the mobilized sediment. These sites mobilized an estimated 870,000 yd^3 of sediment of which 350,000 yd^3 was sediment influx from stream terraces with the remainder being remobilized from stream deposits. Roughly 28,000 yd^3/yr was contributed as suspended sediment. The estimated rate of bedload aggradation between 1977 and 1993 is 1,000 to 7,000 yd^3/yr, which was likely to be concentrated in a total of ten river miles upstream of RM 30.

The study concluded that the dominant causes of channel erosion along the Deschutes River were geologic and topographical. Bank erosion rates were found to be slightly higher than natural due to land-use activities in the watershed. The report also found that bank erosion had not increased systematically over the last 50 years. While natural bank erosion was found to be the dominant source of sediment delivery in the Deschutes River, the report stated that opportunities did exist to reduce sediment mobility by improving riparian management in the agricultural and forestry sectors.

U.S. Geological Survey

The USGS has gaged discharge on the mainstem of the Deschutes River at Rainier (gage no. 12079000) and near the mouth at the E Street Bridge (gage number 12080010) since 1949 and 1945, respectively. Historically, USGS also monitored the Deschutes River at Olympia (gage no. 12080000), but the location was discontinued in 1964. Average annual flows are 263 cfs (7.5 cms) and 406 (11.5 cms) cfs at Rainer and E Street, based on the period from 1950 to 2001 and 1946 to 2001, respectively. USGS estimates for the seven-day average low flow with a ten-year recurrence interval (7Q10) at Rainer are 24.0 cfs (0.68 cms), based on the period 1949 to 2001. The estimated 7Q10 at E-Street Bridge based on the period 1946 to 2002 is 64.1 cfs (1.8 cms) (D. Kresch, Personal Communication).

The USGS has conducted numerous recent hydrologic studies of the Deschutes River Watershed and surrounding environs (Nelson, 1974; Drost et al., 1998; Drost et al., 1999). Nelson (1974) presented the results of a reconnaissance evaluation of fluvial-sediment transport in the Deschutes and Nisqually River Basins. Discharge and suspended sediment data collected at three sites in the Deschutes River Basin were used to establish relationships between instantaneous suspended-sediment concentration and discharge. The study found that much of the sediment transported from the Deschutes River Basin originated in the mountainous southeastern part of the basin primarily due to the greater precipitation and steeper gradients which cause higher and rapid runoff. In general, stream channels within the Deschutes Basin were found to be fairly stable with only minor areas of bank undercutting and sloughing.

Drost et al. (1998) evaluated the hydrology and groundwater quality of northern Thurston County in support of the county's groundwater management area program. The study both updated and refined the hydrologic interpretations of the area originally presented by Noble and

Wallace (1966). Based on groundwater head data collected in 1988-89, the study found that area groundwater generally moves laterally from upland recharge areas toward natural points of discharge along the marine shoreline and the Lower Deschutes River. This interpretation is further supported by seepage studies conducted in August 1988 (Drost et al., 1998) and October 2001 (Thurston County, 2002) which showed that groundwater discharge adds significant flow to the Lower Deschutes River.

Weyerhaeuser Company

Weyerhaeuser Company detailed sediment, temperature, and fish habitat within the Upper Deschutes Watershed using water quality and flow data collected between 1975 and 1986 (Sullivan et al., 1987). Stream temperature was measured each year from May through September at four gaging stations in Hard, Ware, and Thurston Creeks, and along the Deschutes Mainstem at 1000 Road. In addition, air temperature was recorded at the Thurston Creek and Deschutes River sites. Table 11 presents the maximum seven-day average water and air temperatures for each location.

Table 11. Maximum Seven-Day Water Temperatures (°C) in the Deschutes River, Thurston Creek, Ware Creek, and Hard Creek (1975 to 1986).

Year	Air Temperature (Deschutes and Thurston Basins)	Deschutes River (1000 Rd)	Thurston Creek	Air Temperature (Hard and Ware Basins)	Ware Creek	Hard Creek
1975	21.2	21.2	17.8	21.8	10.6	10.6
1976	23.2	19.8	16.1	17.2	10.2	10.3
1977	26.8	21.8	17.9	26.8	11.2	12.8
1978	26.1	21.6	17.8	26.6	11.2	10.3
1979	24.9	22.1	17.0	23.0	11.0	11.0
1980	19.4	20.6	13.9	20.7	11.3	10.5
1981	27.2	21.8	16.1	26.8	15.2	12.0
1982	25.0	20.2	17.1	23.9	18.0	11.8
1983	20.1	18.9	15.5	20.0	16.5	11.6
1984	20.7	20.3	18.0	21.0	19.1	13.4
1985	20.0	21.1	17.2	22.2	19.3	12.8
1986	23.0	20.1	17.0	23.2	19.1	12.1

Department of Fish and Wildlife

WDFW monitored the intake and outflow from its Tumwater Falls facility from April 29, 2002, through June 20, 2002. Total phosphorus of the intake and effluent averaged 0.07 mg/L (Eltrich, Personal Communication). The Percival Cove facilities were monitored from April 29, 2002, through May 30, 2002. Total phosphorus averaged 0.05 mg/L within and outside of the net pens (Eltrich, Personal Communication). No sampling plan or summary report were prepared.

Department of Natural Resources

The DNR conducted a study for Ecology to document slope stability factors in the Upper Deschutes River Basin and to provide a guide for the study of slope failure contributions to basin runoff turbidity (Thorsen and Otherberg, 1978). The mapping and field exercises documented landslides within the upper basin and examined their role in sediment production from forest lands.

The study concluded that although landslides comprise a significant percentage of the land surface in the Upper Deschutes, they are not contributing any more to the river sediment load than similar areas of undisturbed land. It was also determined that because of the relatively small amount of material that has failed and the even smaller amount that reaches streams, the actual volume of sediment contributed is insignificant. Dry flow landslides (the collapse and/or dry flowage of relatively noncohesive glacial terrace materials) were thought to be the primary source of sands and silts within the Mainstem Deschutes. The study did not inventory all dry flow landslides; however, most slides were located along the outside bend of the tight curves along the mainstem of the river.

Natural Resources Conservation Service

The NRCS personnel have evaluated local erosion sites, designed management measures, and worked with local landowners to implement sediment-control programs throughout the Deschutes River Watershed.

Lacey, Olympia, Tumwater, and Thurston County Wastewater Alliance

LOTT initiated the Budd Inlet Scientific Study (Aura Nova Consultants, Inc. et al., 1998) to determine whether the plant could discharge to the inlet without adversely affecting water quality. The study included monitoring and modeling of dissolved oxygen, fecal coliform bacteria, and nutrients within Budd Inlet but also characterized the Deschutes River, Percival Creek, and Capitol Lake. Monitoring data included tributary discharge, fecal coliform, temperature, nutrients, DO, and BOD; inlet water column currents, stratification, nutrients, plankton, dissolved oxygen, and fecal coliform bacteria; and inlet sediment/water flux parameters.

Edinger Associates, Inc., developed the three-dimensional hydrodynamic model using the generalized longitudinal lateral and vertical hydrodynamic and transport model (GLLVHT) (Edinger and Buchak, 1980). The model uses a quasi-curvilinear grid with cell size varying with location within the inlet; layer thickness varies with depth. The water quality model, carbon-based 3-D water quality model for Budd Inlet (WQ3DCB_BI), is based on the EPA eutrophication model EUTRO5 with additional capabilities to simulate nutrient and organic matter cycling not included in the EPA model (Edinger and Buchak, 1995). The model includes phytoplankton production, nitrogen, phosphorus, dissolved oxygen, carbonaceous oxygen demand, and organic carbon. In addition, the effort used the Ocean Margin Exchange nutrient diagenesis (OMEXDIA) model to simulate sediment processes including nitrification, denitrification, oxic and anoxic mineralization, and transport. To simulate the hydraulic effect of the Capitol Lake outlet structure, the effort developed a routing model based on conservation of mass.

The hydrodynamic and water quality models were calibrated to June 25, 1997, through September 15, 1997, and verified with January 25, 1997, through June 24, 1997, using data collected for the project. The dissolved oxygen simulation had a root-mean square error of 2 to 3 mg/L with a tendency to over-predict low levels in both the calibration and verification.

Miller Brewing Company

Miller Brewing Company monitored Capitol Lake and its inflows and developed hydrodynamic and water quality models of the lake as part of an evaluation of wastewater treatment alternatives (CH2MHill, 2001). The October 2000 through June 2001 monitoring program included lake and tide water levels, currents between basins, bathymetry, monthly water quality profiles and grab samples[3], a tracer study, diurnal variations in DO and pH, dry-weather sedimentation rates using traps in the south and middle basins, and a macrophyte biomass survey.

The study found that while phosphorus likely controls productivity most of the year, nitrogen may control productivity during the critical summer period. Plants, primarily macrophytes, reduce nitrate and orthophosphate concentrations in the middle basin as compared with the south. The macrophyte survey found that *Elodea* covered 75% to 90% of the middle basin. Macrophytes contribute 6 to 100 times the primary productivity as compared with phytoplankton in water depths within macrophyte growth ranges. Biomass ranged from 40 to 519 g/m^2.

The study also indicated likely nitrogen and phosphorus release from the sediments due to microbiological activity. The south and middle basins exhibited diurnal DO and pH variations of up to 4 mg/L and 1.5 SU, respectively, while the north basin varied irregularly. Continuous data indicate that all three basins exceeded a pH of 8.5 SU. Sedimentation accumulation rates were 127 and 172 g/m^2/day for the south and middle basins, or 1.9 and 2.6 cm/yr for a low-flow period.

Sources of Pollution

Temperature

The Deschutes River and Percival Creek temperature TMDLs will be developed for heat (i.e., incoming solar radiation). Heat is considered a pollutant under Section 502(6) of the Clean Water Act. The transport and fate of heat in natural waters has been the subject of extensive study. Edinger et al. (1974) provide an excellent and comprehensive report of this research. Thomann and Mueller (1987) and Chapra (1997) have summarized the fundamental approach to the analysis of heat budgets and temperature in natural waters that will be used in this TMDL. Figure 2 shows the major heat energy processes or fluxes across the water surface or stream bed.

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[3] Parameters include BOD5, hardness, chlorophyll a and phaeophytin, conductivity, turbidity, DO, pH, temperature, flow, depth, ammonia, total Kjeldahl nitrogen, nitrate, nitrite, total suspended solids, total dissolved solids, orthophosphate, total phosphorus, fecal coliform, fecal streptococcus, and enterococcus from the Deschutes River, Capitol Lake, Percival Creek, a wetland lagoon, the brewery’s condenser water, and the Custer Avenue storm drain.

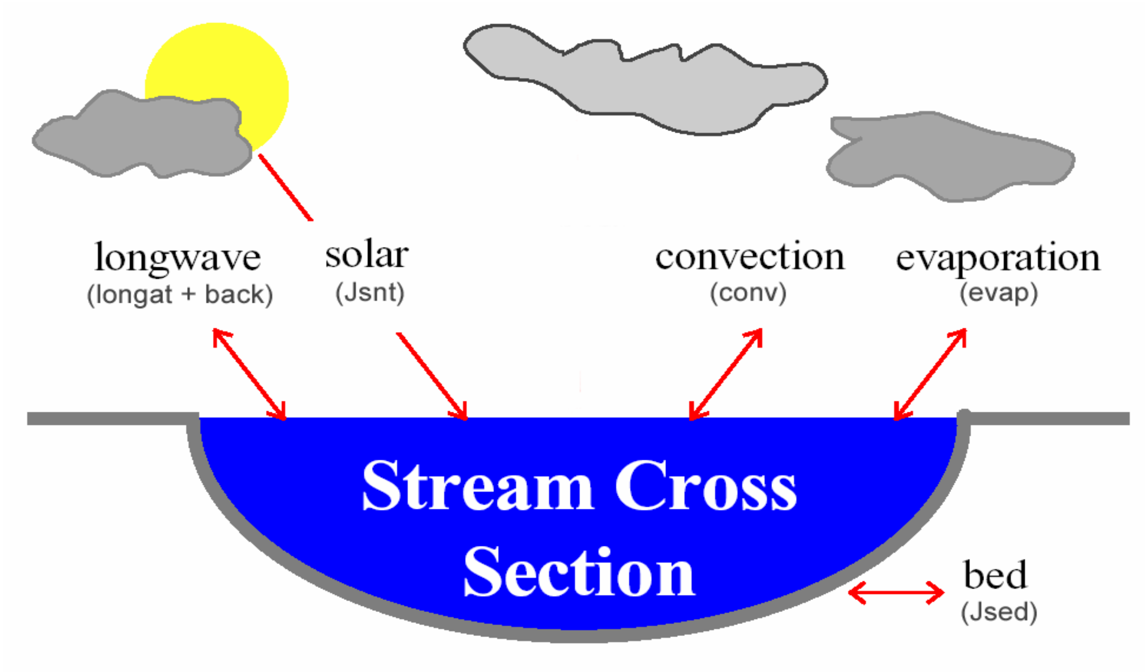

Figure 2. Surface Heat Transfer Processes that Affect Water Temperature.

Adams and Sullivan (1989) reported that the following environmental variables are the most important drivers of water temperature in forested streams:

- *Stream Depth*. Stream depth is the most important variable of stream size for evaluating energy transfer. Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.

- *Air Temperature*. Daily average stream temperatures are strongly influenced by daily average air temperatures. When the sun is not shining, the water temperature in a volume of water tends toward the dewpoint temperature (Edinger et al., 1974).

- *Solar Radiation and Riparian Vegetation*. Net radiation is dominated by the amount of direct-beam solar radiation that reaches the stream surface and this, in turn, is affected by the amount of shade producing vegetation near the stream. The daily *maximum* temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily *average* temperatures are less affected by removal of riparian vegetation. Discharge is an important variable that determines the temperature response to solar radiation; larger streams gain heat more slowly than smaller streams.

- *Groundwater*. Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream and the difference in temperatures between the groundwater and the stream.

The heat exchange processes with the greatest magnitude are as follows (Edinger et al., 1974):

- *Shortwave Solar Radiation*. Shortwave solar radiation is the radiant energy that passes directly from the sun to the earth. Shortwave solar radiation is contained in a wavelength range between 0.14 µm and about 4 µm. The peak values during daylight hours are typically about three times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.

- *Longwave Atmospheric Radiation*. The longwave radiation from the atmosphere ranges in wavelength from about 4 µm to 120 µm. Longwave atmospheric radiation depends primarily on air temperature and humidity and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm, cloudy days. The daily average heat flux from longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes.

- *Longwave Back Radiation from the Water to the Atmosphere*. Water sends heat energy back to the atmosphere in the form of longwave radiation in wavelengths ranging from about 4 µm to 120 µm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from longwave back radiation typically ranges from about 300 to 500 W/m^2.

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation are well documented (for example Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982; Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al. (1992); Beschta et al. (1987); Bolton and Monahan (2001); Castelle and Johnson (2000); CH2MHill (2000); GEI (2002); Ice (2001); and Wenger (1999). All of these summaries of the scientific literature indicate that riparian vegetation plays an important role in controlling stream temperature. The important benefits that riparian vegetation has upon the stream temperature include:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.

- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.

- Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land cover type and condition by affecting floodplain and instream roughness, contributing coarse woody debris and influencing sedimentation, stream substrate composition, and stream bank stability.

Rates of heating to the stream surface can be dramatically reduced when high levels of shade are produced and heat flux from solar radiation is minimized. There is a natural maximum level of shade that a given stream is capable of attaining, which is a function of species composition, soils, climate, and stream morphology.

Lakes and wetlands can be sources of heat to the receiving stream or river. Shallow lakes occupy the headwaters of many tributaries of the Deschutes River, as well as Percival Creek and Black Lake Ditch. The stream is cooled in the downstream direction via groundwater inflow as well as input from cooler spring-fed tributaries. The amount of downstream cooling depends on groundwater and tributary inflow temperatures and volume, and the amount of riparian vegetation available to reduce solar radiation and prevent additional heating.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Mass transfer processes refer to the downstream transport and mixing of water throughout a stream system and inflows of surface water and groundwater. The downstream transport of dissolved/suspended substances and heat associated with flowing water is called advection. Dispersion results from turbulent diffusion that mixes the water column. Due to dispersion, flowing water is usually well mixed vertically. Stream water mixing with inflows from surface tributaries and subsurface groundwater sources also redistributes heat within the stream system. These processes (advection, dispersion, and mixing of surface and subsurface waters) redistribute the heat of a stream system via mass transfer. Turbulent diffusion can be calculated as a function of stream dimensions, channel roughness, and average flow velocity. Dispersion occurs in both the upstream and downstream directions. Tributaries and groundwater inflows can change the temperature of a stream segment when the inflow temperature is different from the receiving water.

The TMDL technical assessment for the Deschutes River and Percival Creek will use riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream will be calculated in the TMDL in a heat budget that accounts for surface heat flux and mass transfer processes. Heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade will be used as a surrogate to thermal load as allowed under EPA regulations (defined as "other appropriate measure" in 40 CFR §130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Other factors influencing the distribution of the solar heat load also will be assessed including increases in the wetted width-to-depth ratios of stream channels. The effect of both varying streamflow levels and groundwater inflows will be assessed in this study.

The *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program* (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional 'pollutant,' the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not."

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

Nonpoint Sources

The water quality standards use fecal coliform bacteria as indicators of pathogenic organisms associated with fecal contamination. Fecal coliform bacteria are produced in the gut of warm-blooded mammals and are present in high concentrations in fecal material. Potential sources of fecal coliform bacteria include humans, domestic animals, and wildlife. Fecal contamination of water is of concern as a human public health threat via incidental ingestion during recreation as well as via direct consumption.

Humans may contribute to nonpoint source fecal contamination via improperly maintained, poorly located, or failing septic systems. Properly functioning septic systems allow solids to settle to the bottom of a tank where they are partially decomposed (Thurston County Public Health and Social Services Department, 2004). If solids accumulate and the tank is not pumped on a regular basis, the settling capacity of the tank is reduced and solids may flow out of the tank with the effluent. In a conventional septic system, the septic tank effluent flows to a drainfield, which is a network of perforated pipes set in gravel-filled trenches. Final treatment of the sewage effluent occurs through biological activity and physical filtration within the gravel trenches and in the unsaturated soil beneath the drainfield. Inadequate inspection and maintenance of a septic system, over use, and physical disturbance represent a few factors that can contribute to system failure. When a system fails, the treatment process is incomplete and nutrients, bacteria, and other contaminants in sewage can reach groundwater, streams, or lakes before levels are attenuated.

Human waste can reach streams directly or indirectly through sewer infrastructure exfiltration or from recreational users. Leaks in sewer systems occur as the infrastructure ages and as surrounding soils are disturbed by construction or by tree roots. Recreational users may contribute nutrients and bacteria due to improper waste disposal practices.

Domestic animals, such as dogs and cats, may contribute to nonpoint source fecal coliform bacterial contamination when owners fail to clean up after pets. Stormwater runoff may suspend the fecal matter in impervious areas and transport it to the stormwater infrastructure or in pervious areas as overland flow to surface water features. Domestic animals such as horses, cows, and sheep may contribute via overland flow during storms, unmanaged animal access, or from improper manure storage and disposal.

Birds and other wildlife may contribute directly to waterbodies or indirectly via overland stormwater runoff. Unless wildlife populations have increased due to anthropogenic activities, wildlife contributions are considered natural background conditions which may be quantified in the TMDL but not decreased.

Nonpoint sources also may contribute to DO or pH impairments. Depressed DO may result from increased nutrient loads that stimulate algae growth, referred to as productivity. The decomposition of dead algae and other organic matter consumes dissolved oxygen. Productivity may be limited by a specific nutrient, generally phosphorus in streams and nitrogen in marine waterbodies, by light to fuel photosynthesis, or by retention time in a waterbody.

Activities or mechanisms that produce nutrients or enhance nutrient transport include the following:

- Septic systems.
- Stormwater runoff from paved and pervious lands.
- Improper manure storage or disposal from commercial and non-commercial agriculture.
- Vegetation removal without erosion control from construction areas or forest harvest.
- Channel bank erosion or bed scour due to high flows or constrained reaches.
- Poor fertilizer and irrigation water management.
- Removal of riparian zone vegetation.

In addition to natural filtering of pollutants through riparian vegetation, streamside trees also reduce solar radiation reaching the stream surface, which may limit algal growth.

The diel cycle of algal growth adds DO during the daylight hours as the plants photosynthesize, but reduces DO levels to a natural minimum around daybreak as respiration occurs. Enhanced growth increases the daily variation resulting in lower levels of DO than would have resulted under natural conditions. These same processes affect pH.

Algae and other aquatic plants consume CO_2 during photosynthesis reducing the amount of CO_2 and bicarbonate in the water. Alkalinity stays essentially constant while pH responds by increasing. This process is exacerbated as more sunlight reaches the stream and as temperatures and nutrient concentrations increase. The pH in streams with high algal productivity typically increases during the daylight hours to its maximum around mid to late afternoon and returns to near background levels at night when plants are respiring and not taking carbon out of the water. This diel swing, like DO, can be dramatic enough to increase the daily high and/or decrease the daily low pH of streams and lakes beyond state standards.

In addition, the pH of rain in western Washington is 4.8 to 5.1 (NADP/NATN, 2004). Therefore, stormwater may have a low pH due to regional atmospheric rather than local watershed conditions. Wetland systems also affect pH by enhancing natural decomposition processes, which results in acidic pH levels.

Anthropogenic activities can lower pH as well. For example, decomposing organic material, such as that found in logging slash, and even acid deposition can lower pH below state standards. Some streams have a naturally low buffering capacity, which makes them more susceptible to pH changes. These streams can have both low and high pH in the same stretch, though often during different times of the year.

Natural sources and mechanisms affect DO and pH as well. The high residence time and high organic matter loading in wetlands, for example, produce low DO and pH levels. Many wetland complexes exist within the Deschutes River system and may contribute to the low levels recorded in the mainstem and the tributaries.

Marine DO levels are affected by nonpoint source nutrient loads from the Deschutes River and other direct tributaries, as well as from the enhanced organic matter loads from Capitol Lake. The flushing rate and water clarity also affect Budd Inlet DO levels.

Point Sources

Several point sources discharge to Budd Inlet, Capitol Lake, or the Deschutes River under NPDES permits. These include both individual and general permits, which are listed in Table 12. Olympia, Tumwater, Lacey, Rainier, and portions of unincorporated Thurston County have been identified tentatively as entities that must receive coverage under the NPDES Phase II municipal stormwater permit program, which Ecology expects to develop by the end of 2004. As discussed above, WSDOT has applied for a statewide NPDES municipal stormwater permit to cover all WSDOT facilities; WSDOT's current Phase I municipal stormwater permit does not cover activities within the project study area.

Table 12. Permitted Surface Water Dischargers in the Budd Inlet Watershed

Permittee	Permit Number	Type of Discharge	Relevant Parameters
Individual Permits			
LOTT	WA0037061	Municipal wastewater**	Fecal coliform, nutrients, DO, BOD
Boston Harbor*	WA0040291	Municipal wastewater	Fecal coliform, nutrients, DO, BOD
Tamoshan	WA0037290	Municipal wastewater	Fecal coliform, nutrients, DO, BOD
Seashore Villa	WA0037273	Municipal wastewater	Fecal coliform, nutrients, DO, BOD
Miller Brewing Co.	WA0001309 (discontinued)	(noncontact cooling water and stormwater)	(discontinued)
Beverly Beach	(discontinued)	(municipal wastewater)	(discontinued)
Port of Olympia	WA0040533	Contaminated groundwater	None (toxics only)
General Permits			
Sand and Gravel	general; 3 facilities	Sand and gravel operations process and stormwater	turbidity, TSS, pH, temperature
Industrial Stormwater	general; 10 facilities	Industrial operations stormwater	pH, BOD5, TSS, ammonia
Stormwater/Construction	general; 9 facilities	Construction site stormwater	pH, turbidity
Dairy	general; 1 facility	All dairy process water and stormwater	Fecal coliform, nutrients

* Discharge at northern boundary of Budd Inlet
** Includes discharges through the Fiddlehead outfall

Wastewater treatment plants contribute treated wastewater. Treated effluent contains fecal coliform bacteria, solids, nutrients, dissolved oxygen, and biochemical oxygen demand (BOD). A small portion of the area served by the LOTT wastewater treatment plant also directs stormwater to the facility. Hydraulic relief points in the system can discharge mixed stormwater and wastewater when the capacity of the system is exceeded, resulting in combined sewer overflows (CSOs). Stormwater can also result in a loss of treatment efficiency. CSOs are a source of biological, chemical, and aesthetic pollution including fecal coliform bacteria, solids, nutrients, dissolved oxygen, and BOD at higher levels than in treated wastewater.

The Miller Brewing Company discharged noncontact cooling water and stormwater to the Deschutes River under NPDES permit number WA0001309 through six separate outfalls near Tumwater Falls. The facility discontinued production and closed June 30, 2003. All cooling water discharges ceased by June 30, 2003, at which time the permit status changed to inactive. Stormwater discharge will continue from the site. If the facility were to resume operation, the permit authorizes discharge of noncontact cooling water only. Cooling water flows were not limited but were about 2.3 mgd. All process wastewater was discharged to the LOTT plant under a separate pretreatment permit administered by LOTT.

Nine facilities have industrial stormwater permits through the Industrial Stormwater General Permit. Permit conditions relate to site best management practices rather than to site-specific conditions. The permit includes the provision in S3.D.1. that "[n]ew facilities that discharge either directly or indirectly via a stormwater conveyance system to waters listed as impaired by the State under Section 303(d) of the Clean Water Act must comply with the State's water quality standards for the named pollutant(s) at the point of discharge…. All new discharges must be in compliance with any applicable TMDL determination."

Currently, ten facilities have stormwater construction permits through a general permit. Sites must follow the requirements of the general permit, and no site-specific information is included. No provision for discharges to impaired waters is included, but section S5 states that the "…permittee is responsible for achieving compliance with state of Washington surface water quality standards…."

Three facilities operate under the Sand and Gravel General Permit. Section S1.D.1.b. states that "Ecology will not provide coverage under this general permit when … the facility discharges to a water body with control plans that the general permit does not adequately address." Control plans include TMDL determinations.

One facility operates under the Dairy Operations General Permit. However, in summer 2003, the facility sold the herd and the site may be inactive. The facility had received a penalty in 2000 and a warning letter in 2002. Another dairy previously operated in the Ayer (Elwanger) Creek subwatershed, but the facility was inactive as of October 2000. The Department of Ecology administers the general permit to cover dairy operations. As of July 1, 2003, the jurisdiction was transferred to the Washington State Department of Agriculture (WSDA) under the Livestock Nutrient Management Program. However, until EPA delegates permit authority to WSDA, Ecology will continue to administer the permit, with inspections performed by WSDA. The current general permit does not cover specific provisions relating to a TMDL, but facilities cannot discharge process waters to surface waterbodies except under catastrophic conditions. Facilities must be "… designed, constructed, and operated to treat all process generated wastewater plus the runoff from a 25-year 24-hour rainfall event…."

The WDFW also operates four net pens in Percival Cove within Capitol Lake. WDFW expected to move the operations to an upland facility, but the project was not funded by the legislature. Currently, Ecology is determining a date by which the facilities must cease operations. Ecology has not issued a permit for the current Percival Cove facilities.

Fine Sediment

Stream sediment results from erosion that may be part of a natural process or one influenced by anthropogenic activities. It can be difficult to identify sediment sources and to distinguish natural from human-caused sources. River channels reflect all the processes operating within their drainage basins. These processes are controlled by climate, geology, regional topography, soils, vegetation, and human land-use practices.

Landslides are a natural part of the landscape, especially in areas of steep slopes and abundant rainfall. Shallow landslides typically occur in very steep terrain. The delivery of large amounts of sediment can result from the failing of unstable slopes. These events can overwhelm the capacity of the channel to transport sediment downstream, which can lead to channel widening, bank erosion, and the shallower water depths. There is evidence that clear-cut logging and forest roads substantially increase landslide rates in most drainage basins (Jones and Grant, 1996; Naiman and Bilby, 1998; Robinson et al., 1999; Spence et al., 1996; and Swanson et al., 1998). Timber harvest on steep terrain increases the likelihood of shallow landslides as the roots rot (typically around four years post-harvest) until the roots of the new vegetation have become established enough to hold the soil in place.

Road building can also increase the likelihood of mass movements by further destabilizing hillslopes, often undercutting the lower part of a slide or adding weight to the top of a slide. A study of debris torrents in two western Oregon watersheds indicated that roads triggered torrents at 40 to 167 times natural rates and clear-cuts initiated torrents at five to ten times natural rates (Swanson and Dyrness, 1975). Improper maintenance of roadside drainage can also lead to roadbed saturation, further destabilizing slopes and increasing mass movements. Roads also create impermeable surfaces, increase the drainage network by intercepting subsurface water from road cuts, and concentrate runoff in the road drainage system. Water flowing through roadside ditches picks up sediment and delivers it to streams, considerably increasing the volume of delivered sediment. The amount of sediment that enters streams from road surfaces and associated drainage networks depends on road condition, vegetative cover on ditch and cutslopes, road steepness, road length, and connectivity to streams. Culverts which are undersized in high fills at stream crossings also present a potential erosion hazard. If a culvert is unable to accommodate high flows, the water may go over the roadway carrying loose debris with it and potentially washing out the road.

Rivers naturally mobilize and transport sediment through bank erosion and down cutting. Sediment transport is directly proportional to the availability of eroded material and the stream power to move it (Bull, 1979). In headwater streams, steep gradients create sufficient stream power to undercut colluvium at the slope toe and to down cut through the streambed surface. As streams move down gradient, they typically erode floodplain banks as they migrate laterally and downstream. Most of the material eroded from floodplain banks deposits in bars and overbank flood deposits. Bank erosion does not constitute a net sediment influx to the river unless channel widening occurs. However, natural equilibrium can be offset by increases in stream power and/or increases in sediment volumes delivered to the stream. Increases in stream power can result from a variety of factors including natural storm events, geologic uplift, clear-cut logging, and road building. Clear-cut logging and road building increase stream power by decreasing natural infiltration rates, which increases overland flow and the volume and speed of water being delivered to the stream (Bull, 1979; Jones and Grant, 1996).

Human activities such as agriculture and urbanization can also increase the delivery of sediment to stream channels. The physical manipulation of soils from agricultural activities can lead to increased soil erosion by both wind and water. The common practice of draining and tiling wet agricultural lands also increases the volume and speeds the delivery of water to the river channel, increasing stream power. The straightening of stream meanders through channelization further increases stream energy and erosive power. Large domestic animals may also increase streamside erosion in areas in which they are allowed direct stream access by damaging stream banks and eliminating riparian vegetation needed for bank stability. Urban sources of sediment include runoff from access roads, driveways, disturbed hillslopes, and particularly new excavation and construction activities. The increase in impervious surfaces, associated with urban development, also increase overland flow and change the timing of water delivery to the channel, again increasing stream power.

Increased delivery of fine sediment can alter substrate composition and channel morphology leading to degradation of spawning habitat for fish. Salmonid eggs require a plentiful supply of dissolved oxygen for survival, which makes them particularly susceptible to pollution from fine sediment. Fine sediments may clog pores between gravel particles impeding the exchange of oxygen between the stream and the underlying gravel beds (Johnson, 1980). Several studies have a found a link between high levels of fine sediment and elevated mortality rates of salmonid embryos (Chapman, 1988; Everest et al., 1985; Iwamoto et al., 1980; Koski, 1966).

Study Design

The 2004 monitoring program is designed to continue fundamental data collection efforts and fill data gaps. Monitoring activities will be coordinated with other agencies to avoid duplication of efforts. Programs include both continuous and short-term efforts throughout the study area.

Temperature

Continuous Monitoring of Water and Air Temperature and Relative Humidity

The 2004 stream temperature monitoring locations will be selected to complement and build on the information provided by the 2003 sampling program and to provide increased spatial resolution in defining the thermal regime of the Deschutes River and Percival Creek Watersheds.

In the Deschutes River, up to 15 mainstem stations will be identified in spring 2004 based on review of the 2003 temperature monitoring results, analysis of TIR images and longitudinal temperature profiles, and initial QUAL2Kw model runs. In the Percival Creek Watershed, up to six stations will be instrumented during the 2003 monitoring period. Any additional placement of thermistors will be based on 2004 temperature monitoring conducted by Thurston County Division of Water and Waste Management.

In the Deschutes River Watershed, instream thermistors will be co-located with piezometer locations and will also record hyporheic temperatures (see groundwater sampling section for details on hyporheic temperature stations).

Installation of temperature data loggers and monthly downloads will follow TFW protocols (Schuett-Hames et al., 1999a). Temperature dataloggers will be installed in areas that are representative of the surrounding environment interacting with the stream and are shaded from direct sunlight. To safeguard against data loss, data from the loggers will be downloaded periodically throughout the sampling season. The locations of air temperature thermistors and relative humidity meters are shown in Figures 3 and 4 for the Deschutes River and Percival Creek Watersheds.

Additional weather information within the watershed can be found at the National Weather Service surface weather observation station (a.k.a. METAR station) at Olympia, Washington. Traditional weather observations are transmitted in METAR format by various agencies and governments around the world. In the United States, the National Weather Service produces the majority of METAR observations but other agencies, such as the Federal Aviation Administration (FAA), provide some observations as well. Many METAR observations are made by automated equipment such as Automated Surface Observing Systems (ASOS) in the United States. Real time data can be obtained through NOAA (2003).

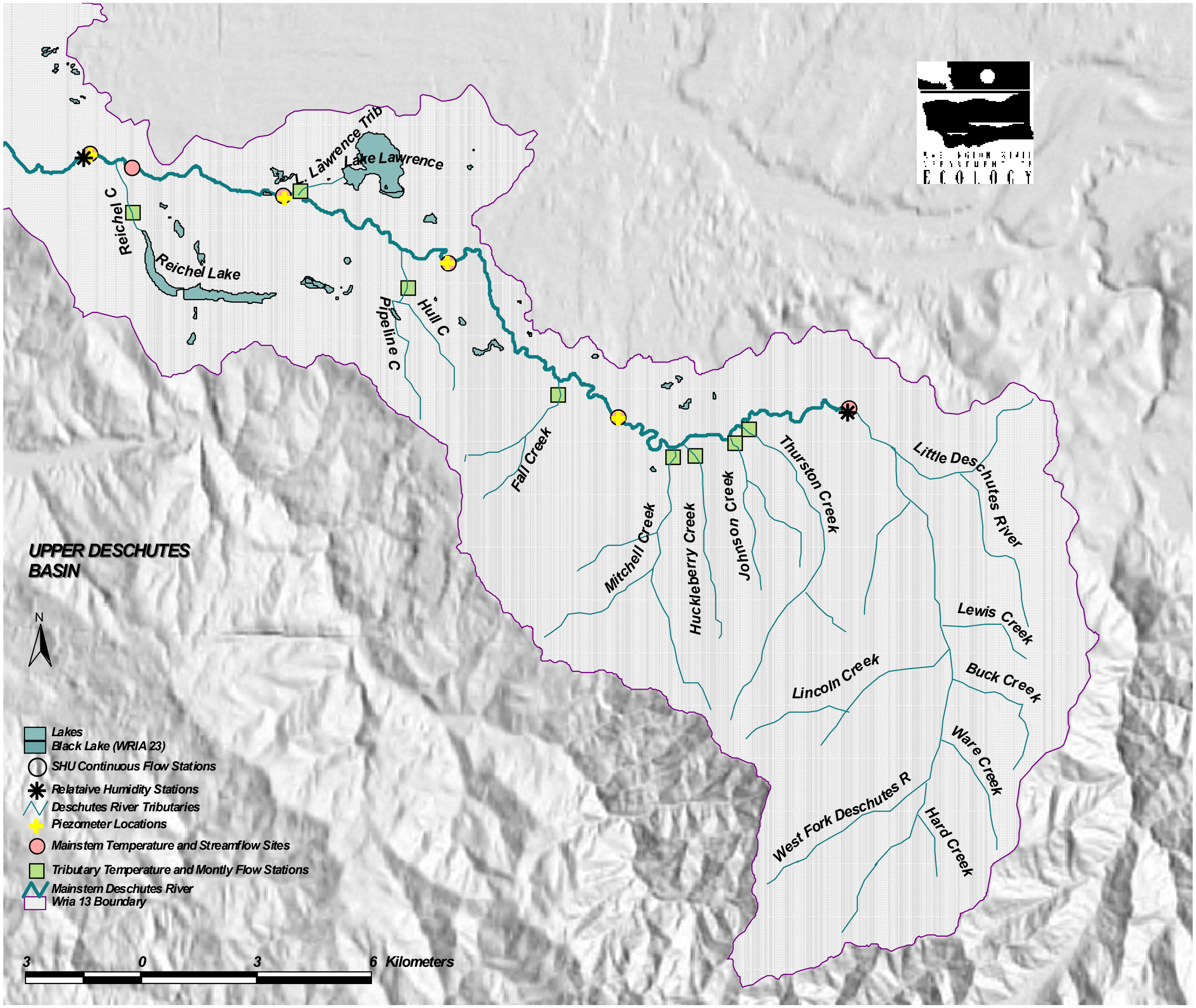

Figure 3. Water and Air Temperature, Hyporheic, Groundwater, Flow, and Relative Humidity Stations in the Upper Deschutes River Basin (2004)

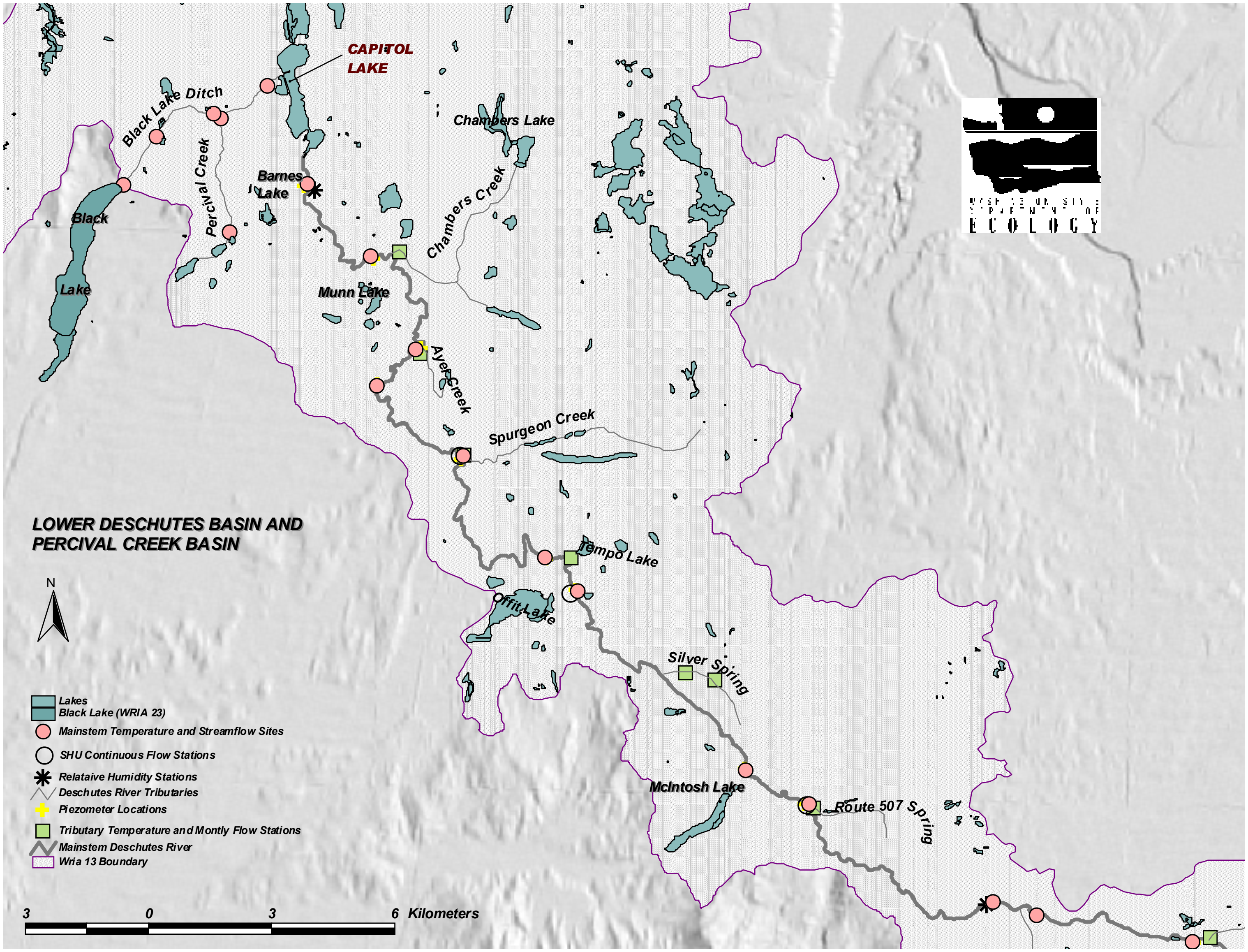

Figure 4. Water and Air Temperature, Hyporheic, Groundwater, Flow, and Relative Humidity Stations in the Lower Deschutes River Basin and Percival Creek Watershed (2004).

Groundwater Monitoring and Hyporheic Investigations

The groundwater and hyporheic investigations planned for study year 2004 are intended to refine the understanding of groundwater's role in mitigating stream temperatures during critical (summer baseflow) conditions. Based on review of the 2003 monitoring results, additional instream piezometers and hyporheic thermistors will be installed in May and June 2004 along those reaches of the Mainstem Deschutes River where groundwater discharge is indicated. To the extent possible monitoring sites will be chosen to provide a representative sampling of the watershed's various geologic units and forested/non-forested land uses.

These piezometers (along with the 13 installed in 2003) will be accessed monthly, between June and November 2004, to download thermistors, to conduct comparative measurements of stream stage and groundwater head, and to make "spot" measurements of stream and groundwater specific conductivity and temperature for later comparison and validation of the data collected with recording thermistors.

The other groundwater related activities planned for year 2004 include:

- Determine what, if any, bias the PVC or steel piezometers impart on the natural thermal regime within a gaining, losing, or neutral stream reach. This evaluation will entail installing "identical" paired PVC and steel piezometers within one gaining, one losing, and one neutral stream reach. Each piezometer will be identically instrumented with recording thermistors for subsequent comparison against a co-located hyporheic thermistor (natural condition).

- Where possible, identify and measure water levels in shallow off-stream (typically domestic) wells to better define the horizontal direction of near-surface groundwater movement in the vicinity of the instream piezometers.

- Locate and monitor additional study area springs to better define both the temporal and spatial distribution of area groundwater temperatures at natural points of groundwater discharge.

- Install additional piezometers at selected monitoring sites to determine if there are gradient and/or temperature differences based on which side of the stream one monitors. A representative gaining, losing, and neutral stream reach will be chosen for this evaluation.

- Conduct specific capacity tests of the instream piezometers as a secondary field check of the streambed hydraulic conductivity values determined through the VS2DI modeling efforts.

Flow Monitoring and Seepage Run Survey

The Ecology Stream Hydrology Unit installed stand-alone flow stations at three sites along the Mainstem Deschutes in July 2003 (Figures 3 and 4). Data are logged every fifteen minutes and downloaded once a month. Data are imported into the stream flow database and published to the Ecology web site (Stream Hydrology Unit, 2002). A formal set of Stream Hydrology Unit operating procedures is also found at this website. Sites installed in 2003 will be maintained during the 2004 sampling period. Rating curves will be developed by the Stream Hydrology Unit personnel for use in TMDL development. Typically six to eight discharge measurements are made during the year to capture the range of flows necessary to construct a rating curve.

A seepage run will be conducted in the Deschutes River Basin and the Percival Creek Watershed in August 2004. Flows will be measured at all mainstem and tributary locations within the Deschutes Basin and Percival Creek Watersheds. All stream velocity measurements will be made following standard field sampling and measurement protocols described in Ecology (2000) and the WAS protocol manual (WAS, 1993).

Deschutes River Time of Travel

Travel times will be estimated within several reaches along the Mainstem Deschutes River. Tracer studies will be conducted in up to five reaches of the Mainstem Deschutes. Final time of travel study reaches will be determined after analysis of TIR thermal imagery and initial QUAL2Kw output to better quantify velocities in gaining and losing reaches.

While several methods can be used, the large number of obstructions precludes the use of drogues. Thus, dissolved tracers will provide the best information on travel time and dispersion, both important parameters for modeling. Pulse releases will be used to inject sufficient salt solution to achieve a measurable conductivity at each downstream station without affecting aquatic species. Conductivity will be measured where fully mixed conditions occur downstream of the injection. Stream flow will be measured at the downstream site when the peak conductivity arrives. Stream velocity will be measured using a Marsh McBirney flowmeter. All stream velocity measurements will be made following the field sampling and measurement protocols described in the WAS protocol manual (WAS, 1993). Conductivity will be measured using a handheld YSI Model 30M handheld salinity, conductivity, and temperature system or other equivalent meter.

Estimates of travel time to each downstream station will be calculated based on the time of arrival of peak concentration, instream flow measurements, length of stream reach, and time series of conductivity. Dispersion will be calculated from the spread of the plume as it is advected downstream.

Surveys of Riparian Vegetation and Channel Morphology - Percival Creek Watershed[4]

Effective shade measurements for riparian vegetation within the Percival Creek Watershed will be collected using hemispherical digital photography and analyzed using the Hemi-view 2.1 software from Delta-T Devices (1998). Sites for hemispherical photography will be selected randomly from a subset of representative vegetation polygons to provide a statistically-based effective shade of each vegetation type.

Vegetation polygons in the riparian corridor within 300 ft (90 m) of each bank of the stream will be digitized from 1-ft (0.3–m) resolution full-color digital orthophotos obtained from Thurston County GeoData Center, an example of which is shown in Figure 5. Vegetation polygon types will be classified by species type, height, and density.

[4] Riparian vegetation surveys were conducted along the mainstem Deschutes River in 2003 using the same protocols described here for the Percival Creek Watershed.

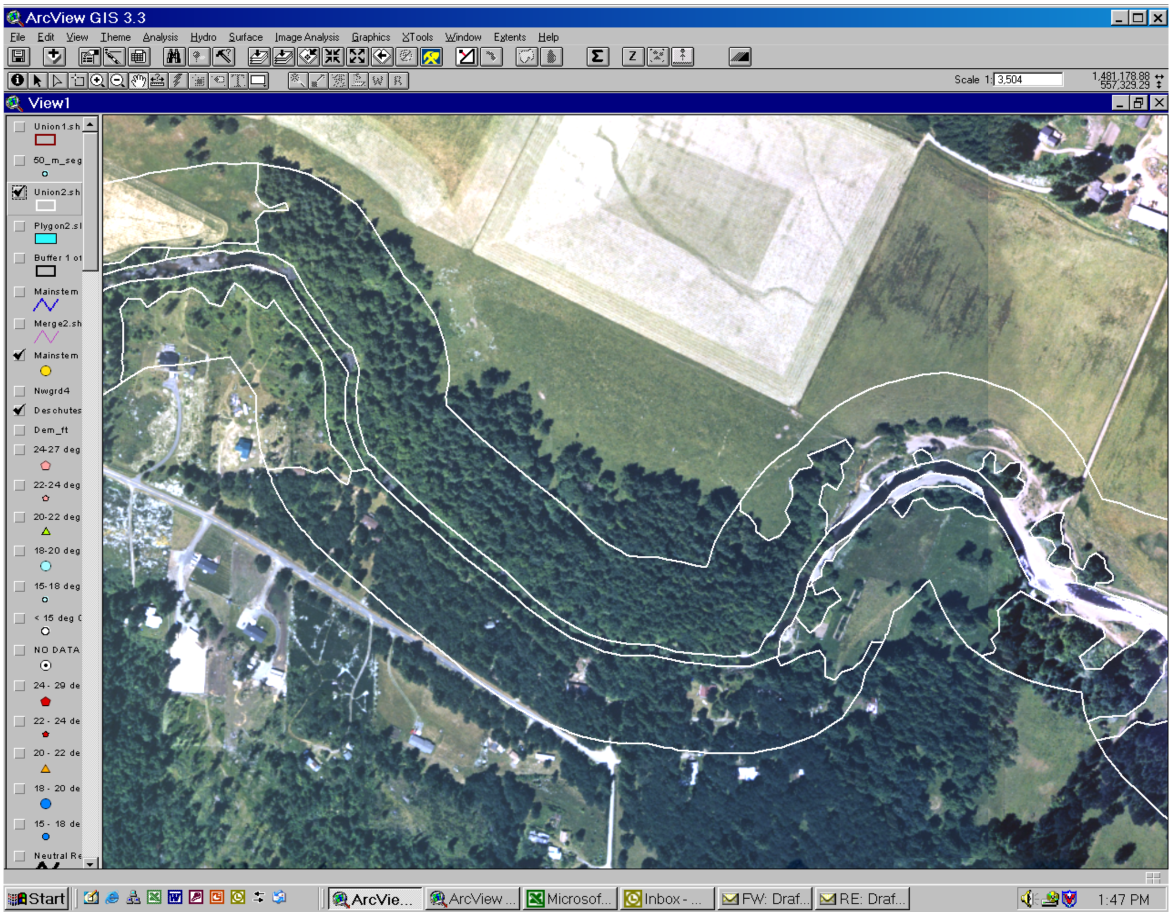

Figure 5. Example of Riparian Vegetation Polygons Within a 300-ft (90-m) Buffer.

Bankfull and wetted width channel cross-sections will be surveyed. There will be three to five transects surveyed at each of the continuous temperature stations in Percival Creek and Black Lake Ditch. Additional surveys will occur in other reaches as necessary. These measurements will be used to determine the relationship between channel geometry and flow. Effective shade measurements at the stream center of each transect will also be made using hemispherical photography.

Manning's equation is commonly used to solve for depth (y) given flow (Q), Manning's roughness coefficient (n), wetted width (B_0), and channel slope (S_e). Manning's equation for a rectangular channel (side slope s=0) is as follows (Chapra, 1997):

Manning's equation

$$Q = \frac{1}{n} \frac{\left[(B_0 + sy)y\right]^{5/3}}{\left(B_0 + 2y\sqrt{s^2+1}\right)^{2/3}} S_e^{1/2}$$

Manning's n typically varies with flow and depth (Gordon et al., 1992). As the depth decreases at low flow, the relative roughness increases. Typical published values of Manning's n, which range from about 0.02 for smooth channels to about 0.15 for rough natural channels, are representative of conditions when the flow is at the bankfull capacity (Rosgen, 1996). Water depth during critical conditions for evaluating the period of highest stream temperatures is generally much less than bankfull depth, and the Manning's roughness may be much higher. Relationships between Manning's n and flow will be developed for each subbasin based on field measurements to characterize hydraulic geometry for stream reaches.

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

The TMDL study includes twice-monthly or monthly *in situ* measurements and grab samples, short-term continuous monitoring, a Deschutes River diel productivity study, and targeted stormwater outfall dry weather and wet weather monitoring. Table 13 summarizes twice-monthly and monthly monitoring stations throughout the watershed.

Table 13. Monitoring Locations for Fecal Coliform, Dissolved Oxygen, Nutrients, Alkalinity, Organic Carbon, and TSS.

Thurston Co Station	Project Station	Description	Q	FC	DO	Nuts	pH	Alk	TSS	TOC/ DOC
		Main Stem Deschutes River								
DESDE0050	13-DES-37.4	Deschutes River at 1000 Rd	Wey.Co.		DO	nuts	pH	alk	TSS	OC
DESDE0040	13-DES-28.6	Deschutes River at Vail Cutoff Rd SE	USGS	FC	DO	nuts	pH	alk	TSS	OC
DESDE0030	13-DES-20.5	Deschutes River at Rte 507	Q	FC	DO	nuts	pH	alk	TSS	OC
DESDE0020	13-DES-09.2	Deschutes River nr Rich Rd SE/Jerry Boe	Q	FC	DO	nuts	pH	alk	TSS	OC
NM	13-DES-05.5	Deschutes River off Riverlea Dr. (below Ayer Ck.)	no	FC	DO	nuts	pH	alk	TSS	OC
DESDE0010	13-DES-02.7	Deschutes River at Henderson Blvd SE	no	FC	DO	nuts	pH	alk	TSS	OC
DESDE0000	13-DES-00.5	Deschutes River at E St Bridge (SRIW 1302)	USGS	FC	DO	nuts	pH	alk	TSS	OC
		Upper Deschutes Tributaries								
DESHU1900	13-HUC-00.3	Huckleberry Creek at 3000 Rd	Wey.Co.	FC	DO					
DESRE1100	13-REI-00.9	Reichel Creek at Vail Loop Rd	Q	FC	DO	nuts	pH			OC
NM	13-LAK-00.0	Lk. Lawrence trib. (~800ft upstream from 13-DES-28.6)	estimate		DO		pH			
		Lower Deschutes Tributaries								
DESSP0500	13-SPU-00.0	Spurgeon Creek at Rich Road/Jerry Boe	Q	FC	DO	nuts	pH			OC
DESAY0400	13-AYE-00.0	Ayer (Elwanger) Creek off Riverlea Dr	Q	FC	DO	nuts	pH			OC
DESCH0300	13-CHA-00.1	Chambers Creek off 58th Ave SE	Th.Co.	FC	DO	nuts	pH			OC
		Capitol Lake and Tributaries								
BUDBL0399	13-BLA-02.3	Black Lake outlet at Belmore Rd	Th.Co.	FC	DO	nuts	pH			
NM	13-BLA-00.0	Black Lake Ditch nr Percival confluence	Th.Co.	FC	DO		pH			
BUDPE0020	13-PER-01.0	Percival Creek nr Black Lake Ditch confluence	Th.Co.	FC	DO	nuts	pH			
BUDPE0000	13-PER-00.1	Percival Creek nr mouth	no	FC	DO	nuts	pH		TSS	OC
BUDCAL010	13-CAP-00.4	Capitol Lake at Railroad Trestle	no	FC	DO	nuts	pH		TSS	OC
NM	13-CAP-00.0	Capitol Lake at 5th Ave. (outlet to Budd Inlet)	no		DO	nuts	pH		TSS	OC
		Budd Inlet Tributaries								
BUDAD0000	13-ADA-00.5	Adams Creek at Boston Harbor Rd	Q	FC			pH			
BUDBU0000	13-BUT-00.1	Butler Creek at French Loop Rd	Q	FC			pH			
BUDEL0000	13-ELL-00.0	Ellis Creek at East Bay Dr	Q	FC			pH			
BUDIN0010	13-IND-00.2	Indian Creek at Quince Ave	Q	FC						
BUDMI0000	13-MIS-00.1	Mission Creek at East Bay Drive	Q	FC						
BUDMO0030	13-MOX-00.6	Moxlie Creek at Plum St and Henderson	Q	FC			pH			
NM	13-MOX-00.0	Moxlie Creek at East Bay	no	FC						
BUDSC0000	13-SCH-00.1	Schneider Creek at West Bay Dr	Q	FC			pH			

NM = not monitored
Wey. Co. = Weyerhaeuser Company (requires permission to access site)

Routine Monitoring

The sampling design addresses the geographic extent of the pH, DO, and bacteria problems, and associated temporal variation, including seasonal fluctuations. Therefore, sampling will occur at all sites monthly for nutrients and twice monthly for bacteria from January through December. Any sites that have met the water quality standards from July 2003 through June 2004 will be discontinued as of July 2004.

All monitoring will be coordinated with local monitoring groups and Ecology temperature TMDL programs. Temperature and discharge data collected by these groups will be useful for interpreting the diel and instantaneous data. Habitat data and local knowledge of potential instream influences or contaminant sources will be essential for data interpretation.

Productivity Surveys

Dissolved oxygen and pH undergo natural diel changes in response to physical and chemical influences on the aquatic community. However, as sunlight intensity, nutrients, and biological oxygen demand increase from anthropogenic sources, natural diel fluctuations can be greatly exaggerated. The Mainstem Deschutes River productivity surveys will examine diel changes in DO, pH, temperature, and nutrients, and the effects on productivity. Hydrolab DataSondes® will be deployed at strategic locations on the Mainstem Deschutes River over a period of up to four days in late summer 2004. Surveys may also include taking habitat measurements to reduce site variability from water velocity, depth, incident light, and substrate characteristics. Ecology may also evaluate reference conditions where measurements indicate pH and DO criteria are met. Reference conditions can be helpful in determining the background water quality conditions and what factors are most important in affecting instream pH and dissolved oxygen. The data will be used with the free-water diel curve method to estimate community primary productivity (APHA, 1998). DataSondes® will also be placed in Ayer Creek, Reichel Creek, Capitol Lake, Inner Budd Inlet, and other sites if necessary for up to two weeks in late summer 2004 to continuously measure DO, conductivity, temperature, and pH.

Dry and Wet Weather Storm Outfall Sampling

Ecology will conduct two rounds of dry-weather stormwater outfall monitoring in late summer 2004 at up to 25 locations to be determined in cooperation with the city of Olympia, city of Tumwater, GA, Thurston County, and Department of Transportation. A subset of sites will be sampled over three to six storm events, two to four times over the storm. Samples will be analyzed for fecal coliform bacteria, nutrients (dissolved and total), BOD, and organic carbon.

Capitol Lake Bathymetry Survey

Ecology will conduct a bathymetric survey of Capitol Lake to establish the current lake volume for modeling purposes. Lake level will be monitored during the survey to account for any changes in water surface elevation. The survey will be conducted on a grid with horizontal and vertical positions located at ≤10-m distances along transects located ≤ 10 m apart. Additional fine-scale measurements will be used to define surfaces around bridges and the outlet structure.

Ecology will use differential global positioning systems to achieve a horizontal accuracy of ±1 m. We will conduct a pilot study to determine whether echosounders or acoustic doppler equipment will be adequate for the shallow water depths, macrophyte and phytoplankton growth, and silty substrate of Capitol Lake. If the pilot study is unsuccessful, Ecology will record depth using a staff or weighted chain. The survey will target a vertical accuracy of ±0.1 m.

Capitol Lake Water Quality Surveys

Three rounds of monitoring will be conducted on Capitol Lake to supplement ongoing data collection efforts by Thurston County for GA. During sampling rounds, planned for late summer 2004, Ecology will record temperature, dissolved oxygen, and conductivity/salinity profiles throughout the lake and collect samples to be analyzed for fecal coliform, nutrients, chlorophyll a, ultimate BOD, and organic carbon at the stations shown in Figure 6. Grab samples will be analyzed for dominant algae species, and the list of species present will be reported. If GA has not installed a water level monitor by summer 2004, Ecology will record lake level both inside and outside the Capitol Lake outlet structure.

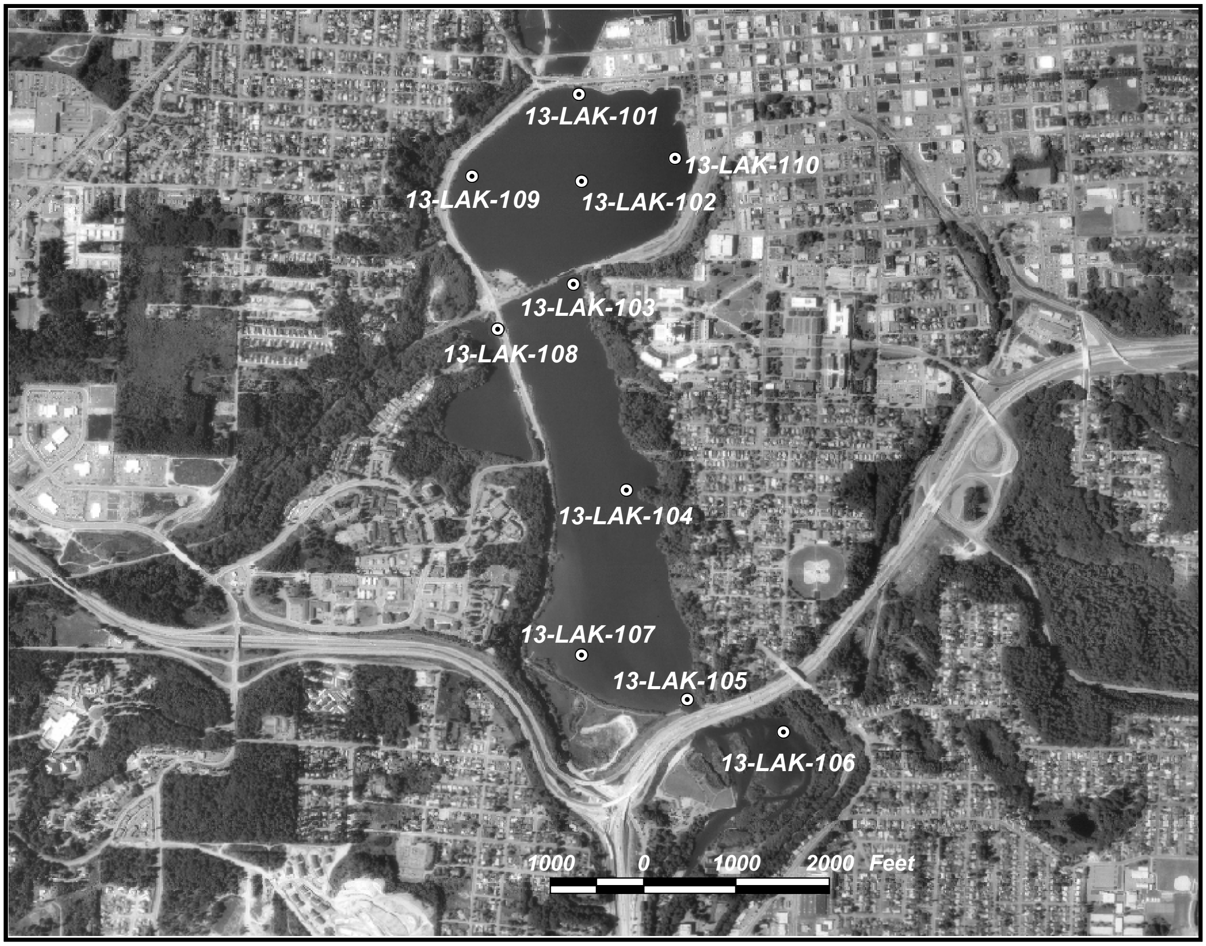

Figure 6. Capitol Lake Monitoring Stations for 2004.

Capitol Lake Macrophyte Survey

Ecology will analyze macrophyte biomass and frequency of occurrence in Capitol Lake using standard protocols (Parsons, 2001). The survey will quantify the biomass above the sediment surface by species using a SCUBA diver and a 0.1-m^2 quadrat or macrophyte rake from the boat. Frequency will be determined using a point-intercept approach. The number of sampling points will be determined per Madsen (1993) and Spencer and Whitehand (1993). A stratified random approach will be used to select sites from a 30-m grid or line transects. The survey will be conducted when the plants have reached maximum biomass.

Follow-Up Source Identification Surveys

Thurston County will conduct additional source identification surveys in response to the 2003 and 2004 monitoring results. The work will begin in 2004 and will continue through 2005, following completion of the Ecology data collection activities. Sites will be selected based on high fecal coliform bacteria concentrations or other indicators, and the frequency and time period for sampling will depend on the nature of the suspected sources. Bacteria analyses will be conducted by the Thurston County Environmental Health Division Laboratory.

Fine Sediment

The Squaxin Island Tribe will conduct technical studies under a grant from EPA to assist with the development of the fine sediment TMDL. The final approach will be detailed in a separate QA Project Plan submitted to EPA and Ecology by the tribe in March 2004. The tribe will provide an updated sediment source inventory and sediment trend analysis to be used by Ecology in developing the sediment load allocations. Sediment yield from channel migration, channel erosion, and mass movements will be determined through aerial photograph analysis and field investigations. These sediment yields will be used to update the latest sediment source inventory developed for the Deschutes River (Collins, 1994). The Squaxin Island Tribe will also measure fine sediment levels in spawning gravel and provide a sediment trend analysis based on the comparison of this data to historical data collected by the Tribe.

Channel Erosion

The Squaxin Island Tribe will update sediment yield estimates from mainstem erosion sites developed in Collins (1994). The study identified erosion sites on the Deschutes River by mapping lateral bank movement from the comparison of aerial photos taken in 1941, 1953/54, 1965/66, 1972, 1981, and 1991. One hundred twenty-seven bank erosion sites were identified between RM 2 and RM 41 for the 1981 to 1991 period. Photo-measured lengths and widths were combined with field-measured bank heights to estimate volumetric sediment yield from the sites. The tribe will replicate this procedure by analyzing 1991 aerial photography and 2003 riparian conditions videos that accompany the TIR images in order to update the condition of previously identified erosion sites and identify new erosion sites. Erosion sites will then be measured by aerial photograph interpretation and field investigation to create volumetric estimates of sediment yield. Protocols for field investigation will be based on the DNR's standard methodology for conducting watershed analysis (WFPB, 1997).

Mass Movements

The Tribe will update sediment yields for mass movements contributing sediment to the Deschutes River. Collins used aerial photography, field investigation, and previous landslide inventories by Sullivan et al. (1987), Toth (1991), and Weyerhaeuser Company (1993) to identify 39 major tributary landslides contributing sediment to the Deschutes River. The Tribe will use aerial photography and field measurement to update the condition of the landslides and to identify new slides initiated since 1994. Field measurements will be consistent with the DNR's standard methodology for conducting watershed analysis (WFPB, 1997).

Spawning Gravel

The tribe will measure fine sediment volume in spawning gravel in five reaches in the Deschutes River. The segments were previously selected as representative reaches in the system in which the adverse effects to fish habitat and water quality were likely to occur. The reaches include: Segment 19 (RM 33.0-35.7), Segment 22 (RM 28.5-29.5), Segment 28 (RM 20.8-22.0), Segment 31 (RM 15.0-17.5), and Segment 36 (RM 2.5-4.5). The tribe will use the TFW Method Manual for the Salmonid Spawning Gravel Survey (Schuett-Hames et al., 1999b) to estimate fine sediment volume in the gravel beds.

Measurement Quality Objectives

Measurement quality objectives (MQOs) refer to the performance or acceptance criteria for individual data quality indicators such as precision, bias, and lower reporting limit. MQOs provide the basis for determining the procedures that should be used for sampling and analysis.

Temperature

Accuracy of the thermograph data loggers (both Onset StowAway TidBits and Dallas Maxim Semiconductor Corporation DS1921L-F51 iButtons) will be maintained by a two-point comparison between the thermograph, a field thermometer, and a Certified Reference Thermometer. The Certified Reference Thermometer, manufactured by HB Instrument Co. (part number 61099-035, serial number 2L2087), is certified to meet ISO9000 standards and calibrated against National Institute of Standards and Technology traceable equipment.

The field thermometer is a Brooklyn Alcohol Thermometer (model number 67857). First, the field thermometer's accuracy will be evaluated by comparison to a National Institute of Standards and Technology (NIST)-certified thermometer. If there is a temperature difference of greater than 0.2°C, the field thermometer's temperature readings will be adjusted by the mean difference.

Manufacturer specifications report an accuracy of ±0.2°C for the Onset StowAway TidBit (-5°C to +37°C) and ±0.4°C for the Onset StowAway TidBit (-20°C to +50°C). The DS1921L-F51 Thermochron iButton has an operating range of -10°C to +85°C and a temperature accuracy specification of ±1°C over that entire range.

If the mean difference between the NIST-certified thermometer and the thermal data loggers differs by more than the manufacturer's reported specifications during the pre-study calibration, the thermal data logger will not be used during field work.

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, and seasonal variation of instream flow and temperatures in the subbasin. Extra calibrated field thermometers and thermograph data loggers will be taken in the field during site visits and surveys to minimize data loss due to damaged or lost equipment.

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

Field studies are designed to generate data adequate to reliably estimate the temporal and spatial variability of that parameter. Sampling, laboratory analysis, and data evaluation steps have several sources of error that should be addressed by measurement quality objectives. Accuracy in laboratory measurements (measurement quality objectives) can be more easily controlled than field sampling variability. Analytical bias needs to be low and precision as high as possible in the laboratory. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time. Finally, laboratory and field errors are further expanded by estimate errors in seasonal loading calculations and modeling estimates.

The Deschutes River, Capitol Lake, and Budd Inlet TMDL study includes a variety of parameters (fecal coliform, pH, dissolved oxygen, and ancillary parameters) that are quite variable in the aquatic environment. Table 14 summarizes the field and laboratory measurement quality objectives for reasonable decisions for the study. Stratified seasonal sampling and other sampling design features will be used to better evaluate critical conditions on which to develop TMDL targets for the parameters.

Table 14. Summary of Measurement Quality Objectives and Required Reporting Limits of Laboratory and Field Parameters.

Measurement	Accuracy (% Deviation from True Value)	Precision (Relative Standard Deviation, RSD)	Bias (% Deviation from True Value)	Required Reporting Limits
Field Measurements				
Velocity*	0.1 ft/s	0.1 ft/s	N/A	0.05 ft/s
pH*	0.2 SU	0.05 SU	N/A	1 to 14 SU
Temperature*	0.1°C	0.025°C	0.05°C	1°C to 40°C
Dissolved Oxygen	15	5% RSD	5	0.1 mg/L to 15 mg/L
Specific Conductivity	25	10% RSD	5	1 umhos/cm
Laboratory Analyses				
Fecal Coliform (MF)	N/A	25% RSD**	N/A	1 cfu/100 mL
E. coli	N/A	25% RSD**	N/A	1 cfu/100 mL
Biochemical Oxygen Demand	N/A	25% RSD	N/A	1 mg/L
Chlorophyll a	N/A	20% RSD	N/A	0.05 ug/L
Dissolved Organic Carbon	30	10% RSD	10	1 mg/L
Total Organic Carbon	30	10% RSD	10	1 mg/L
Total Persulfate Nitrogen	30	10% RSD	10	25 ug/L
Ammonia Nitrogen	25	10% RSD	5	10 ug/L
Nitrate & Nitrite Nitrogen	25	10% RSD	5	10 ug/L
Orthophosphate P	25	10% RSD	5	3 ug/L
Total Phosphorus	25	10% RSD	5	10 ug/L
Alkalinity	N/A	10% RSD	N/A	10 mg/L
Total Suspended Solids	20	10% RSD	N/A	1 mg/L

* As units of measurements, not percentages
** Log transformed data

Field Procedures

Standard Ecology protocols will be used for sample collection, preservation, and shipping to the Manchester Environmental Laboratory (MEL) (WAS, 1993; MEL, 2003). Chain-of-custody signatures will be required during sample transport. EA Program field methods will be followed for the collection of flow, dissolved oxygen, pH, temperature, and specific conductance and for the deployment of data recording equipment (WAS, 1993). Field meter calibration will follow EA Program protocols (WAS, 1993) under manufacturer's instructions. Ecology does not have strict criteria for accepting or rejecting field meter post-calibration results and subsequent field data; however, measurements that do not fall within the limits in Table 14 are generally rejected unless they can otherwise be explained. The principal investigator will determine the quality of the data and address usability in the final report. Calibration data, field measurement data, and other notes will be maintained on water resistant paper in field notebooks. All sampling sites will have unique identification numbers.

Samples will be collected directly into pre-cleaned containers supplied by MEL. Samples will be stored in the dark, on ice, and shipped to MEL. Samples will be available at MEL for analysis within 24 hours of collection.

Hydrolab DataSonde® dissolved oxygen, pH, conductivity, and temperature probes will be maintained, calibrated, and checked as adopted from the manufacturers' instructions (Electronic Data Solution, 2002 and Hydrolab Corporation, 1999). All probes will be cleaned, maintained, calibrated, and checked before and after each DataSonde® deployment to ensure proper functioning in the field. DataSondes® and their probes will be properly stored when not in use, following Hydrolab's recommendations.

Laboratory Procedures

The required quantification limits for laboratory data to meet the measurement quality objectives in Table 14 should be attainable through the analytical methods listed in Table 15. The MEL laboratory staff will consult the project manager if any changes in procedures over the course of the project are recommended or if matrix difficulties are encountered. MEL will analyze all samples in accordance with standard protocols (MEL, 2003). Thurston County Environmental Health Laboratory, certified by Ecology, will analyze fecal coliform bacteria in a portion of the stormwater samples and in source identification samples in accordance with Thurston County's standard protocols (Clark, 1998).

Table 15. Recommended Methods for Field Measurements and for Laboratory Determinations in Water Samples Taken from the Deschutes River, Capitol Lake, and Budd Inlet Watersheds for the TMDL Evaluation.

Parameter	Method*	Holding Time	Preservation Method	Estimated Range (Including Detection Limit)
Field Measurements				
Velocity	WAS, 1993	NA	NA	0 – 9 ft/s
pH	EPA 150.1/ SM 4500H	NA	NA	6.0 – 9.0 SU
Temperature	(no EPA) / SM 2550B	NA	NA	0 – 30°C
Dissolved Oxygen	EPA 360.2 / SM 4500-OC	7 days for "fixed" Winklers	Store in cool dark place	0 – 15 mg/L
Specific Conductivity	EPA 120.1 / SM 2510B	NA	NA	10 – >24,000 umhos/cm
Laboratory Determination				
Fecal Coliform (MF)	EPA 16-909C / SM 9222D	24 hours	Cool to 4°C; 0.008% Sodium Thiosulfate	<1 – > 5000 cfu/100 mL
E. coli (MF)	EPA 1105 / SM 9222G1	24 hours	Cool to 4°C; 0.008% Sodium Thiosulfate	<1 – > 5000 cfu/100 mL
Biochemical Oxygen Demand	EPA 405.1 / SM 5210B	48 hours	Cool to 4°C	<3 – 20 mg/L
Chlorophyll a	(no EPA) / SM 10300H3M	24 hrs to filtration - 28 days after filtration	Freeze filters in 90% acetone	<1 – 100 ug/L
Total Organic Carbon	EPA 415.1 / SM 5310B	28 days	Cool to 4°C; H2SO4 to pH<2	1 – 20 mg/L
Dissolved Organic Carbon	EPA 415.1 / SM 5310B	28 days	Cool to 4°C; H2SO4 to pH<2	1 – 20 mg/L
Total Suspended Solids	EPA 160.2 / SM 2540D	7 days	Cool to 4°C	1 – 5000 mg/L
Hardness	EPA 200.7 / SM 2340B	6 months	HNO3 to pH<2	0.03 – > 100 mg/L
Alkalinity	EPA 310.2 / SM 2320B	14 days	Cool to 4°C	5 – > 100 mg/L
Total Persulfate Nitrogen	(no EPA) / SM 4500-NB	28 days	Cool to 4°C; H2SO4 to pH<2	0.025 – 20 mg/L
Ammonia Nitrogen	(no EPA) / SM 4500-NH3H	28 days	Cool to 4°C - H2SO4 to pH<2	0.01 – 20 mg/L
Nitrate & Nitrite Nitrogen	(no EPA) / SM 4500-NO3I	28 days	Cool to 4°C; H2SO4 to pH<2	0.01 – 10 mg/L
Orthophosphate P	(no EPA) / SM 4500PG	48 hours	Filter; Cool to 4°C	0.003 – 0.5 mg/L
Total Phosphorus	EPA 200.8 / (no SM)	7 days	Cool to 4°C	0.01 – 10 mg/L

* Two methods are presented and refer to the following documents (separated by a forward slash): (1) USEPA, 1983 and (2) APHA, et al., 1998 (Standard Methods). Where a single method from one of the two sources is used, either the EPA method number is given before the slash or the Standard Method number is given following the slash.

Fine Sediment

Field procedures will be described in a separate QA Project Plan developed by the Squaxin Island Tribe by March 2004.

Data Verification and Validation

Field and laboratory data will be verified and validated at the completion of the data collection period. Data verification refers to "the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirmements" (EPA, 2002). Field staff will verify *in situ* and Winkler DO data, while MEL staff will verify all lab-based data.

Data validation refers to "the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set" (EPA, 2002). Principal investigators will validate data collected under the present QA Project Plan.

Following data verification and validation, principal investigators will complete measurement quality assurance and control checks by comparing against the measurement quality objectives in Table 14.

Quality Control Procedures

Quality control procedures refer to the routine application of statistical procedures to evaluate and control the accuracy of measurement data. The results for quality control samples determine whether the MQOs have been met.

Temperature

The Onset StowAway TidBits and the Dallas Maxim iButtons will be calibrated pre- and post-study in accordance with TFW Stream Temperature Survey protocols (Schuett-Hames et al., 1999a) to document instrument bias and performance at representative temperatures. A NIST-certified reference thermometer will be used for the calibration. At the completion of the monitoring, the raw data will be adjusted for instrument bias, based on the pre- and post-calibration results, if the bias is greater than ±0.2°C or ±0.4ºC depending on the temperature accuracy of the TidBit.

Variation for field sampling of instream temperatures will be addressed with a field check of the data loggers with a hand-held thermometer at all thermograph sites upon deployment, download events, and at TidBit removals at the end of the study period. Field sampling and measurements will follow quality control protocols described in the WAS protocol manual (WAS, 1993) and the TFW Stream Temperature Survey Manual (Schuett-Hames et al., 1999a).

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

Collecting replicate samples will assess total variation for field sampling and laboratory analysis and thereby provide an estimate of total precision. At least 10% of the total number of laboratory samples and field measurements per parameter (except velocity/discharge) will be replicated as detailed in Table 16. In addition, Hydrolabs will be calibrated in accordance with standard Ecology protocols, which includes pre- and post-deployment Winkler DO analyses and standards for pH.

Table 16. Summary of Field and Laboratory Quality Control Procedures for the Deschutes River, Capitol Lake, and Budd Inlet Tributaries.

Analysis	Field Replicates	Lab Check Standard	Lab Method Blank	Lab Duplicate	Matrix Spikes
Field Measurements					
Velocity/Discharge	1/run	N/A	N/A	N/A	N/A
pH	3/run	N/A	N/A	N/A	N/A
Temperature	3/run	N/A	N/A	N/A	N/A
Laboratory Analyses					
Dissolved Oxygen (Winkler)	1/10 samples	N/A	N/A	N/A	N/A
Fecal Coliform (MF)	1/10 samples	N/A	1/run	1/run	N/A
E. Coli	1/10samples	N/A	1/run	1/run	N/A
Biochemical Oxygen Demand	1/run	1/run	1/run	N/A	N/A
Chlorophyll a	1/10 samples	N/A	N/A	1/10 samples	N/A
Total Organic Carbon	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Dissolved Organic Carbon	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Alkalinity	1/10 samples	1/run	1/run	1/10 samples	N/A
Total Persulfate Nitrogen	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Ammonia Nitrogen	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Nitrate & Nitrite Nitrogen	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Orthophosphate P	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Total Phosphorus	1/10 samples	1/run	1/run	1/10 samples	1/20 samples
Hardness	1/10 samples	1/run	1/run	1/10 samples	N/A
Total Suspended Solids	1/10 samples	1/run	1/run	1/10 samples	N/A

All water samples for laboratory analysis will be collected directly in pre-cleaned containers supplied by MEL except ortho-phosphorus and dissolved organic carbon, which will be collected in a syringe and filtered into pre-cleaned containers. The syringe will be rinsed with ambient water at each sampling site three times before filtering. All samples for laboratory analysis will be preserved as specified by the lab (MEL, 2003) and delivered to MEL within 24 hours of collection.

Fine Sediment

Results for check standards will be compared to the MQOs for precision, bias, and accuracy wherever possible. Reporting limits for the project data will be compared to those in the MQOs. If any of these targets are not met, the associated results will be qualified and used with caution.

EPA regulations indicate that load allocations are “best estimates of loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading” [40 CFR 130.2(g)].

Data Analysis and Use

Model Descriptions

Several models will be used to evaluate the loading capacity and to determine the wasteload and load allocations necessary to meet the water quality standards. These are described below and will be applied to the waterbodies and parameters listed in Table 17.

Table 17. Analyses and Models Used by Waterbody and Parameter.

Waterbody	Parameter	Model	Reference
Deschutes River, Percival Creek	Temperature	TTools, Shade, QUAL2K	Ecology (2003a and 2003b)
Deschutes River	Groundwater exchange	VS2DI	Hsieh et al. (2000)
All freshwater systems	Fecal coliform bacteria	Statistical rollback	Ott (1995)
Deschutes River	Nutrients, DO, pH	QUAL2K	Ecology (2003b)
Capitol Lake	DO, pH	GEMSS, QUAL2K	Edinger and Buchak (1980 and 1995); Ecology (2003b)
Budd Inlet	DO	GEMSS	Edinger and Buchak (1980 and 1995)
Deschutes River	Fine sediment	GIS-based analyses	WFPB (1997), Reid and Dunne (1996)

Year 2004 data collection, compilation, and assessment are based on the data requirements of the two models used in this study, which are described below.

TTools

TTools is an ArcView extension developed by Oregon Department of Environmental Quality (ODEQ, 2001) to develop GIS-based data from polygon coverages and grids. The tool develops vegetation and topography perpendicular to the stream channel and samples longitudinal stream channel characteristics, such as the near-stream disturbance zone and elevation.

Shade Model

Shade.xls was adapted from a program that was originally developed by the Oregon Department of Environmental Quality (ODEQ) as part of the HeatSource model. Shade.xls calculates shade using one of two optional methods:

- ODEQ's original method from the HeatSource model version 6 (ODEQ, 2003).
- Chen's method based on the Fortran program HSPF SHADE (Chen, 1996). The method uses a slightly different approach to modeling the attenuation of solar radiation through the canopy (Chen et al., 1998a and 1998b).

All data will be assembled from Ecology field surveys (2003 and 2004) and Thurston County water temperature and flow data. Table 18 summarizes specific data requirements.

Table 18. Temperature Model Data Requirements and Field Data Collection Parameters.

		MODEL		Field Data
	PARAMETER	Shade	Qual2Kw	Collection
Flow	discharge - tributary		x	x
	discharge (upstream & downstream)		x	x
	flow velocity		x	x
	groundwater inflow rate/discharge		x	x
	travel time		x	
General	calendar day/date	x	x	
	duration of simulation	x	x	
	elevation - downstrean	x	x	
	elevation - upstream	x	x	
	elevation/altitude	x	x	x
	latitude	x	x	x
	longitude	x	x	x
	time zone	x		
Physical	channel azimuth/stream aspect	x		
	cross-sectional area	x	x	x
	Manning's n value	x	x	
	percent bedrock	x	x	x
	reach length	x	x	x
	stream bank slope	x		x
	stream bed slope	x	x	x
	width - bankfull	x		x
	width - stream	x	x	x
Temperature	temperature - groundwater		x	x
	temperature - tributaries		x	x
	temperature - water downstream		x	x
	temperatures - water upstream		x	x
	temperature - air		x	x
Vegetation	% forest cover on each side	x		x
	canopy-shading coefficient/veg density	x		x
	diameter of shade-tree crowns	x		
	distance to shading vegetation	x		
	topographic shade angle	x		
	vegetation height	x		x
	vegetation shade angle	x		
	vegetation width	x		
Weather	relative humidity		x	x
	% possible sun/cloud cover		x	
	solar radiation		x	x
	temperature - air		x	x
	wind speed/direction		x	x

QUAL2K

QUAL2K (Q2K) is a river and stream water quality model that represents a modernized version of QUAL2E (Brown and Barnwell, 1987). QUAL2Kw is adapted from the Q2K model originally developed by Chapra (Chapra and Pelletier, 2003). Q2K is similar to QUAL2E in the following respects:

- *One Dimensional*. The channel is well-mixed vertically and laterally. Non-uniform, steady flow is simulated.
- *Diurnal Heat Budget*. The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale.
- *Diurnal Water-Quality Kinetics*. All water quality variables are simulated on a diurnal time scale.
- *Heat and Mass Inputs*. Point and nonpoint loads and abstractions (withdrawals or losses) are simulated.

The QUAL2Kw framework includes the following new elements:

- *Software Environment and Interface*. Q2K is implemented within the Microsoft Windows environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface.
- *Model Segmentation*. Q2K can use either constant or varying segment lengths. In addition, multiple loadings and abstractions can be input to any reach.
- *Carbon Speciation*. Q2K uses two forms of carbon, rather than BOD, to represent organic carbon. These forms are a slowly oxidizing form (slow carbon) and a rapidly oxidizing form (fast carbon). In addition, non-living particulate organic matter (detritus) is simulated. This detrital material is composed of particulate carbon, nitrogen, and phosphorus in a fixed stoichiometry. Q2K will be used to simulate pH in the Deschutes River and in Capitol Lake.
- *Anoxia*. Q2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.
- *Sediment-Water Interactions*. Sediment-water fluxes of dissolved oxygen and nutrients from aerobic/anaerobic sediment diagenesis are simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- *Bottom Algae*. The model explicitly simulates attached bottom algae.
- *Light Extinction*. Light extinction is calculated as a function of algae, detritus and inorganic solids.
- *pH*. Both alkalinity and total inorganic carbon are used to simulate pH.

- *Pathogens*. A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.
- *Hyporheic Exchange and Sediment Pore Water Quality*. Q2K also has the ability to simulate the metabolism of heterotrophic bacteria in the hyporheic zone.

VS2DI

VS2DI is a graphical public domain software package developed by the USGS to simulate fluid flow and solute/energy transport within variably saturated porous media (Hsieh, et al., 2000). VS2DI can be used to analyze one- or two-dimensional energy or solute transport problems. The model will be used during this study to develop one-dimensional heat (energy) transport simulations for those piezometer sites where continuous groundwater temperatures were logged. These simulations will provide an estimate of both the temperature and volume of groundwater discharge to the river during summer baseflow conditions.

Generalized Environmental Modeling System for Surface Waters (GEMSS)

The GEMSS was developed by J. E. Edinger Associates, Inc. as an integrated hydrodynamic and water quality model package with GIS and environmental data management. The Budd Inlet Scientific Study (Aura Nova Consultants, Inc. et al., 1998) applied the GLHVTT model for three-dimensional transport and the carbon-based, 3-D water quality model for Budd Inlet (WQ3DCB_BI) to simulate dissolved oxygen dynamics including phytoplankton and nutrient cycling (Edinger and Buchak, 1995 and 1980).

Under the present project, the Budd Inlet application will be updated with the GEMSS software. In addition, the upper model boundary condition will shift from the Capitol Lake outlet structure to the Deschutes River inflow to Capitol Lake, such that Capitol Lake and Budd Inlet can be modeled as an integrated system. The model will use time series of inflows from the Deschutes River, Percival Creek and direct inflows to Capitol Lake to simulate the three-dimensional hydrodynamics and water quality of the lake. The Budd Inlet model will incorporate the effect of Capitol Lake by comparing Budd Inlet DO levels with and without the outlet structure in place, and the model will simulate point source, tributary, and direct inflow contributions from the watershed. The model will be parameterized to simulate Budd Inlet dissolved oxygen both with and without the Capitol Lake outlet structure.

Temperature Approach

Data collected during this TMDL effort will allow the development of a temperature simulation model that is both spatially continuous and which spans full-day lengths (quasi-dynamic steady-state diel simulations). The GIS and modeling analyses will be conducted using four software tools:

- Oregon Department of Environmental Quality's TTools extension for ArcView (ODEQ, 2001) will be used to sample and process GIS data for input to the Shade and QUAL2Kw models.

- Ecology's Shade model (Ecology, 2003a) will be used to estimate effective shade along the mainstem of the Deschutes River, Percival Creek, and Black Lake Ditch Effective shade will be calculated at 50-meter (160-ft) intervals along the streams and then averaged over 500-meter (1600-ft) intervals for input to the QUAL2Kw model.
- The QUAL2Kw model (Chapra, 2001; Ecology, 2003b) will be used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw will be applied by assuming that flow remains constant for a given condition such as a seven-day or one-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget described in Chapra (1997). Diurnally varying water temperatures at 500-meter (1,640 ft) intervals along the streams in the basin will be simulated using a finite difference numerical method. The water temperature model will be calibrated to instream data along the mainstems of the Deschutes River and Percival Creek.
- The USGS model VS2DI (Hsieh et al., 2000) will be used to evaluate the continuous groundwater temperature data for selected (influent) piezometer sites to estimate both the temperature and volume of groundwater discharge to the river during summer baseflow conditions. These flux estimates will be integrated with stream seepage run information to estimate reach-specific streamflow gains and losses for later inclusion in the QUAL2Kw model development.

All input data for the Shade and QUAL2Kw models will be longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments.

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH Approach

Laboratory data reduction, review, and reporting will follow procedures outlined in MEL's User Manual (MEL, 2003). Laboratory staff will be responsible for internal quality control validation and for proper data transfer and reporting data to the project manager via the Laboratory Information Management System (LIMS).

All laboratory data, except microbiological data, will be transferred to the principal investigator within 30 days if possible. Elevated fecal coliform densities (>200 cfu/100 mL) will be reported to the principal investigator within a week so that Ecology's Southwest Regional Office (SWRO) can be notified in accordance with the standard notification procedure. The project manager or principal investigator will validate the quality of the data received from the laboratory and collected in the field in reference to the MQO in Table 14. The review will be performed as often as possible. Adjustments to field or laboratory procedures or to MQOs may be necessary after such a review, and clients and QA Project Plan signature parties will be notified of major changes.

All water quality data will be entered into Ecology's Environmental Information Management (EIM) system. Data will be verified and a random set of 10% of the data entries will be independently reviewed for errors. If errors are detected, another 10% will be reviewed until no errors are detected. All preliminary data will be made available to the SWRO for disbursement after basic quality control and EIM data entry are completed.

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using EXCEL or WQHYDRO (Aroner, 1994) computer software.

The modeling software Ecology will use includes: QUAL2Kw (Ecology, 2003b) for quasi-dynamic analysis of dissolved oxygen and pH during critical conditions in critical reaches, and the Statistical Rollback method (Ott, 1995) for bacteria with tributary targets matching river target reductions. The Deschutes River, Capitol Lake, and Budd Inlet TMDL data analysis will also rank the relative importance of reaches or tributaries as sources for TMDL actions.

Fine Sediment Approach

Data collected by the Squaxin Island Tribe will be used by Ecology to develop sediment load allocations for the Deschutes River based on the EPA sediment TMDL protocols (EPA, 1999). The analysis will follow the approach used for the Upper White sediment TMDL (Ketcheson et al., 2003).

All non-continuous water quality data will be entered into Ecology's EIM system. Data will be verified and a random 10% of the data entries will be independently reviewed for errors. Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using SYSTAT/SYGRAPH8 (SPSS, 1997) and EXCEL (Microsoft, 2001) software.

Project Organization

The roles and responsibilities of Ecology project staff are as follows:

- *Mindy Roberts*, *Watershed Ecology Section Project Manager*, *Environmental Assessment Program, Water Quality Studies Unit*. Responsible for overall project management of all water quality parameters. Responsible for overall design of fecal coliform, dissolved oxygen, nutrients, pH, and fine sediment program. Co-author of the QA Project Plan and responsible for overall review. Manages fecal coliform bacteria, DO, nutrients, pH, and fine sediment data collection program. Writes TMDL technical study report.
- *Brian Zalewsky*, *Temperature Project Manager*, *Environmental Assessment Program*, *Nonpoint Studies Unit*. Responsible for temperature project management. Defines temperature objectives, scope, and study design. Co-author of QA Project Plan. Manages temperature data collection program. Applies QUAL2Kw and Shade.xls models to Deschutes River, Percival Creek, and Black Lake Ditch. Writes TMDL technical study report.
- *Mike LeMoine and Dustin Bilhimer*, *Principal Investigators*, *Environmental Assessment Program, Nonpoint Studies Unit*. Assists in defining temperature project objectives, scope, and study design. Responsible for writing sections of the QA Project Plan, data collection, data entry to the EIM system, and sections of technical report related to data collection, field methods, and data quality review.
- *Trevor Swanson*, *Principal Investigator*, *Environmental Assessment Program, Water Quality Studies Unit.* Assists in defining project objectives, scope, and study design for fecal coliform, dissolved oxygen, nutrients, and pH. Responsible for writing sections of the QA Project Plan, data collection, data entry to the EIM system, and sections of technical report related to data collection, field methods, and data quality review.
- *Lawrence Sullivan*, *Principal Investigator*, *Environmental Assessment Program, Water Quality Studies Unit*. Assists in defining project objectives, scope, and study design for fine sediment. Responsible for writing sections of the QA Project Plan, data collection, data entry to the EIM system, and sections of technical report related to data collection, field methods, and data quality review.
- *Greg Pelletier*, *Water Quality Modeler*, *Environmental Assessment Program, Nonpoint Studies Unit.* Responsible for reviewing portions of the QA Project Plan related to Capitol Lake and Budd Inlet. Applies model to Capitol Lake and Budd Inlet.
- *Kirk Sinclair*, *Hydrogeologist*, *Environmental Assessment Program, Nonpoint Studies Unit*. Designs groundwater monitoring program and installs all required equipment. Provides technical assistance related to groundwater influences. Drafts portions of QA Project Plan and final TMDL report related to groundwater.
- *Chuck Springer*, *Hydrologist*, *Environmental Assessment Program*, *Stream Hydrology Unit*. Responsible for deploying and maintaining continuous flow loggers and staff gages. Responsible for producing records of hourly flow data at sites selected for the study.

- Karol Erickson, *Unit Supervisor*, *Environmental Assessment Program, Water Quality Studies Unit*. Reviews portions of QA Project Plan, final TMDL report, and technical study budget related to fecal coliform bacteria, dissolved oxygen, nutrients, pH, and fine sediment.
- *Darrel Anderson*, *Unit Supervisor*, *Environmental Assessment Program, Nonpoint Studies Unit*. Reviews temperature portions of QA Project Plan, final TMDL report, and technical study budget.
- *Will Kendra*, *Section Manager*, *Environmental Assessment Program, Watershed Ecology Section*. Responsible for approval of QA Project Plan and final TMDL report.
- *Stuart Magoon*, *Director*, *Environmental Assessment Program, Manchester Environmental Laboratory*. Provides laboratory and staff resources, sample processing, analytical results, laboratory contract services, and QA/QC of data. Reviews sections of the QA Project Plan relating to laboratory analysis.
- *Cliff Kirchmer*, *Quality Assurance Officer*, *Environmental Assessment Program*. Reviews QA Project Plan and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of the project.
- *Chris Hempleman*, *TMDL Project Lead*, *Water Quality Program, Southwest Regional Office*. Acts as point of contact between Ecology technical study staff and interested parties and coordinates information exchange and meetings. Supports, reviews, and comments on QA Project Plan and technical report. Responsible for implementation planning and preparation of TMDL submittal document for EPA.
- *Kim McKee*, *Unit Supervisor*, *Water Quality Program, Southwest Regional Office*. Responsible for approval of TMDL submittal to EPA.
- *Kelly Susewind*, *Section Manager*, *Southwest Regional Office.* Responsible for approval of TMDL submittal to EPA.

The following organizations also contribute data that will be used in the study:

- *Thurston County Environmental Health Division and Water and Waste Management*. Coordinates data collection with Ecology and supports model development based on previous and ongoing modeling efforts.
- *Squaxin Island Tribe*. Assists in defining project objectives, scope, and study design for fine sediment. Conducts gravel composition and sediment source surveys under a grant from EPA to assist with the development of the TMDL.
- *J. E. Edinger Associates, Inc***.** Develops model of Budd Inlet and Capitol Lake.
- *Thurston Regional Planning Council and General Administration*. Coordinates with Ecology regarding data collection related to Capitol Lake.
- *City of Olympia.* Coordinates stormwater and ambient monitoring programs with Ecology.

Project Schedule

Table 19 lists the proposed schedule for data collection, analysis, modeling, and reporting throughout the project.

Table 19. Proposed Schedule for TMDL Study.

Document or Activities	Date
Reconnaissance (2003) monitoring plan summary	July 2003
Reconnaissance (2003) monitoring	July through December 2003
Quarterly reports	July 2003 and ongoing
Final QA Project Plan	January 2004
2004 monitoring	January through December 2004
Analyses and modeling	January through December 2005
EIM data completion	December 2005
Draft TMDL technical report for external review	March 2006
Final TMDL technical report	June 2006

Laboratory Budget

The laboratory budget in Table 20 includes all analyses to be conducted by Manchester Environmental Laboratory. The additional fecal coliform bacteria samples to be analyzed by Thurston County Environmental Health Laboratory are funded by a Centennial grant awarded to Thurston County.

Table 20. Deschutes River/Capitol Lake/Budd Inlet TMDL Laboratory Cost Estimate for 2004.

Program	No. Stations	No. Events	Samples per event	Parameter	Unit Cost	Total Samples	Total Cost	Subtotal
Twice-monthly tribs	18	24	1	FC MF	20	432	$8,640	
	9	12	1	Nutrients*	77	108	$8,316	
	3	12	1	TSS	10	36	$360	
	0	0	1	Alkalinity	14	0	$0	
	7	12	1	TOC/DOC	58	84	$4,872	$22,188
Twice-monthly main stem	6	24	1	FC MF	20	144	$2,880	
	7	12	1	Nutrients*	77	84	$6,468	
	1	4	1	Chlorophyll a	46	4	$184	
	3	2	1	BOD5	46	6	$276	
	7	12	1	TSS	10	84	$840	
	7	12	1	Alkalinity	14	84	$1,176	
	7	12	1	TOC/DOC	58	84	$4,872	$16,696
Dry weather synoptic survey	25	1	1	FC MF	20	25	$500	$500
Wet weather stormwater survey	25	4	4	FC MF	20	400	$8,000	
	5	4	4	Nutrients*	77	80	$6,160	
	5	4	4	TSS	10	80	$800	
	5	2	4	TOC/DOC	58	40	$2,320	$17,280
Capitol Lake	8	3	2	FC MF	20	48	$960	
	5	3	2	Nutrients*	77	30	$2,310	
	5	3	2	Chlorophyll a	46	30	$1,380	
	4	2	1	Phytoplankton ID	86	8	$688	
	4	2	2	BODU	426	16	$6,816	
	5	3	2	TOC/DOC	58	30	$1,740	$13,894

*Nutrients include: TP, TPN, OP, NO3+NO2, TPLL

	Samples per Parameter	Total Cost
FC MF	1049	$20,980
Nutrients	302	$23,254
Chlorophyll a	34	$1,564
Phytoplankton ID	8	$688
BOD5	6	$276
BODU	16	$6,816
TSS	200	$2,000
Alkalinity	84	$1,176
TOC/DOC	238	$13,804
total	**1937**	**$70,558**
plus 10% (QA)	**2131**	**$77,614**[5]

[5] Costs include 50% discount for Manchester Environmental Laboratory.

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Appendices

Appendix A
Reconnaissance Monitoring Plan (2003)

Appendix A

Reconnaissance Monitoring Plan (2003)

Memorandum

To: Files
From: Mindy Roberts, Mike LeMoine, Greg Pelletier, Kirk Sinclair, Lawrence Sullivan, Trevor Swanson, and Brian Zalewsky (Department of Ecology)
Date: July 31, 2003
Subject: Final Reconnaissance Study Plan for Deschutes River/Capitol Lake/Budd Inlet Total Maximum Daily Loads

This memorandum summarizes initial monitoring to be conducted throughout the Deschutes River/Budd Inlet watershed from June through December 2003. The primary field work in support of the TMDL water quality studies will occur in calendar year 2004. Ecology will develop a Quality Assurance Project Plan (QAPP) in fall 2003 for internal and external review and comment. The purpose of the proposed 2003 monitoring is to update historical data and generate new information with which to design the 2004 monitoring program. The 2003 data may provide a second year for validation of models or other analyses.

Introduction

The Deschutes River, Capitol Lake, and Budd Inlet TMDL project encompasses the entire watershed, from the Deschutes River headwaters through the marine areas (Figure 1). Tributaries to the Deschutes River, Capitol Lake, and Budd Inlet are included. The Clean Water Act section 303(d) listings addressed in the study include the following:

- fecal coliform bacteria
- temperature
- dissolved oxygen and nutrients
- pH
- fine sediment

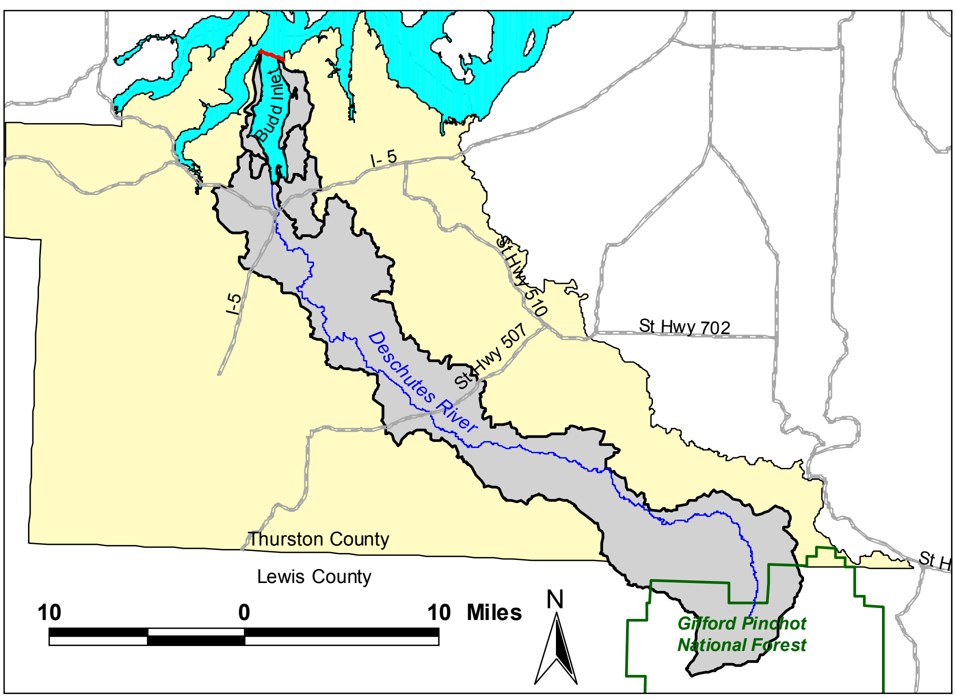

Figure 1. Deschutes River, Capitol Lake, and Budd Inlet TMDL study extent.

A number of previous and ongoing studies by USGS, Thurston County, and Department of Ecology characterize flow and surface water/groundwater interaction at various Deschutes River and tributary locations. Thurston County has monitored 75 locations throughout the project area for fecal coliform bacteria, dissolved oxygen, temperature, pH, nutrients, and chlorophyll. Ecology maintains ambient monitoring stations on the Deschutes River and in Budd Inlet; in addition, Ecology's Salmon Recovery Index Watershed monitoring project includes continuous temperature data, nutrients, and other water quality parameters at three locations on the Deschutes River. The Squaxin Island Tribe has monitored temperature, fine sediment, and related parameters. Weyerhaeuser Company has monitored flow, temperature, sediment, and habitat at several stations in the headwaters. The LOTT Budd Inlet study and Miller Brewing Company discharge study provide significant water body data sets for Capitol Lake and Budd Inlet.

Proposed 2003 Study Sites

The reconnaissance studies include continuous temperature monitoring, twice-monthly or monthly *in situ* measurements and grab samples, short-term continuous monitoring, and targeted stormwater outfall dry weather and wet weather monitoring. Where sampling locations coincide with existing Ecology or Thurston County monitoring stations, the original station identifiers are included. Monitoring will be conducted in accordance with standard Department of Ecology protocols. Figure 2 summarizes station locations.

Table 1 summarizes temperature monitoring stations. Continuous temperature monitors (i.e., Onset StowAway TidBits and Maxim Dallas i-buttons) will be used to record surface water, hyporheic water, and air temperatures. Relative humidity probes will be installed in a subset of locations. The Ecology Stream Hydrology Unit will install staff gages and continuous flow recorders at three stations. Piezometers will be used to characterize vertical hydraulic gradients at monitoring locations. Field teams will record streamflow during monthly downloads. Some sites are located on lands owned by Weyerhaeuser Company, and Ecology has received permission to access those sites.

Table 2 summarizes twice-monthly (July through October) and monthly (November and December) monitoring stations throughout the watershed. Grab samples will be collected and analyzed for fecal coliform, nutrients (dissolved and total), organic carbon, and/or alkalinity and hardness. Dissolved oxygen samples will be analyzed using Winkler titrations. *In situ* pH will be measured with field meters. Field replicates will be collected at a frequency of 5 to 10%. Flows will be measured at the time of sampling as indicated in the table.

In addition, Hydrolabs will be installed for up to two weeks in Ayer (Elwanger) Creek, Reichel Creek, Capitol Lake, and inner Budd Inlet, contingent on finding a secure location for deployment. Critical periods include August and September 2003.

Two rounds of monitoring will be conducted on Capitol Lake. During sampling rounds, planned for August and September 2003, Ecology will record temperature and conductivity/salinity profiles throughout the lake, and will collect samples to be analyzed for fecal coliform, nutrients, chlorophyll a, ultimate BOD, and organic carbon.

Ecology will conduct a round of dry-weather stormwater outfall monitoring in late summer 2003 at up to 25 locations to be determined in cooperation with the City of Olympia, City of Tumwater, General Administration, Thurston County, and Department of Transportation. A subset of sites will be sampled over two storm events in fall/winter 2003, two to four times over the hydrograph. Samples will be analyzed for fecal coliform bacteria, nutrients (dissolved and total), BOD, and organic carbon.

Project Schedule and Products

Interim results will be summarized in quarterly reports that will be distributed to interested parties via e-mail. Quarterly reports will continue through subsequent calendar year 2004 monitoring. The project will culminate in a technical report summarizing all analyses in 2005.

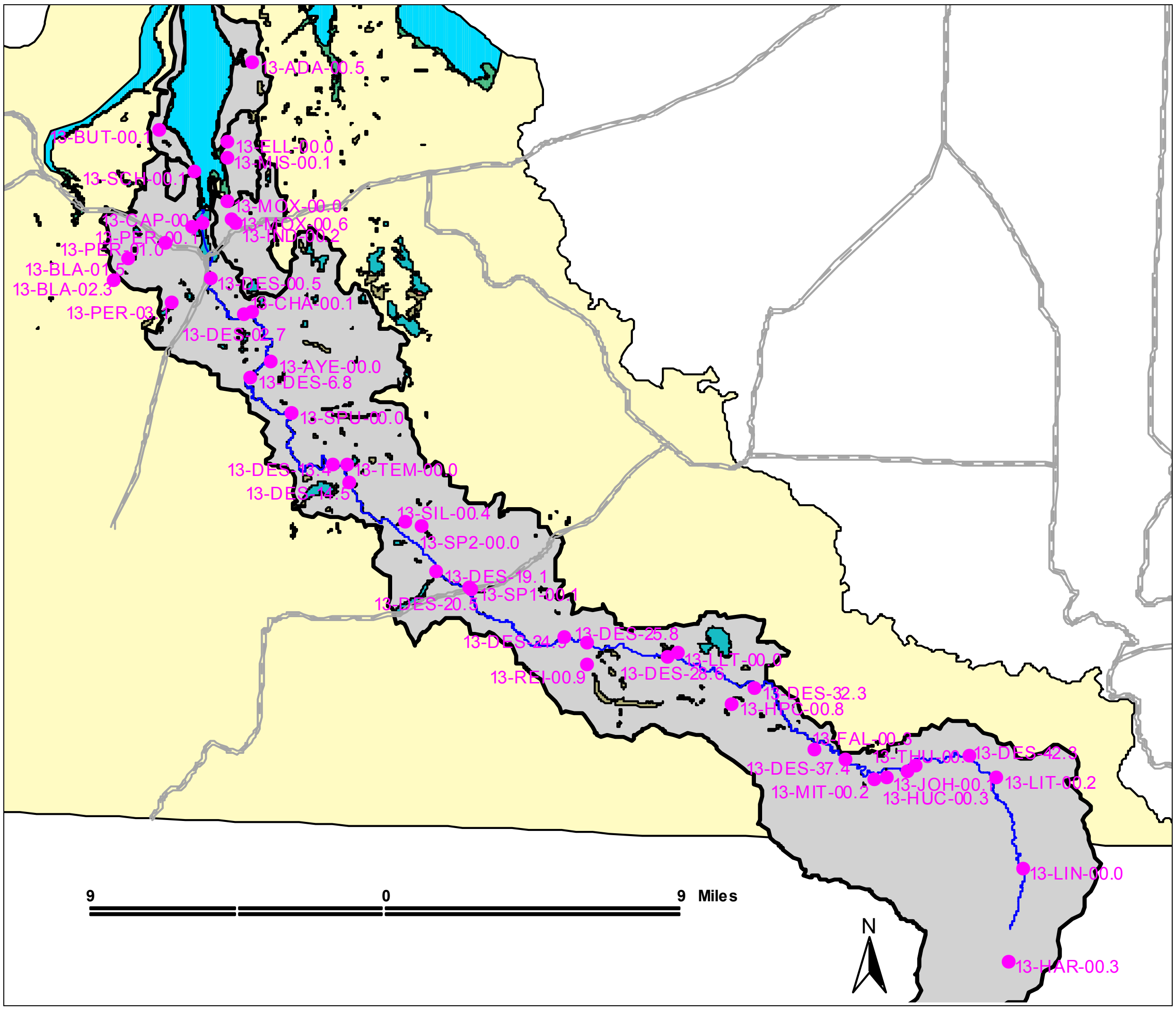

Figure 2. Stations for 2003 initial monitoring.

Table 1. Monitoring locations for temperature and related parameters.

Station Location	Thur. County Station	Project Station	Water Temp	Air Temp/ RH	Hypo-rheic Temp	SHU flows	Meas. flows	Staff Gage	Piezo-meter	Wey. Co. Permission Received
Main Stem Deschutes River										
Deschutes nr. Upper Falls	NM	13-DES-42.3	X	RH			X			
Deschutes at 1000 Rd	DESDE 0050	13-DES-37.4	X	X	X					X
Deschutes at 18731 old Camp Lane (Art Schacher)	NM	13-DES-32.3	X	X	X		X		X	
Deschutes at Vail Cutoff Road SE nr Lake Lawrence	DESDE 0040	13-DES-28.6	X		X		X		X	
Deschutes at Woodbrook Lane (SRIW Station 1307)	NM	13-DES-25.8	SRIW							
Deschutes at Vail Loop Rd SE (USGS sta 12079000)	DESDE 0045	13-DES-24.9	X	RH	X		X	USGS	X	
Deschutes at Rte 507	DESDE 0030	13-DES-20.5	X		X	X	SHU	SHU	X	
Deschutes at Military Rd	NM	13-DES-19.1	X		X		X		X	
Deschutes at Waldrick Road (SRIW Station 1304)	NM	13-DES-14.5	SRIW		X	X	SHU	SHU	X	
Deschutes nr Rich Rd SE/Jerry Boe	DESDE 0020	13-DES-09.2	X		X	X	SHU	SHU	X	
Deschutes nr Olympia Fuel & Asphalt off 84th/99	NM	13-DES-06.8	X	X	X		X		X	
Deschutes at Henderson Blvd SE	DESDE 0010	13-DES-02.7	X		X		X		X	
Deschutes at E St Bridge nr brewery (SRIW Sta 1302)	DESDE 0000	13-DES-00.5	SRIW	RH	X		USGS	USGS	X	
Upper Deschutes Tributaries										
Thurston Creek at 3000 Rd	DESTH 2100	13-THU-00.1	X				X			X
Johnson Creek at 3000 Rd	NM	13-JOH-00.1	X				X			X
Huckleberry Creek at 3000 Rd	DESHU 1900	13-HUC-00.3	X				X			
Mitchell Creek nr mouth at Gordon Rd SE/1000 Rd	NM	13-MIT-00.2	X				X			X
Fall Crk at Gordon Rd SE/ 1000 Rd	NM	13-FAL-00.3	X				X			X
Hull and Pipeline Creek at Gordon Rd SE/1000 Rd	NM	13-HPC-00.8	X				X			X
Lake Lawrence trib nr Vail Loop Rd SE	NM	13-LLT-00.0	X				X			
Reichel Lake Creek at Vail Loop Rd SE	DESRE 1100	13-REI-00.9	X				X			
Spring nr Rte 507 just upstream of Deschutes R. at Rte 507	NM	13-SP1-00.1	X				X			
Lower Deschutes River Tributaries										
Silver Spring near mouth	NM	13-SIL-00.4	X				X			
Small spring nr Silver Spring Artist Facility	NM	13-SP2-00.0	X							
Tempo Lake outflow nr Stedman Road	NM	13-TEM-00.0	X				X			
Spurgeon Cr at Rich Rd SE (access at 9431 Rich Rd SE/Jerry Boe)	DESSP 0500	13-SPU-00.0	X				X			
Ayer (Elwanger) Cr at Riverlea Dr	DESAY 0400	13-AYE-00.0	X				X			
Chambers Cr off Rich Rd SE (Q); off 58th Ave SE (T)	DESCH 0300	13-CHA-00.1	X				X	Th. Co.		

Station Location	Thur. County Station	Project Station	Water Temp	Air Temp/ RH	Hypo-rheic Temp	SHU flows	Meas. flows	Staff Gage	Piezo-meter	Wey. Co. Permission Received
Capitol Lake Tributaries										
Black Lake outlet at Belmore Rd	BUDBL 0399	13-BLA-02.3	X	X			X	Th. Co.		
Black Lake Ditch at Jones Quarry Bridge	NM	13-BLA-01.5	X				X	Th. Co.		
Black Lake Ditch nr Percival confluence	NM	13-BLA-00.0	X				X	Th. Co.		
Percival Creek at Trosper Rd SW	NM	13-PER-03.1	X							
Percival Creek nr Black Lake Ditch confluence	BUDPE 0020	13-PER-01.0	X	X			X			
Percival Creek nr mouth	BUDPE 0000	13-PER-00.1	X				X			

Flow at shaded stations will be monitored by the Department of Ecology Stream Hydrology Unit.
NM = not monitored previously by Thurston County

Table 2. Monitoring locations for fecal coliform, dissolved oxygen, nutrients, alkalinity/hardness, and organic carbon.

Thurston Co Station	Project Station	Description	Q	FC	DO	Nuts	pH	Alk/Hard	TOC/ DOC	Wey. Co. permission
		Main Stem Deschutes River								
DESDE0050	13-DES-37.4	Deschutes River at 1000 Rd	Wey.Co.				pH	alk/hard		
DESDE0040	13-DES-28.6	Deschutes River at Vail Cutoff Rd SE	USGS				pH	alk/hard		
DESDE0030	13-DES-20.5	Deschutes River at Rte 507	Q			nuts	pH	alk/hard		
DESDE0020	13-DES-09.2	Deschutes River nr Rich Rd SE/Jerry Boe	Q				pH	alk/hard		
DESDE0010	13-DES-02.7	Deschutes River at Henderson Blvd SE	no	FC	DO	nuts	pH			
DESDE0000	13-DES-00.5	Deschutes River at E St bridge (SRIW 1302)	USGS	FC	DO	nuts	pH	alk/hard	OC	
		Upper Deschutes Tributaries								
DESHD3700	13-HAR-00.3	Hard Creek above confluence w/ upper Deschutes	Wey.Co.				pH			X
DESLI3100	13-LIN-00.0	Lincoln Creek above confluence w/ upper Deschutes	Wey.Co.				pH			X
DESLD2700	13-LIT-00.2	Little Deschutes River above confluence w/ Deschutes	Wey.Co.				pH			X
DESTH2100	13-THU-00.1	Thurston Creek at 3000 Rd	Wey.Co.				pH			X
DESHU1900	13-HUC-00.3	Huckleberry Creek at 3000 Rd	Wey.Co.		DO		pH			X
DESRE1100	13-REI-00.9	Reichel Creek at Vail Loop Rd	Q	FC	DO		pH			
		Lower Deschutes Tributaries								
DESSP0500	13-SPU-00.0	Spurgeon Creek at Rich Road/Jerry Boe	Q	FC			pH			
DESAY0400	13-AYE-00.0	Ayer (Elwanger) Creek off Riverlea Dr	Q	FC	DO		pH			
DESCH0300	13-CHA-00.1	Chambers Creek off 58th Ave SE	Th.Co.	FC			pH			
		Capitol Lake and Tributaries								
BUDBL0399	13-BLA-02.3	Black Lake outlet at Belmore Rd	Th.Co.	FC	DO		pH			
NM	13-BLA-00.0	Black Lake Ditch nr Percival confluence	Th.Co.	FC	DO		pH			
BUDPE0020	13-PER-01.0	Percival Creek nr Black Lake Ditch confluence	Th.Co.	FC						
BUDPE0000	13-PER-00.1	Percival Creek nr mouth	no	FC	DO	nuts	pH			
BUDCAL010	13-CAP-00.4	Capitol Lake at Railroad Trestle	no	FC	DO	nuts			OC	
		Budd Inlet Tributaries								
BUDAD0000	13-ADA-00.5	Adams Creek at Boston Harbor Rd	Q	FC			pH			
BUDBU0000	13-BUT-00.1	Butler Creek at French Loop Rd	Q	FC			pH			
BUDEL0000	13-ELL-00.0	Ellis Creek at East Bay Dr	Q	FC			pH			
BUDIN0010	13-IND-00.2	Indian Creek at Quince Ave	Q	FC						
BUDMI0000	13-MIS-00.1	Mission Creek at East Bay Drive	Q	FC						
BUDMO0030	13-MOX-00.6	Moxlie Creek at Plum St and Henderson	Q	FC			pH			
NM	13-MOX-00.0	Moxlie Creek at East Bay	no	FC						
BUDSC0000	13-SCH-00.1	Schneider Creek at West Bay Dr	Q	FC			pH			

NM = not monitored

Appendix B
Capitol Lake Classification

Appendix B

Capitol Lake Classification

Memorandum

From: Hicks, Mark
Sent: Monday, August 25, 2003 10:40 AM
To: Roberts, Mindy
Cc: Erickson, Karol; Pelletier, Greg; Braley, Susan
Subject: RE: Capitol Lake classification

Mindy,

I concur with your assessment on how to apply the standards in determining whether to apply lake or riverine standards to Capitol Lake. It is particularly important, as you note at the end, to recognize that the reason the standards make this distinction is to protect the water quality and uses of such systems. Where there is doubt as to whether a regulated systems meets the 15 day threshold due to variable control factors, the default should be to provide the most protection for the water quality and uses of that system. It is important to recognize that the narrative antidegradation requirement to protect existing and designated uses overrides the specific numeric criteria anytime the scientific information suggests those numeric criteria will not appropriately protect the uses of the waterbody. As can be noted by visiting Capitol Lake at this time of year, there are significant problems with algal growth which interfere with both fisheries and recreational uses of the waters.

Thanks for your thorough attention to the proper application of the water quality standards.

Mark Hicks
Water Quality Standards

-----Original Message-----
From: Roberts, Mindy
Sent: Monday, August 11, 2003 1:52 PM
To: Hicks, Mark
Cc: Erickson, Karol; Pelletier, Greg
Subject: Capitol Lake classification

The Environmental Assessment Program has begun the Deschutes River/Capitol Lake/Budd Inlet TMDL. Capitol Lake's classification has been discussed by a number of other agencies in previous publications, but Ecology has had no avenue to verify classification until the TMDL study began. Because the loading capacity of the system depends on its water quality classification, the project must establish the water quality target at the outset. Can you verify my interpretation of the water quality standards, that Capitol Lake water quality be compared with the lake standards? Please revise any text that is inconsistent with the standards.

WAC 173-201A-020 states that lakes "shall be distinguished from riverine systems as being water bodies, including reservoirs, with a mean detention time of greater than fifteen days." Mean detention time is defined as "the time obtained by dividing a reservoir's mean annual minimum total storage by the thirty-day ten-year low-flow [30Q10] from the reservoir." Therefore, if the storage volume divided by the 30Q10 low flow is greater than fifteen days, the lake standards apply; otherwise, the stream standards apply.

No outflows from Capitol Lake are available on which to base the outflow 30Q10 discharge. The Deschutes River, with two USGS gaging locations, is the primary inflow to Capitol Lake. USGS estimated the 30Q10 flows for the Deschutes River at E Street, based on monitoring data from 1991-2001 at 59.8 cfs (D. Kretsch, personal communication, 2003). Mean annual minimum total storage is difficult to estimate, given that the water level may be drawn down prior to an event expected to produce high river discharge. The typical lake volume is estimated as 1800 ac-ft, back-calculated from information presented in CH2MHill (2001). The resulting detention time is 15.2 days.

However, the detention time could be affected by three conditions and trends. First, the estimate excludes inflows from Percival Creek, which would decrease the detention time slightly assuming no net change in Capitol Lake storage volumes and that outflow is the sum of the inflows. Second, 30Q10 flows were higher historically (e.g., 82.4 cfs for the period 1945-1964; D. Kretsch, personal communication, 2003); if the statistics represent a decreasing trend in baseflow discharge, then future detention time would increase from that calculated. Finally, the active volume of Capitol Lake has decreased over time since dredging ceased; as the volume decreases, the detention time decreases.

Regardless of the estimated detention time, the intention of the water quality standards is to protect beneficial uses. Capitol Lake functions as and is managed as a lake; therefore, the lake water quality standards should apply.

References

CH2MHill. 2001. Technical Evaluation Report for the Discharge of Treated Wastewater from the Tumwater Brewery. Report prepared for Miller Brewing Company, Tumwater Brewery.

Appendix C
Summary of 2003 Reconnaissance Monitoring

Appendix C
Results of 2003 Reconnaissance Monitoring Program

Introduction

The Washington State Department of Ecology (Ecology) 2003 data collection effort was designed to confirm temperature impairments within the Deschutes River and Percival Creek Watersheds, and generate new information with which to design the 2004 monitoring program. The study is outlined in Appendix A. The 2003 data will also provide an additional year for validation of models or other analyses. Due to extreme low flow conditions in the Deschutes Basin during the summer and fall of 2003, additional field surveys were conducted to provide better resolution and insight into the thermal regime of the study area. The purpose of this document is to summarize the 2003 data collection program results to date.

The 2003 data collection program identified temperature, fecal coliform, dissolved oxygen, and pH impairments and began to quantify the sources or factors contributing to those impairments. Temperature-related studies include the following:

- Continuous air and water temperature monitoring at 15 mainstem locations and 13 tributary locations within the Deschutes Basin and at six locations in the Percival/Black Lake system. Continuous water temperature monitoring within the hyporheic zone at 14 mainstem locations within the Deschutes Basin.

- Installation and maintenance of three stand-alone stream flow stations in the Deschutes Mainstem. Monthly discharge measurements (June to October) at all mainstem locations. One seepage run was conducted on August 5, 2003, that included discharge measurements at 28 mainstem and tributary locations. One seepage run was conducted August 6, 2003, in the Percival Creek system.

- Installation and instrumentation of 14 piezometers within the Deschutes Mainstem.

- Stream walk of approximately 30 km of Deschutes Mainstem. Information on wetted width, bankfull width, channel substrate, and riparian vegetation height, density, and species was collected. Use of hemispherical digital photography within selected mainstem locations.

- Thermal infrared remote sensing (TIR) survey flown on August 20, 2003, by Watershed Sciences, LLC for Deschutes River from Deschutes Falls to Capitol Lake.

The fecal coliform, DO, and pH monitoring program included the following:

- Twice-monthly monitoring in the Deschutes River, Percival Creek, Capitol Lake, and tributaries to each.

- Stream walk of approximately 30 km of the Mainstem Deschutes River. Instantaneous water temperature, conductivity, DO, and pH were recorded.

- Capitol Lake spatial and temporal variability.
- Dry-weather monitoring of stormwater outfalls.

Methods

All data were collected based on standard Ecology protocols. Discharge was recorded according to Ecology (2000). Temperature and relative humidity were monitored in accordance with Schuett-Hames et al. (1999). Grab samples and in situ values of fecal coliform, nutrients, DO, pH, and conductivity were monitored based on WAS (1993). Surface water and groundwater interactions were evaluated using the methodologies described in Stallman (1983).

Results

The following results are preliminary, since the QA/QC data checks have not been completed to date.

Temperature-Related Monitoring

Continuous Monitoring of Relative Humidity and Water and Air Temperature Stations

Figure C-1 presents temperature, flow, relative humidity, and groundwater monitoring stations within the Upper Deschutes Basin. Hyporheic temperature recording devices were co-located with piezometers (see groundwater sampling section for details on hyporheic temperature stations). Figure C-2 details temperature, flow, relative humidity, and groundwater monitoring stations within the Lower Deschutes Basin and Percival Creek Watershed.

Groundwater Sampling

Thirteen steel and one PVC in-stream piezometers were installed along the Mainstem Deschutes River during June and July 2003 to enable reconnaissance monitoring of surface water and groundwater head relationships, groundwater temperatures, and specific conductivity. The piezometers were distributed throughout the length of the river between the Upper Deschutes Falls and the lower falls at Tumwater to correspond with the mainstem stream temperature and flow monitoring locations (Figures C-1 and C-2).

Each of the steel piezometers consists of a 7-ft (2.1-m) length of 1- or 1.5-in diameter galvanized pipe, one end of which is crimped and slotted. The upper end of each pipe is fitted with a standard pipe coupler to provide a robust strike surface and to enable the piezometers to be securely capped between sampling events. The piezometers were driven into the stream bed within a few meters of the shoreline to a maximum depth of approximately 5 ft (1.5 m).

After installation, each piezometer was developed and then instrumented with three Dallas Maxim Ibutton® thermistors for continuous monitoring of shallow groundwater temperatures. In a typical installation, one thermistor was located at the bottom of the piezometer, one was located approximately one foot below the streambed, and one was located roughly equidistant between the upper and lower thermistors. The piezometers were accessed monthly (between June and November) to download thermistors and to make "spot" measurements of stream and groundwater temperature for later comparison against and validation of the thermistor data. The monthly spot measurements were made with properly maintained and calibrated field meters in accordance with standard Department of Ecology Watershed Ecology Section methodology.

During the monthly site visits, surface water and groundwater head relationships were measured using a calibrated electric well probe, steel tape, or manometer board in accordance with standard USGS methodology (Stallman, 1983). The head difference between the internal piezometer water level and the external river stage provided an indication of the vertical hydraulic gradient and the direction of flow between the river and groundwater.

In addition, thermistors were placed within the hyporheic zone adjacent to each piezometer. The hyporheic zone is the region of saturated sediments beneath and beside the active river channel that contains some proportion of river water. The hyporheic thermistors were placed within the streambed sediments at a depth of approximately 1 to 1.5 ft (0.3 to 0.5 m). The hyporheic thermistors were removed and downloaded at the end of October 2003.

Hyporheic temperature varied with depth below the sediment surface, surface water temperature, and whether the reach gained or lost water, as indicated by the vertical hydraulic gradient. In general, temperatures below 3 ft (1 m) showed little hourly variability but reflected weekly or seasonal trends. Hyporheic temperatures within 1 ft (0.3 m) of the sediment surface demonstrated hourly temperature variations, with the highest daily range at the strongest downwelling site (4°C at the Deschutes River at Waldrick Road). Gaining reaches also exhibited weak hourly variations within 1 ft (0.3 m) of the surface, due to shallow gravel interflows.

Thermal Infrared (TIR) and Color Videography Surveys

On August 20, 2003, Ecology commissioned a TIR flight along approximately 70 km of the Mainstem Deschutes River from Deschutes Falls to Tumwater Falls. A helicopter-mounted TIR sensor and color video camera were used to take thermal infrared and visible color images of the Deschutes River and riparian area to provide a spatially continuous image of surface temperature. The contractor placed temperature gages in the mainstem to confirm flight data with field readings.

The images typically cover an area of approximately 100 by 150 meters (330 by 490 feet) centered on the stream and having a spatial resolution of approximately 0.5 meters (less than two feet). Infrared and photographic images were collected along the entire length of the surveyed mainstem. Data are not yet available.
Ecology will use the information collected from the surface of the streams to measure the stream temperatures on a spatial scale and to support the temperature model development. The information from the adjacent land areas may also be used to estimate shading from vegetation.

TIR imagery and derived data products will also provide a means for detecting and measuring tributary and other point source inflows along the entire mainstem. The results, expected in March 2004, will be used to refine the summer monitoring plan.

Riparian Vegetation and Channel Morphology Surveys

Effective shade measurements for riparian vegetation within the Deschutes River Watershed were collected using hemispherical digital photography and will be analyzed using the Hemi-view 2.1 software from Delta-T Devices. Eleven sites for hemispherical photography were selected randomly from a subset of representative vegetation polygons to provide a statistically-based effective shade of each vegetation type. Photos will be analyzed in 2004 to provide data for the shade model verification.

During the week of August 18, 2003, Ecology surveyed approximately 30 (non-contiguous) kilometers of the Deschutes Mainstem. A total of 60 cross-sections were sampled in the mainstem (approximately one cross-section per 500 m). At each cross-section, measurements of wetted width; bankfull width; channel substrate; channel incision; and vegetation species, height, and overhang were measured. Other measured parameters included pH, dissolved oxygen, conductivity, and temperature. Figure C-3 shows measured bankfull and wetted widths versus river mile in the Deschutes Mainstem. Bankfull widths are generally greater than wetted widths except in areas exhibiting significant channel incision, most notably between RM 6.9 and 9.0 and RM 11.5 to12.1. Regression analysis shows a slight decrease in wetted and bankfull widths with distance from the headwater. Water quality data are presented in the Stream Walk Survey section below.

Flow Monitoring and Seepage Run Survey

The Ecology Stream Hydrology Unit installed three stand-alone flow stations at three sites along the Mainstem Deschutes at Route 507, Waldrick Road, and Rich Road (Figures C-1 and C-2). River stage is logged every fifteen minutes and downloaded once a month. Data are imported into the stream flow database and published to the Ecology website. Stream flow data from these stations can be accessed from the Ecology website http://www.ecy.wa.gov/programs/eap/flow/shu_main.html.

A seepage run was conducted in the Deschutes River Basin on August 5, 2003, and in the Percival Creek Basin on August 6, 2003. A seepage run consists of measuring the flow of a river or stream at several locations along its length including any sources of input such as tributaries. Comparisons are then made between adjacent flow stations by looking for changes in flow volume not accounted for by the tributary inputs. Such changes are presumably a result of seepage into or out of the river or stream.

Flows were measured at 28 mainstem and tributary locations within the Deschutes Basin and six mainstem and tributary locations within the Percival Creek Basin. All stream velocity measurements were made following the field sampling and measurement protocols described in Ecology (2000) and the WAS protocol manual (WAS, 1993). Flow data for the Deschutes and

Percival Basins are shown in Table C-1. Figures C-4 and C-5 show gaining and losing reaches of the Deschutes River.

Maximum losses of 3.80 cfs (0.11 cms) were measured along a 5.1-mile (8.2 km) reach of the Upper Deschutes River between Sorensen Road and Cougar Mountain Trail. Maximum gains of 21.5 cfs (0.61 cms) were measured along a 5.2-mile (8.4-km) reach of the Lower Deschutes River between the Ayer Creek confluence and E-Street Bridge. Calculated seepages along the Deschutes River between Vail Loop Road and Vail Cutoff Road were inconclusive because seepage values were within the range of discharge measurement error.

Continuous Stream Temperature Monitoring

Continuous temperature monitors (i.e., Onset StowAway TidBits) were used to record surface water, hyporheic, and air temperatures. Relative humidity probes were installed in the upper, mid, and lower portion of the Deschutes Mainstem (Figure C-1 and C-2).

Deschutes River Basin

During the summer of 2003, the Deschutes River Basin exceeded class A state water quality standards for temperature at 16 out of 25 sites, as indicated in Table C-2. Most of these exceedences occurred around July 30, 2003. Figures C-6 and C-7 summarize the daily maximum and the seven-day average daily maximum temperatures in the Upper Deschutes Watershed, while Figures C-8 and C-9 summarize the daily maximum and the seven-day average daily maximum temperatures in the Lower Deschutes and Percival Creek Watersheds.

Along the Deschutes River Mainstem all but one site (13-DES-42.3) exceeded class A state water quality standards for temperature. The highest maximum temperature recorded on the mainstem was 24.7°C at Old Camp Lane (13-DES-32.3), as shown in Figure C-6. Downstream from Old Camp Lane (13-DES-32.3), peak daily temperatures decrease to a summer maximum of 20.6°C at Vail Loop Rd (13-DES-24.9). From Vail Loop Road, temperatures increase to 24.0°C just above the confluence with Ayer Creek (13-DES-05.8) and then decrease to 20.9°C at E Street bridge (13-DES-00.5).

Major tributaries of the Deschutes River varied in temperatures from the highest maximum of 25.1°C to the lowest maximum of 14.4°C. Four tributaries (Ayer Creek, Reichel Creek, Spurgeon Creek, and the Tempo Lake outflow) exceeded the Class A state water quality standard for temperature. All other tributaries were within standards and well within temperature tolerance range of salmonid species.

Figures C-10 and C-11 present the daily maximum water temperatures along the mainstem of the Deschutes and its tributaries, respectively. All mainstem stations and four tributaries exceeded 18°C during summer 2003.

Percival Creek Basin

Percival Creek Basin exceeded Class AA[1] state water quality standards in six of seven sites. Figures C-8 and C-9 summarize the daily maximum and the seven-day average daily maximum temperatures in the Percival Creek Watershed. Figure C-12 provides the time series of daily maximum water temperatures. All sites exceeded the Class AA temperature standard.

Percival Creek Basin stream temperatures tend to oppose most stream temperature trends by cooling as they flow downstream. Lake outflows form the headwaters of both Percival Creek and Black Lake Ditch. The warmest maximum temperatures recorded in 2003 were located at the most upstream sites on Percival Creek (13-PER-03.1) and Black Lake Ditch (13-BLA-02.3), which were 26.2°C and 28.4°C, respectively. Maximum temperatures decreased downstream of these sites to 18.6°C on Percival (13-PER-01.0) and 23.2°C on Black Lake Ditch (13-BLA-00.0), likely due to the cooling effects from groundwater inflow.

Fecal Coliform Bacteria, Dissolved Oxygen, Nutrients, and pH

Routine Monitoring

Twice monthly samples were analyzed for fecal coliform bacteria, dissolved oxygen, nutrients, and pH. Through November 2003, four sites have geometric mean fecal coliform concentrations >100/100 mL. Both sites on Moxlie Creek and one site each on Indian and Mission Creeks exceed the water quality standards based on up to nine samples. In addition, 12 sites had at least one value >200/100 mL, which exceeds the second part of the water quality standards: Adams, Ayer, Black Lake Ditch, Butler, Capitol Lake, Ellis, Indian, Mission, Moxlie, Percival, Reichel, and Spurgeon. These are limited datasets that do not include winter monitoring scheduled for 2003/2004.

In situ instantaneous pH was recorded at several locations along the Mainstem Deschutes, Percival Creek, and tributaries during daylight hours, as reported in Table C-3. Only Ayer Creek exhibited a pH beyond the range established in the water quality standards. However, other stations may exceed either the low, or the high, value during early morning or late afternoon conditions. Continuous monitoring will be conducted under the 2004 program.

Of the nine sites monitored for DO, five sites exhibited DO in grab samples below the 8 mg/L water quality standard (Table C-4). Reichel Creek and Ayer Creek are low-gradient streams that traverse areas where wetlands occurred historically. Both will be evaluated further in 2004. Black Lake Ditch carries water from Black Lake with DO concentrations less than the standard. Water coming from Lake Lawrence has very low DO levels. Additional investigations and analyses in 2004 will evaluate the extent of natural conditions contributing to these levels.

[1] Because Percival Creek discharges to Capitol Lake and Capitol Lake is considered lake class, Percival Creek is a Class AA waterbody (see Appendix B). Black Lake Ditch is also a Class AA waterbody because it discharges to Percival Creek.

Stream Walk Survey

Water quality data were collected during a stream walk to ascertain longitudinal variability within the Deschutes River. Temperature, dissolved oxygen, conductivity, and pH were measured along 30 river miles over five days. Since data were collected over a period of hours, temporal variation will affect direct interpretations of water quality data; however, general trends can be understood within the context of ecological theory and local land use.

Dissolved oxygen fluctuated temporally and spatially in the Deschutes River, as evident in Figure C-13. Ecological theory suggests that dissolved oxygen in most lotic systems increases during the daylight hours, due to the release of oxygen from photosynthesizing aquatic plants from a minimum near sunrise. Dissolved oxygen measurements in the Deschutes River followed this pattern; however, some exceptions can be seen around river miles 5, 21, and 31. At river miles 21 and 31, Ecology staff observed signs of cattle in the stream and fecal material both directly in the stream and within the stream corridor. Pastures can be sources of organic pollution which can cause increases in biological oxygen demand and decreases in dissolved oxygen levels. Tributary inflows also could have contributed to the low DO values. River mile 5 below the confluence of Ayer Creek and the Deschutes River also had low dissolved oxygen readings, but the data were recorded earlier in the day than other sites rendering direct comparison with other data difficult. However, DO levels near RM 5 and 31 likely fall below the standard in the early morning hours.

Figure C-14 shows that pH levels fluctuated in the same manner as dissolved oxygen, generally increasing over the daylight hours. However, pH decreased sharply around river miles 9, 11, and 14. These areas may be influenced by tributary inputs, which tend to have lower pH levels. Other decreases of pH at river miles 5, 21, and 31 coincided with decreases in dissolved oxygen. In addition, RM 6 and 10 were visited both in the morning and afternoon. The greater range at RM 6 could indicate greater productivity. Decreases in pH downstream of RM 6 could reflect the effect of wetland processes. A similar pattern occurs between RM 23 and 21 and between RM 32 and 31.

Conductivity remained fairly constant, as illustrated in Figure C-15. General increases were measured in the upper part of the watershed with slight decreases found in the lower part of the watershed. Groundwater and hyporheic conductivity recorded in piezometers ranged from 90 to 160 μS/cm during this period. The rise in conductivity between RM 25 and 22 will be investigated further in 2004. Conductivity does not appear to reflect diel variations, and longitudinal variations found during the stream walk indicate changes in water sources.

Temperatures generally increase during the daylight hours, as shown in Figure C-16. However, between river miles 21 and 22 temperatures decreased by 0.62°C and remained nearly constant with time of day between RM 32 and 29. Both patterns could indicate areas of cooler groundwater inflows.

Capitol Lake Monitoring

Capitol Lake was monitored intensively on September 17, 2003, to evaluate spatial variability of productivity-related parameters in grab samples. Table C-5 presents the results. Fecal coliform levels were very low to moderate. DO levels remained above the standard. Alkalinity, total organic carbon, dissolved organic carbon, and ammonia exhibited low variability. Most organic carbon was dissolved. Chlorophyll was much higher at stations 003 and 004 where nitrite plus nitrate was <0.2 mg/L. Where chlorophyll concentrations were low (stations 001 and 002), nitrite plus nitrate levels were elevated. Orthophosphate levels varied from 0.012 to 0.018 mg/L but did not correlate with chlorophyll levels. Total phosphorus was elevated at station 004.

Figure C-17 summarizes continuous DO recorded at the outlet from Capitol Lake. Minimum values exceeded 8 mg/L at all times, but the daily DO swing ranged up to 5 mg/L indicating high productivity.

Stormwater Outfall Monitoring

Ten stormwater outfalls were visited October 14, 2003 to verify locations and to collect a sample if the pipe carried water. Three of ten pipes had flowing water, but fecal coliform levels were low (Table C-6). The sites will be monitored during wet weather conditions.

References

Ecology. 2000. DRAFT - Instantaneous Flow Measurements: Determination of Instantaneous Flow Measurements of Rivers and Streams. Stream Hydrology Unit, Washington State Department of Ecology. Olympia, Washington.

Schuett-Hames, D., A. Pleus, E. Rashin, and J. Matthews. 1999. TFW Monitoring Program Method Manual for the Stream Temperature Survey. Prepared for the Washington State Department of Natural Resources Under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-005. DNR # 107.

Stallman, R. W. 1983. Aquifer-Test Design, Observation, and Data Analysis. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter B1, 26 P.

WAS. 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Ecology Manual, Washington Department of Ecology, Environmental Assessment Program. Olympia, Washington.

Tables and Figures

Table C-1. Results of August 5, 2003, Seepage Run Survey in the Deschutes River and Percival Creek Watersheds.

Site (# of meas taken)	Waterbody	Discharge in cfs	Discharge in cms	Wetted Width (ft)	Average Velocity (fps)	Average Depth (ft)
13-BLA-00.0	Black Lake Ditch	3.48	0.10	17.2	0.62	0.32
13-BLA-01.5	Black Lake Ditch	2.61	0.07	12.4	0.21	1.00
13-BLA-02.3	Black Lake Ditch	2.43	0.07	18.9	0.17	0.74
13-CHA-00.1	Chambers Creek	1.15	0.03	7.0	0.61	0.27
13-DES	Deschutes River	53.08	1.50	22.8	2.56	0.91
13-DES-00.5	Deschutes River	79.26	2.24	82.5	0.87	1.10
13-DES-00.5(2)	Deschutes River	78.97	2.24	82.5	0.87	1.10
13-DES-02.7	Deschutes River	70.81	2.01	47.8	1.50	0.99
13-DES-06.8	Deschutes River	51.74	1.47	36.5	1.39	1.02
13-DES-09.2	Deschutes River	49.60	1.40	42.3	0.99	1.18
13-DES-13.4	Deschutes River	41.59	1.18	41.0	1.05	0.97
13-DES-13.4(2)	Deschutes River	47.58	1.35	41.2	1.10	1.05
13-DES-14.5	Deschutes River	42.22	1.20	39.9	0.93	1.14
13-DES-14.5(2)	Deschutes River	40.79	1.15	40	0.86	1.18
13-DES-19.1	Deschutes River	29.41	0.83	51.4	0.48	1.20
13-DES-19.1(2)	Deschutes River	28.74	0.81	49.0	0.48	1.23
13-DES-20.5	Deschutes River	30.48	0.86	34	0.71	1.26
13-DES-20.5(2)	Deschutes River	30.96	0.88	34.2	0.74	1.23
13-DES-24.9	Deschutes River	23.78	0.67	68	0.29	1.20
13-DES-24.9(2)	Deschutes River	23.81	0.67	68.6	0.30	1.17
13-DES-26.2	Deschutes River	19.50	0.55	56.3	0.23	1.50
13-DES-28.6	Deschutes River	17.86	0.51	43	0.34	1.23
13-DES-28.6(2)	Deschutes River	17.58	0.50	43	0.31	1.33
13-DES-32.3	Deschutes River	14.13	0.40	61.7	0.38	0.60
13-DES-37.4	Deschutes River	17.23	0.49	46.9	0.75	0.49
13-DES-37.4(2)	Deschutes River	14.82	0.42	46.7	0.22	1.42
13-DES-42.3	Deschutes River	12.24	0.35	36.6	0.27	1.23
13-FAL-00.3	Fall Creek	0.25	0.01	1.8	0.52	0.27
13-HUC-00.3	Huckleberry Creek	0.46	0.01	3.6	1.01	0.13
13-JOH-00.1	Johnson Creek	0.19	0.01	4.7	0.19	0.21
13-MIT-00.2	Mitchell Creek	2.20	0.06	15.9	0.28	0.50
13-MIT-00.2(2)	Mitchell Creek	1.93	0.05	15.9	0.25	0.49
13-PER-00.1	Percival Creek	7.13	0.20	18.1	0.76	0.52
13-PER-01.0	Percival Creek	5.94	0.17	13.4	0.56	0.79
13-PER-03.1	Percival Creek	0.99	0.03	4.3	0.60	0.38
13-REI-00.9	Reichel Lake Creek	0.21	0.01	8.7	0.25	0.10
13-SIL-00.4	Silver Spring	1.99	0.06	9.7	0.48	0.43
13-SP1-00.0	Spring	3.25	0.09	9.8	0.35	0.96
13-SPU-00.0	Spurgeon Creek	3.48	0.10	9.45	0.66	0.56
13-THU-00.1	Thurston Creek	1.69	0.05	8.2	0.49	0.42

Table C-2. Temperature Monitoring Data in the Deschutes River and Percival Creek Watersheds.

	Station Id	Description	Maximum Summer Temperature (°C)	Date of Maximum Summer Temperature	Maximum of the 7day avg of the Max (°C)	the 7day avg of the Max (°C)
Main Stem Deschutes River	13-DES-42.3	Deschutes River @ upper Falls in Thurston County Park	18.48	7/30/2003	17.52	8/2/2003
	13-DES-37.4	Deschutes River @ 1000 Rd Weyerhauser	22.02	7/30/2003	**20.98**	8/1/2003
	13-DES-32.3	Deschutes at Old Camp Lane	24.72	7/30/2003	**23.59**	8/1/2003
	13-DES-28.6	Deschutes at Vail Cutoff Road SE nr Lake Lawrence	22.46	7/21/2003	**21.39**	7/24/2003
	13-DES-25.8	Deschutes at Woodbrook Lane (SRIW Station 1307)	20.59	7/30/2003	**19.93**	7/24/2003
	13-DES-24.9	Deschutes at Vail Loop Rd SE (USGS sta 12079000)	20.57	7/30/2003	no data	no data
	13-DES-20.5	Deschutes at Rte 507	20.8	7/30/2003	**19.77**	7/26/2003
	13-DES-19.1	Deschutes @ Military Rd	21.47	7/30/2003	**20.49**	7/25/2003
	13-DES-14.5	Deschutes @ Waldrick Rd (SRIW Station 1304)	22.66	7/30/2003, 7/21/03	**21.56**	7/25/2003
	13-DES-13.4	Deschutes @ Cowlitz Drive	no data	no data	no data	no data
	13-DES-09.2	Deschutes nr Rich Rd	22.12	7/21/2003	**20.85**	7/25/2003
	13-DES-05.8	Deschutes above Ayer Creek Confluence	23.99	7/30/2003	**22.68**	7/31/2003
	13-DES-06.8	Deschutes nr Olympia Fule & Asphalt off 84th	22.59	7/30/2003	**21.33**	7/31/2003
	13-DES-02.7	Deschutes @ Henderson Blvd SE	20.6	7/30/2003	**19.76**	7/31/2003
	13-DES-00.5	Deschutes @ E st Bridge	20.91	7/30/2003	**19.9**	7/31/2003
Upper Deschutes Tributaries	13-THU-00.1	Thurston Creek at 3000 Road	17.83	7/24/2003	16.87	7/24/2003
	13-JOH-00.1	Johnson Creek at 3000 Road	18.12	7/30/2003	16.16	7/24/2003
	13-HUC-00.3	Huckleberry Creek 3000	16.30	7/30/2003	15.62	8/2/2003
	13-MIT-00.2	Mitchell Creek at 3000 Road	17.96	7/30/2003	17.34	8/2/2003
	13-FAL-00.3	Fall Creek at 1000 Road	15.76	7/30/2003	15.13	8/4/2003
	13-REI-00.9	Reichel Lake Creek @ Vail Loop Rd SE	19.96	7/21/2003	**19.01**	7/25/2003
	13-SP1-00.1	Spring nr Hwy 507 upstream of Deschutes	16.6	6/7/2003	15.65	7/31/2003
Lower Deschutes Tributaries	13-SIL-00.4	Silver Spring nr mouth	14.42	7/30/2003	14	8/4/2003
	13-TEM-00.0	Tempo Lake outflow nr Stedman Road	25.07	9/5/2003	**22.88**	9/8/2003
	13-SPU-00.0	Spurgeon Crk near Rich Rd SE	20.1	7/30/2003	**18.94**	8/1/2003
	13-AYE-00.0	Ayer Creek off Sienna Ct	22.56	7/21/2003	**21.64**	7/24/2003
	13-CHA-00.1	Chambers Creek off Rich Rd SE off 58th Ave SE	17.24	7/30/2003	16.24	7/31/2003
Capitol Lake Tributaries	13-BLA-02.3	Black Lake Ditch outlet @ Belmore Rd	28.44	7/30/2003	**26.96**	7/24/2003
	13-BLA-01.5	Black Lake Ditch @ Jones Quarry Bridge	24.78	7/30/2003	**24.19**	7/25/2003
	13-BLA-00.0	Black Lake Ditch nr confluence with Percival Creek	23.23	7/21/2003	**22.14**	7/25/2003
	13-PER-03.1	Percival Creek @ Trosper Rd SW	26.18	7/30/2003	**24.67**	7/31/2003
	13-PER-01.0	Percival Creek nr Confluence with Black Lake Ditch	18.57	7/30/2003	17.33	8/2/2003
	13-PER-00.1	Percival Creek nr mouth	21.56	7/21/2003	**20.43**	7/24/2003
			Total Number of Exceedences (> 18 °C)		**21**	

***Bold** Values are in Exceedence of Class A State water quality standards for temperature (7 day average of the Daily max > 18 °C)

Table C-3. pH Values by Date in the Deschutes River, Capitol Lake, and Budd Inlet Watersheds. Values Beyond the Water Quality Standards are Shaded.

	DATE (2003)														
SITE	7/1	7/2	7/9	7/21	7/22	7/23	7/24	8/4	8/5	8/18	8/19	8/20	8/21	9/2	9/3
13-DES-00.5	7.45				7.43				7.50			7.40		7.60	
13-DES-02.7	7.32				7.43				7.44			7.31		7.53	
13-DES-09.2	7.60				7.44				7.47			7.51		7.80	
13-DES-20.5	7.61					7.55			7.72				7.69		
13-DES-28.6	7.50					7.20			7.05			7.05			7.09
13-DES-37.4		7.97					8.16		8.02						8.38
13-HAR-00.3		7.64					7.40		7.67						7.53
13-HUC-00.3		7.36					7.49		7.40						7.55
13-LIT-00.2		7.92					7.95		7.93						8.01
13-LIN-00.0		7.83					7.72		7.86						7.95
13-THU-00.1		7.67					7.79		8.02						7.85
13-REI-00.9	7.07					6.95			6.96				7.15		7.30
13-SPU-00.0			7.65		7.52				7.47			7.56		7.62	
13-AYE-00.0			6.60		**6.45**			6.66				6.70		6.58	
13-CHA-00.1			7.45		7.42			7.95				7.50		7.41	
13-LAK-0.00															6.52
13-CAP-00.4															
13-BLA-02.3			7.75	7.60				8.12			7.60			7.03	
13-BLA-00.0			7.26	7.40				7.50			7.44			7.44	
13-PER-00.1	7.55			7.48				7.62			7.59			7.70	
13-PER-01.0			7.56	7.55				7.68			7.60				
13-ADA-00.5	6.80			7.18				6.95		6.85				7.08	
13-BUT-00.1	7.84			7.83				7.95		7.66				7.85	
13-ELL-00.0	7.67			7.43				7.61		7.36				7.49	
13-IND-00.2				7.61											
13-MIS-00.1														7.70	
13-MOX-00.0				7.70											
13-MOX-00.6	7.53							7.61		7.54				7.63	
13-SCH-00.1	7.58			7.53				7.75		7.51				7.61	

Table C-4. Dissolved Oxygen Levels below 8 mg/L.

	DATE (2003)														
SITE	7/1	7/2	7/9	7/21	7/22	7/23	7/24	8/4	8/5	8/18	8/19	8/20	8/21	9/2	9/3
13-REI-00.9	7.75					5.25			5.13				5.00		6.10
13-AYE-00.0			3.15		2.08				2.24			2.15		3.46	
13-BLA-00.0			7.84	7.58											
13-BLA-02.3														7.60	
13-LAK-0.00															2.50

Table C-5. Sampling Results for Capitol Lake (9/17/03).

Site	FC	DO	Alk	Chl. a	DOC	NH3	NO2NO3	OP	TOC	TP	TPN
South Basin	49	9.6	52.7	1.21	1.7	0.018	0.635	0.018	1.4	0.0293	0.787
Middle Basin, South	7	11	51.7	2.5	1.1	0.011	0.491	0.012	1.2	0.0201	0.64
Middle Basin, North	2	10.8	53.7	15.4	1.4	0.015	0.16	0.018	1.6	0.0295	0.32
North Basin Outlet	1	11.7	53.9	16	1.5	0.01	0.018	0.015	1.9	0.0671	0.165
Middle Basin, Western Shallows	36	10.3									
Percival Cove Outlet	8	10.5									
North Basin, Western Shallows	1	11.2									
North Basin, Eastern Shallows	2	12.2									

Table C-6. Dry Weather Stormwater Outfall Information Collected 10/14/03.

Site	F.C.	Entity	Receiving Water Body	System Name	Total Basin Area (ac)
13-CPL-OUTF	Dry	Olympia	Capitol Lake	7th Avenue outfall	25
13-AUT-OUTF	19	Olympia	Percival Creek	Automall outfall	145
13-BLM-OUTF	Dry	Olympia	Black Lake Ditch	Black Lake Meadows	775
13-GIL-OUTF	Dry	Olympia	Schneider Creek	Giles Ave outfall	215
13-SCH-OUTF	28	Olympia	Schneider Creek	Elliott and Milroy outfall	45
13-IND-OUTF	Dry	Olympia	Indian Creek	Pacific Avenue outfall	20
13-MOX-OUTF	23	Olympia	Moxlie Creek	State Avenue outfall	235
13-MIS-OUTF	Dry	Olympia	Mission Creek	Roosevelt and Yew outfall	30
13-MST-OUTF	Dry	Tumwater	Deschutes River	M Street	257
13-LST-OUTF	Dry	Tumwater	Deschutes River	Linda Street	

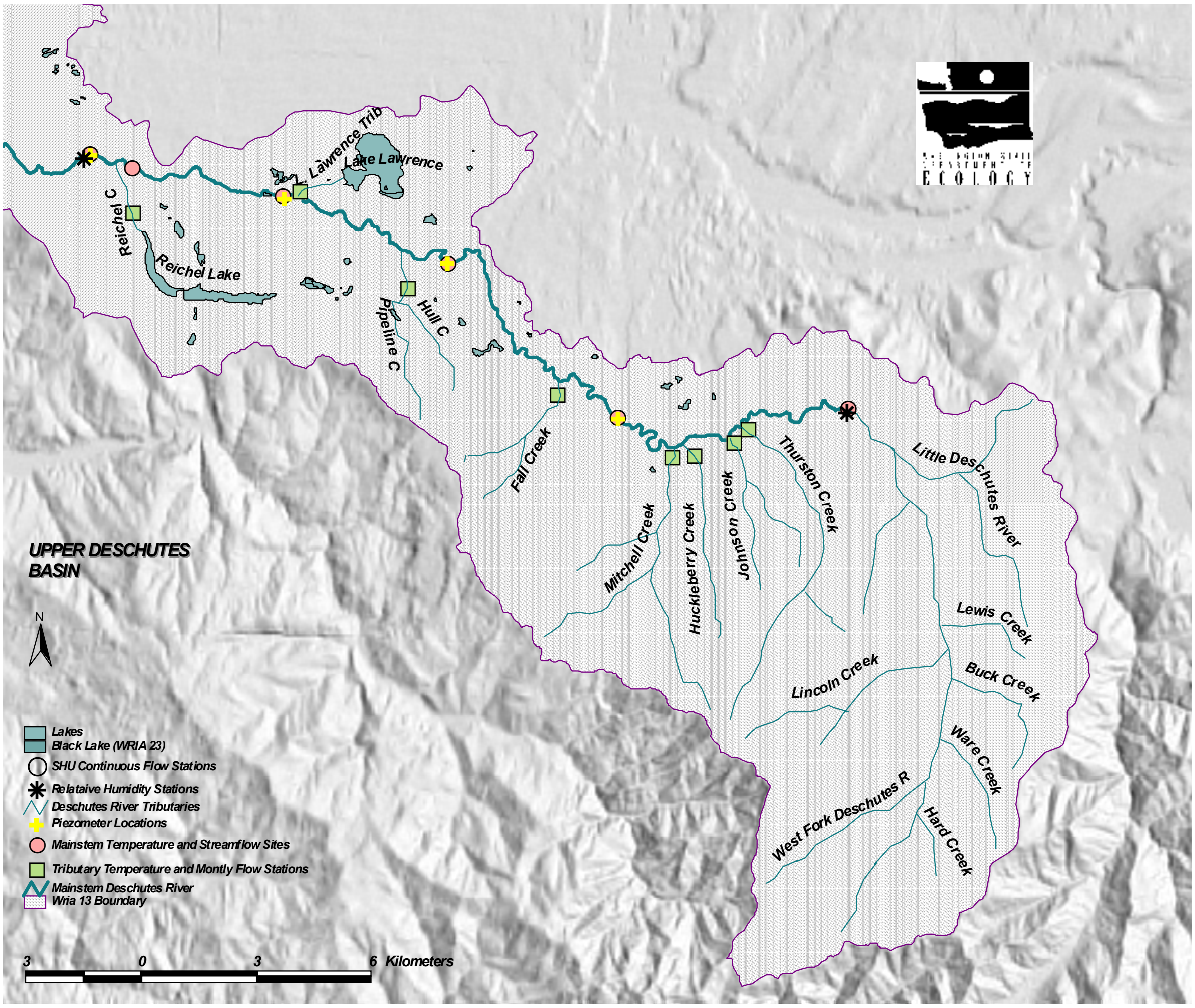

Figure C-1. Temperature, Flow, Relative Humidity, and Groundwater Monitoring Station Locations Within the Upper Deschutes River Basin.

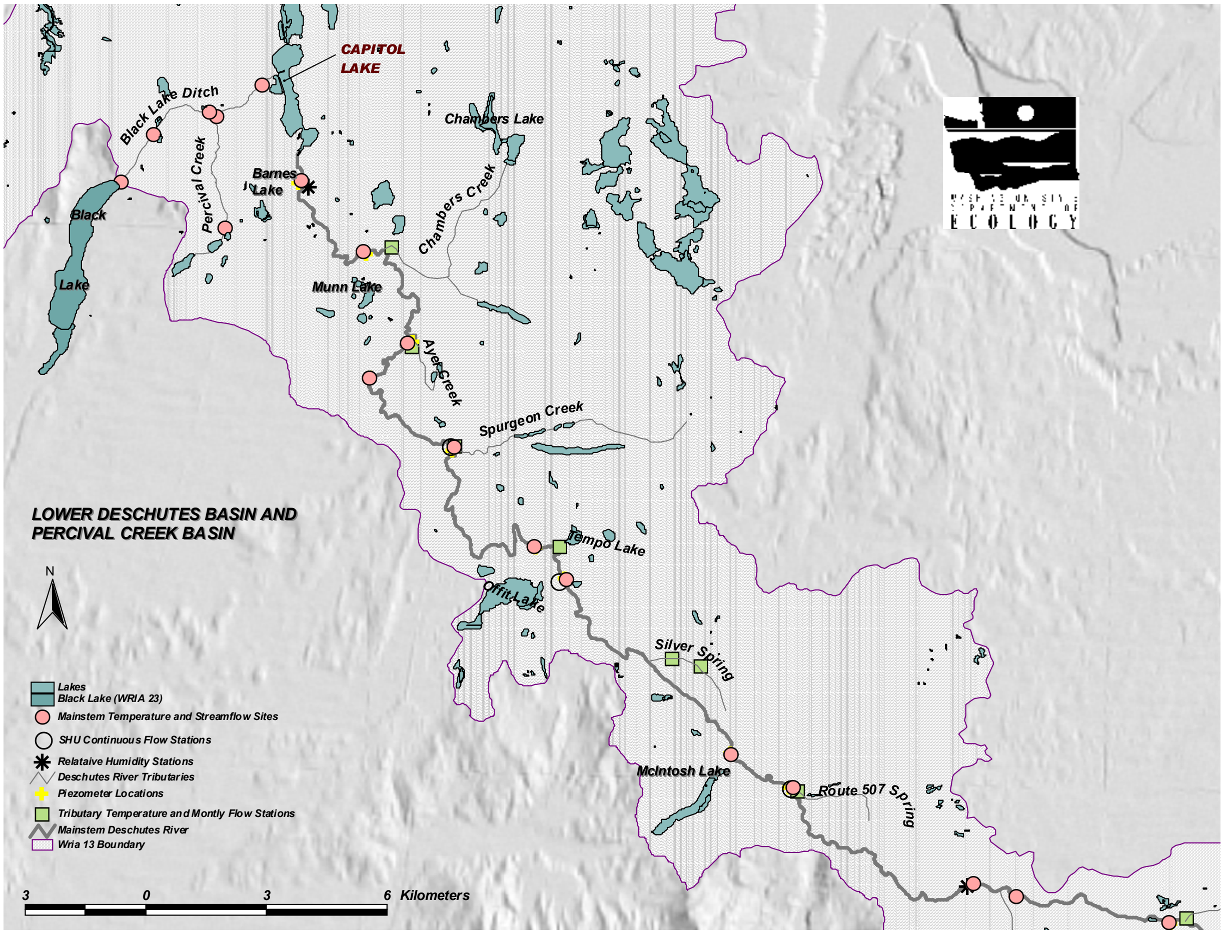

Figure C-2. Temperature, Flow, Relative Humidity, and Groundwater Monitoring Station Locations Within the Lower Deschutes River Basin and Percival Creek Watershed.

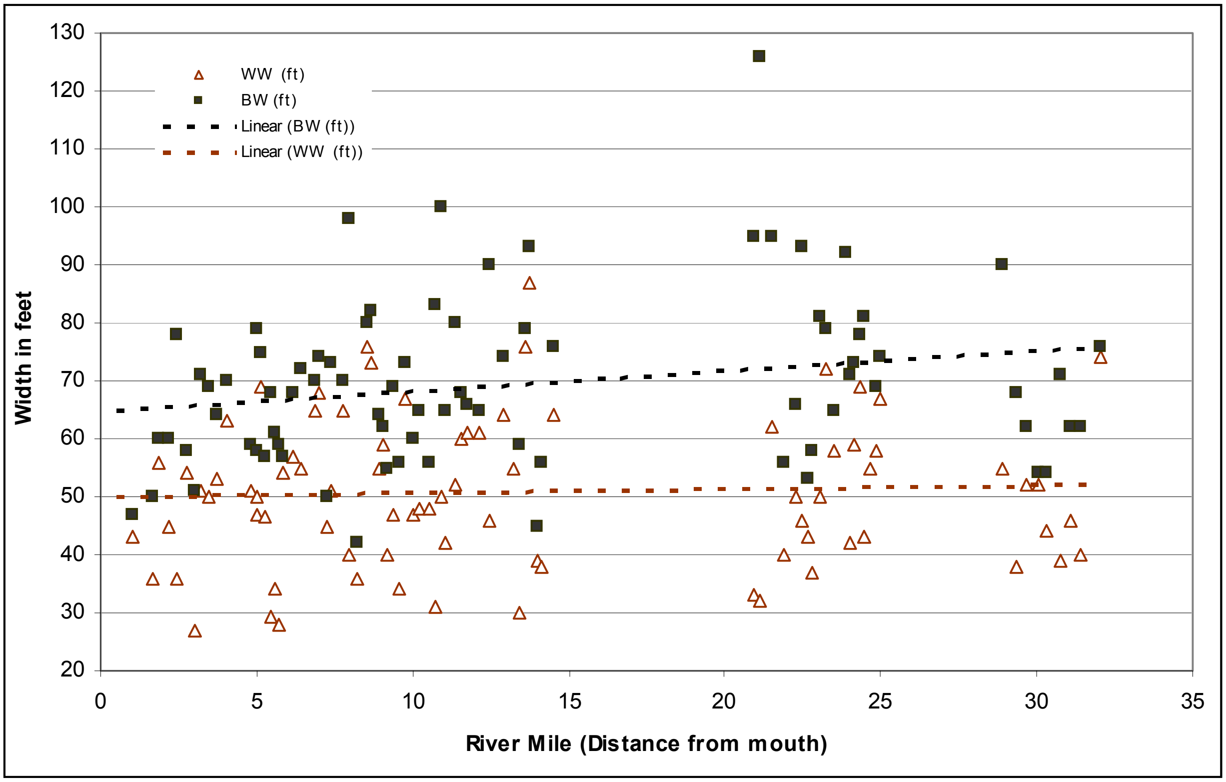

Figure C-3. Deschutes River Geomorphology Information from Summer 2003.

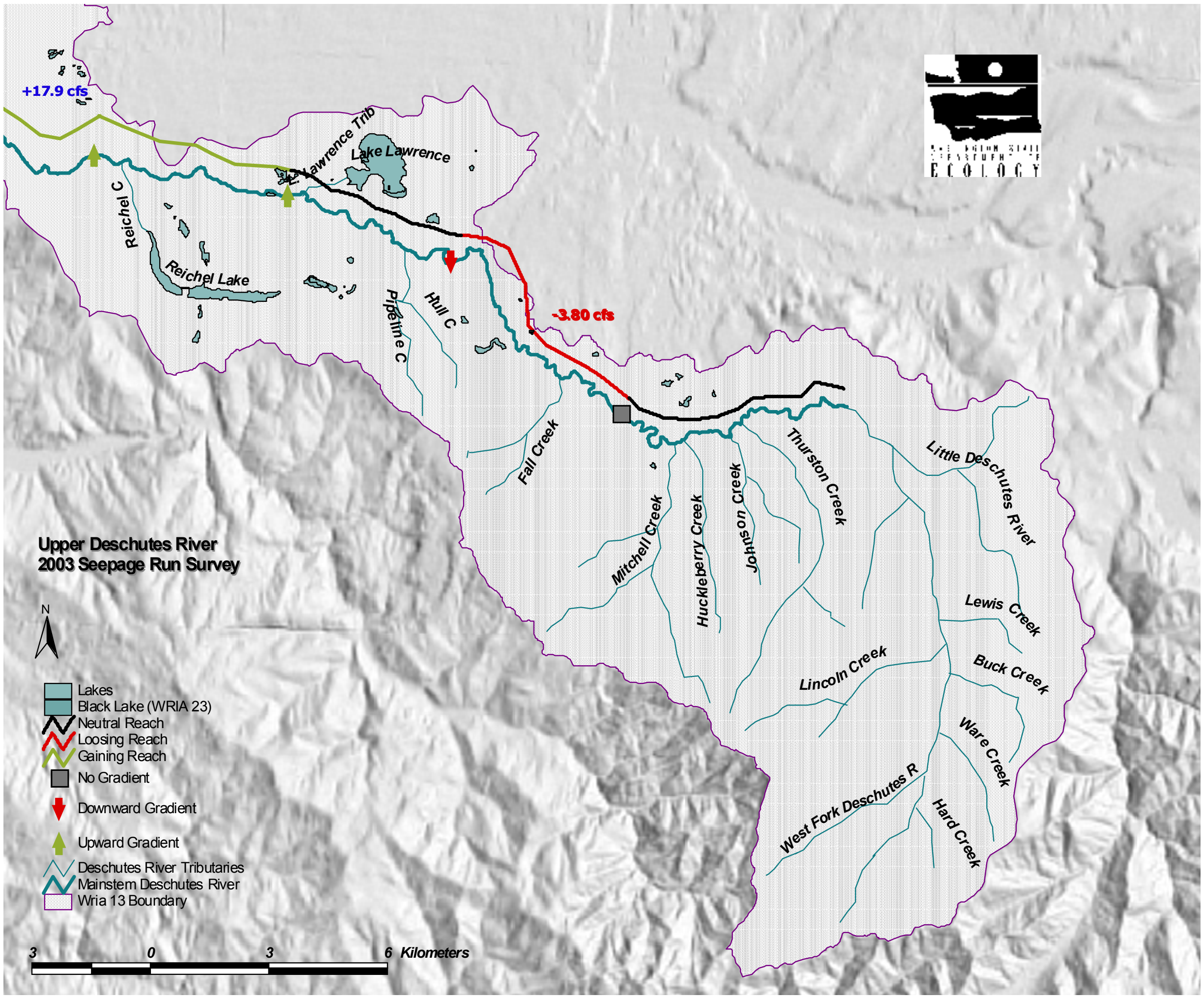

Figure C-4. Results of August 5, 2003, Seepage Run in the Upper Deschutes River Basin and Sites of Stream Loss and Gain from Piezometer Data.

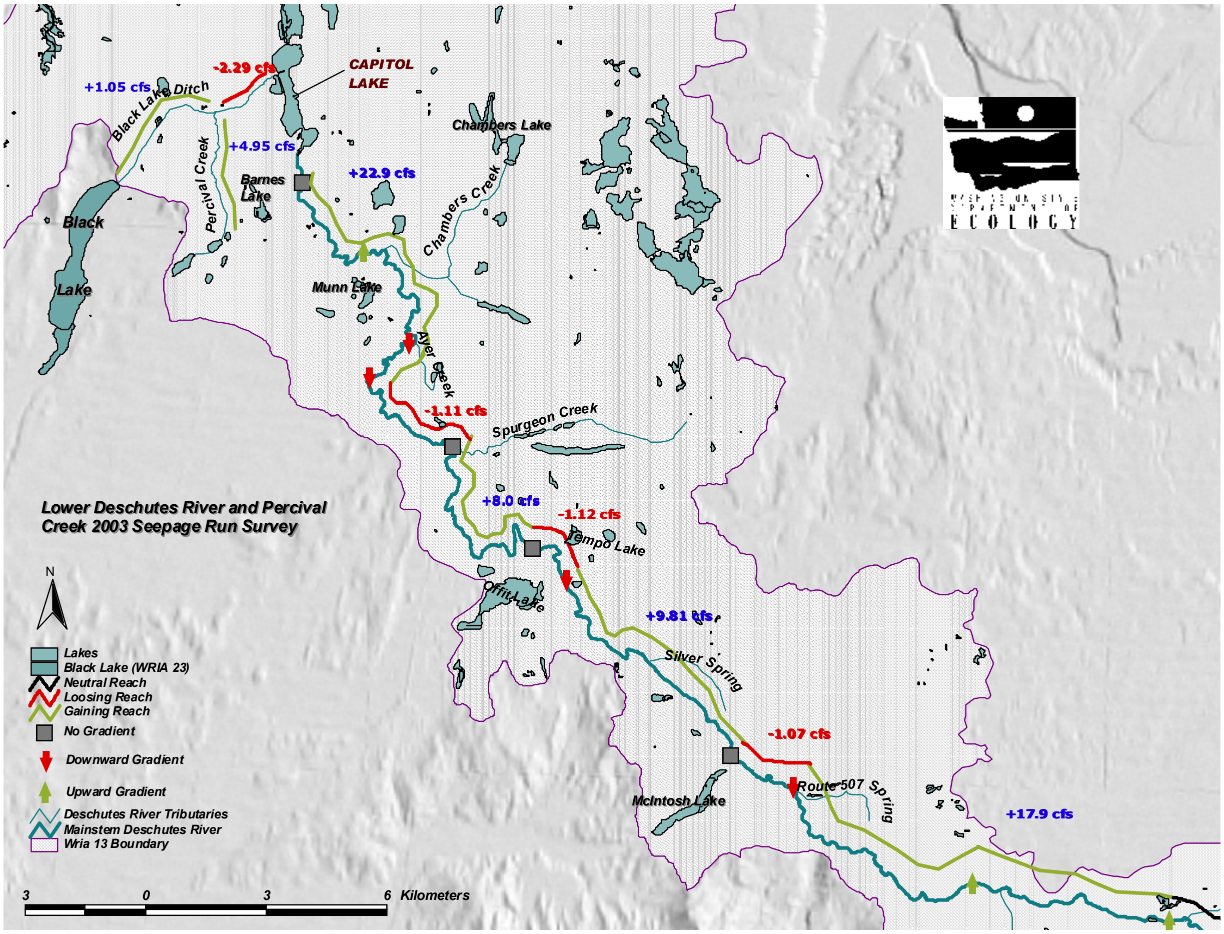

Figure C-5. Results of August 5, 2003, Seepage Run in the Lower Deschutes River Basin and Percival Creek Watershed and Areas of Stream Loss and Gain from Piezometer Data.

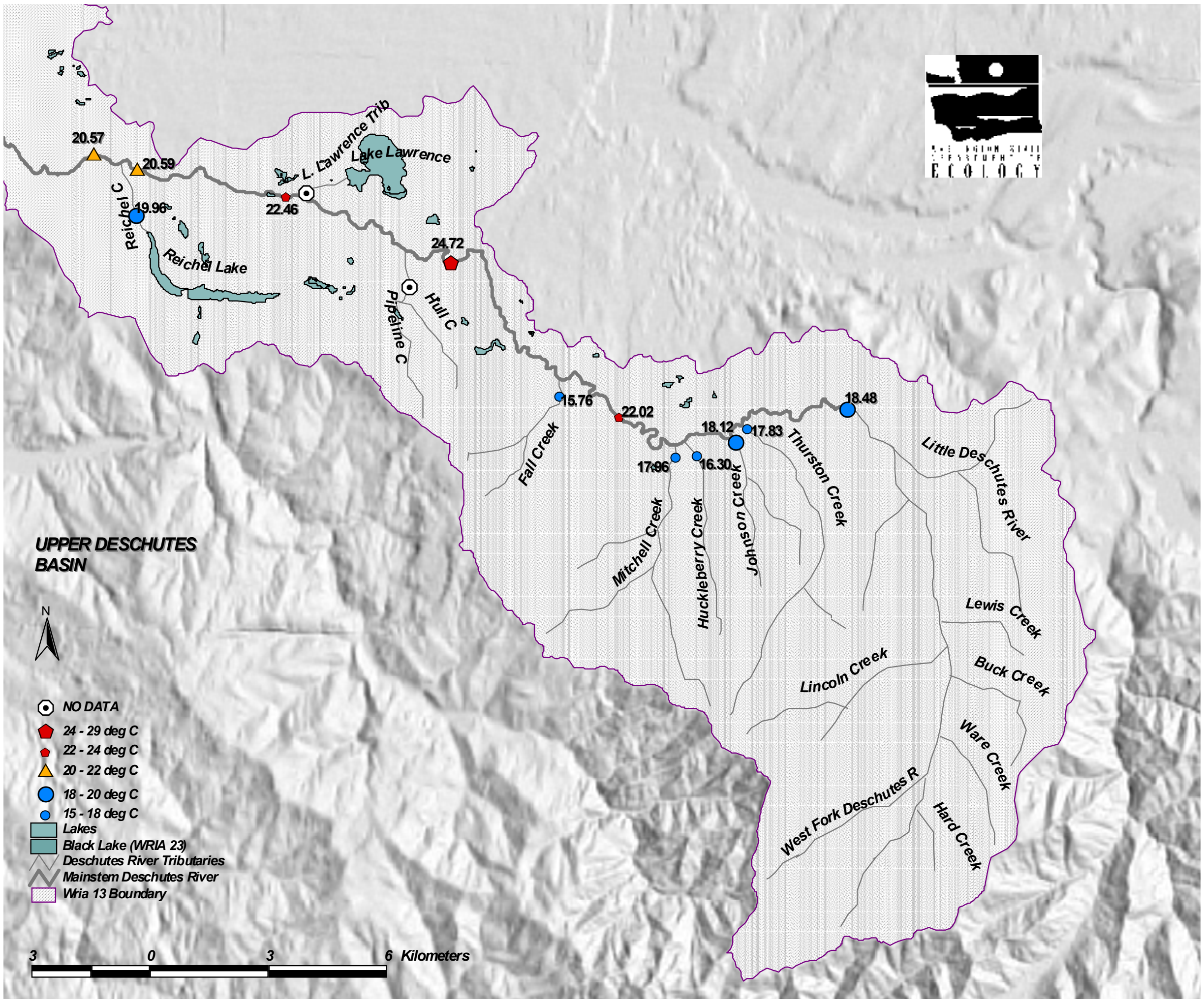

Figure C-6. Highest Daily Maximum Stream Temperatures in the Upper Deschutes River Basin During Hottest Day of 2003 for Each Station.

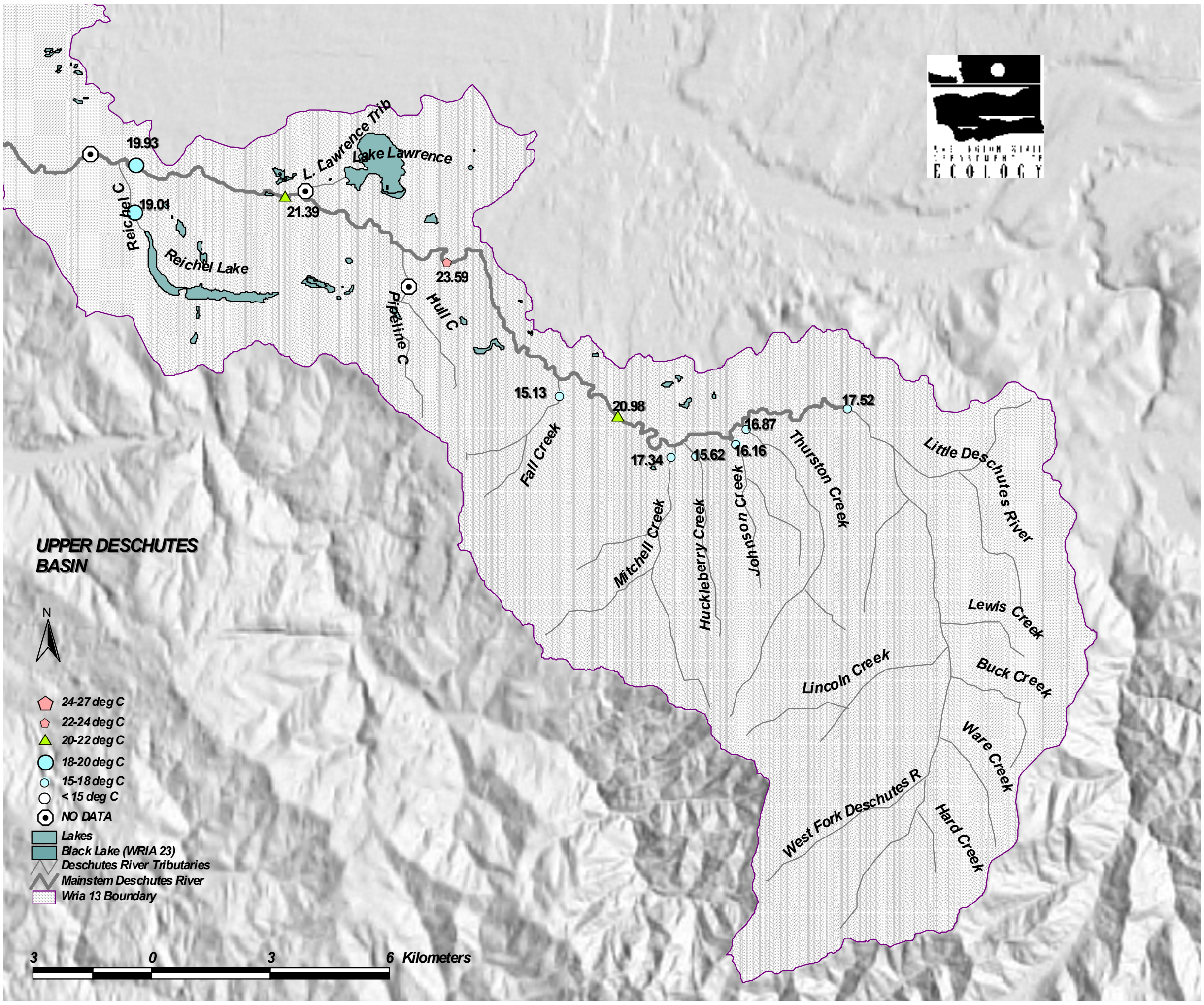

Figure C-7. Maximum Seven-Day Averages of Daily Maximum Stream Temperature in the Upper Deschutes River Basin in 2003.

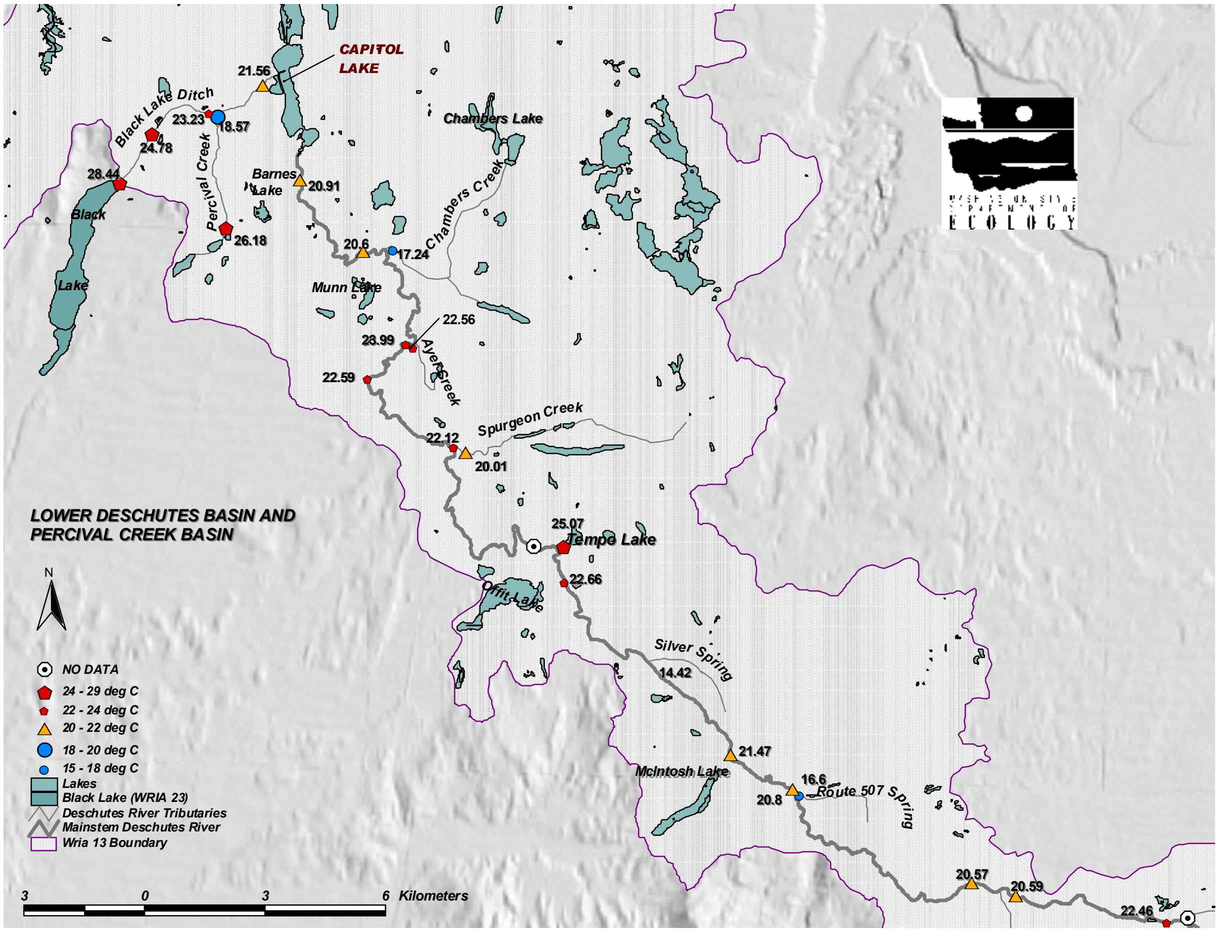

Figure C-8. Highest Daily Maximum Stream Temperatures in the Lower Deschutes River Basin and Percival Creek Watersheds During Hottest Day of 2003 for Each Station.

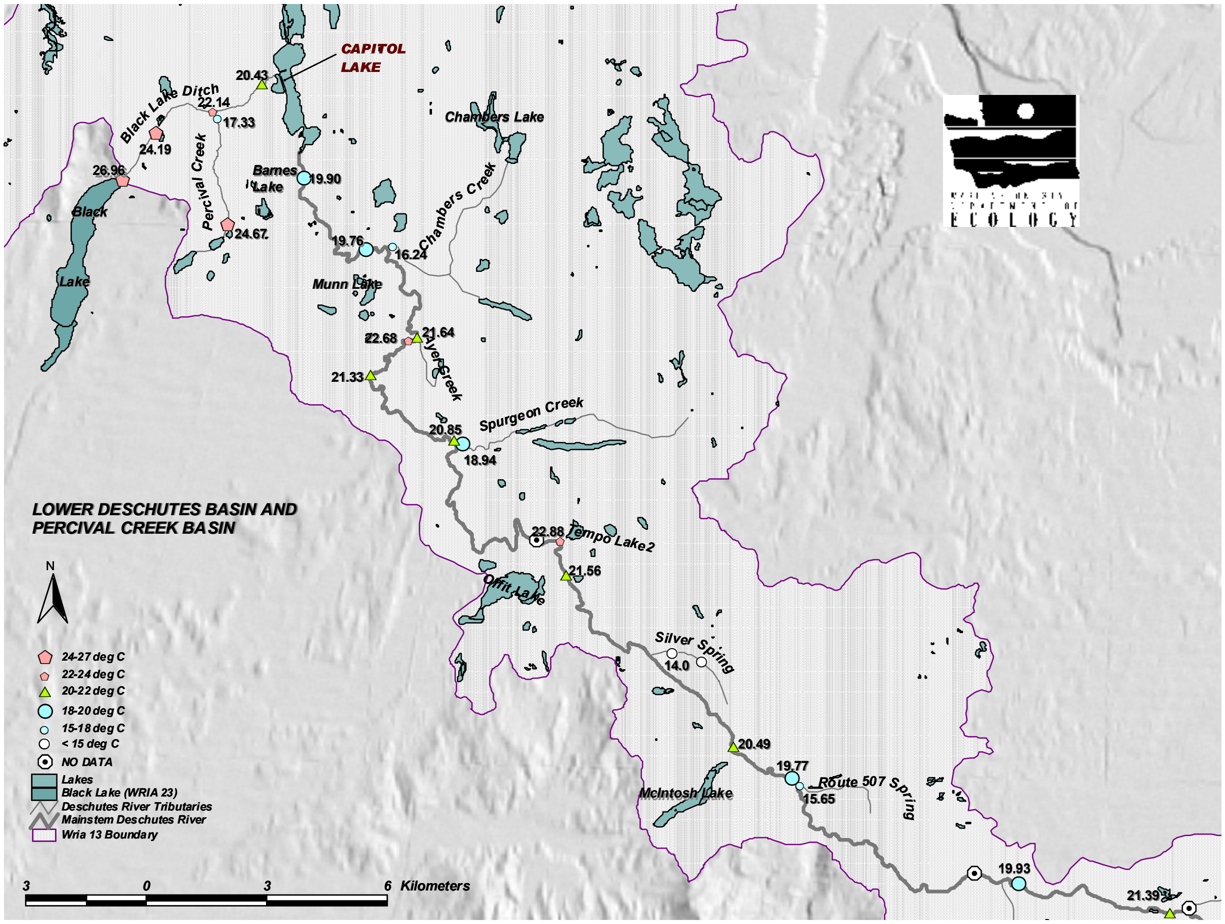

Figure C-9. Maximum Seven-Day Averages of Daily Maximum Stream Temperature in the Lower Deschutes River Basin and Percival Creek Watersheds in 2003.

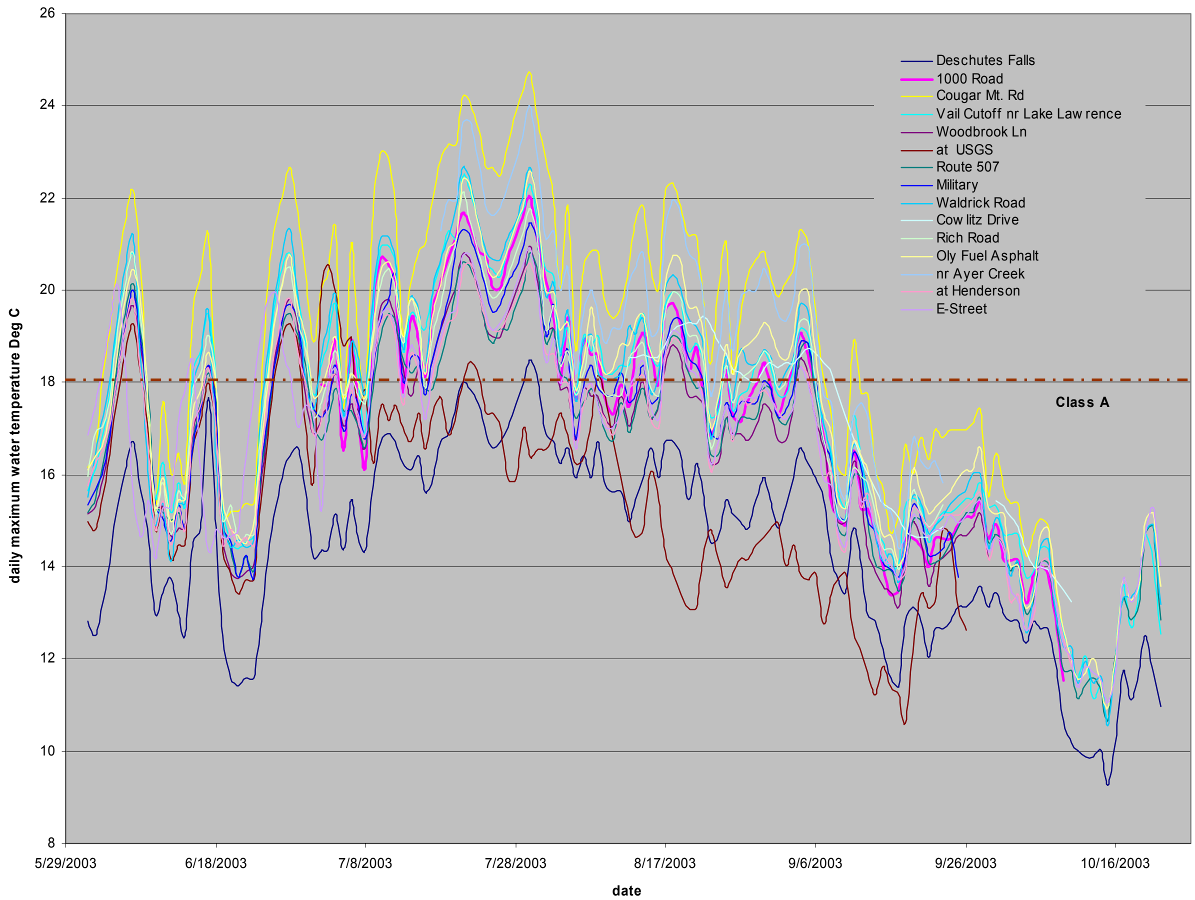

Figure C-10. Daily Maximum Stream Temperatures Along the Mainstem Deschutes River.

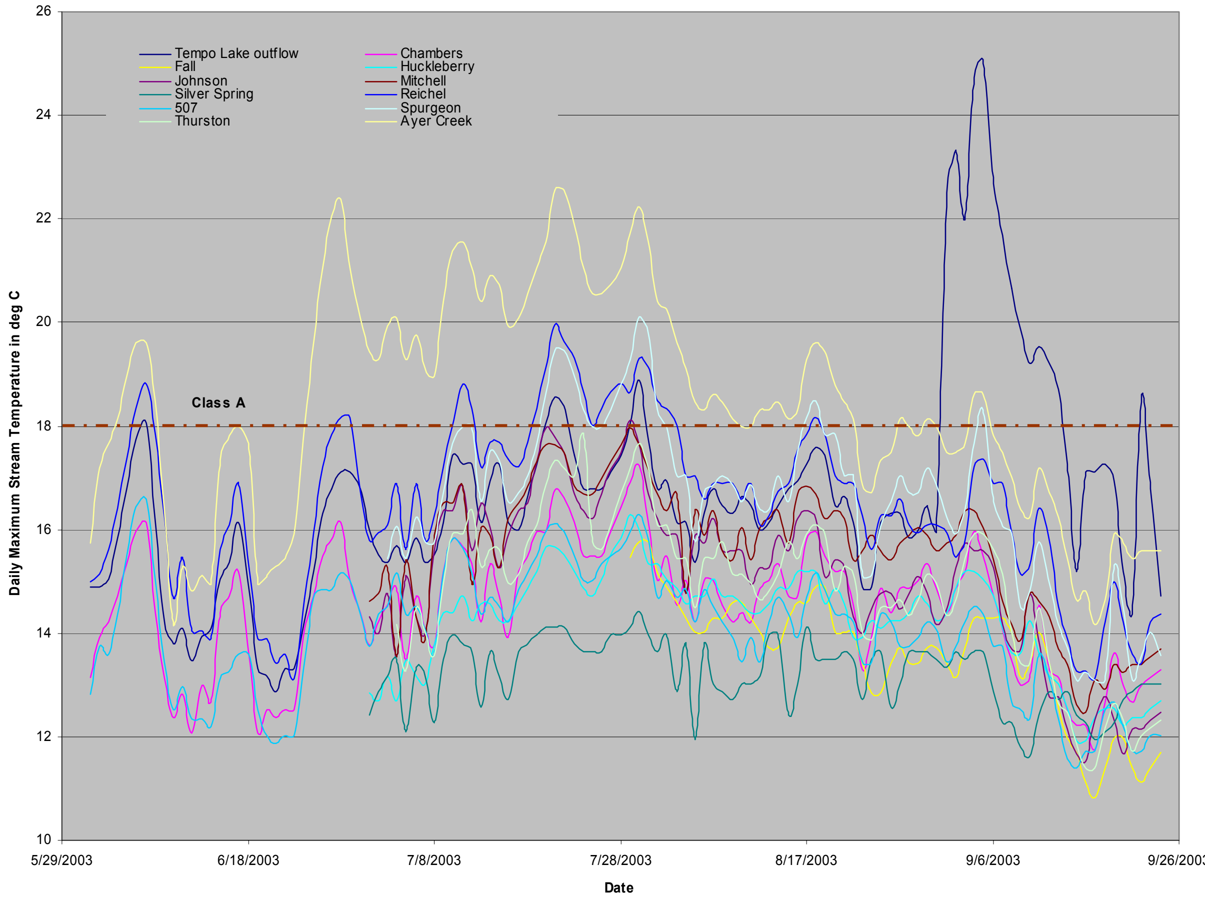

Figure C-11. Daily Maximum Stream Temperatures in Tributaries to the Deschutes River.

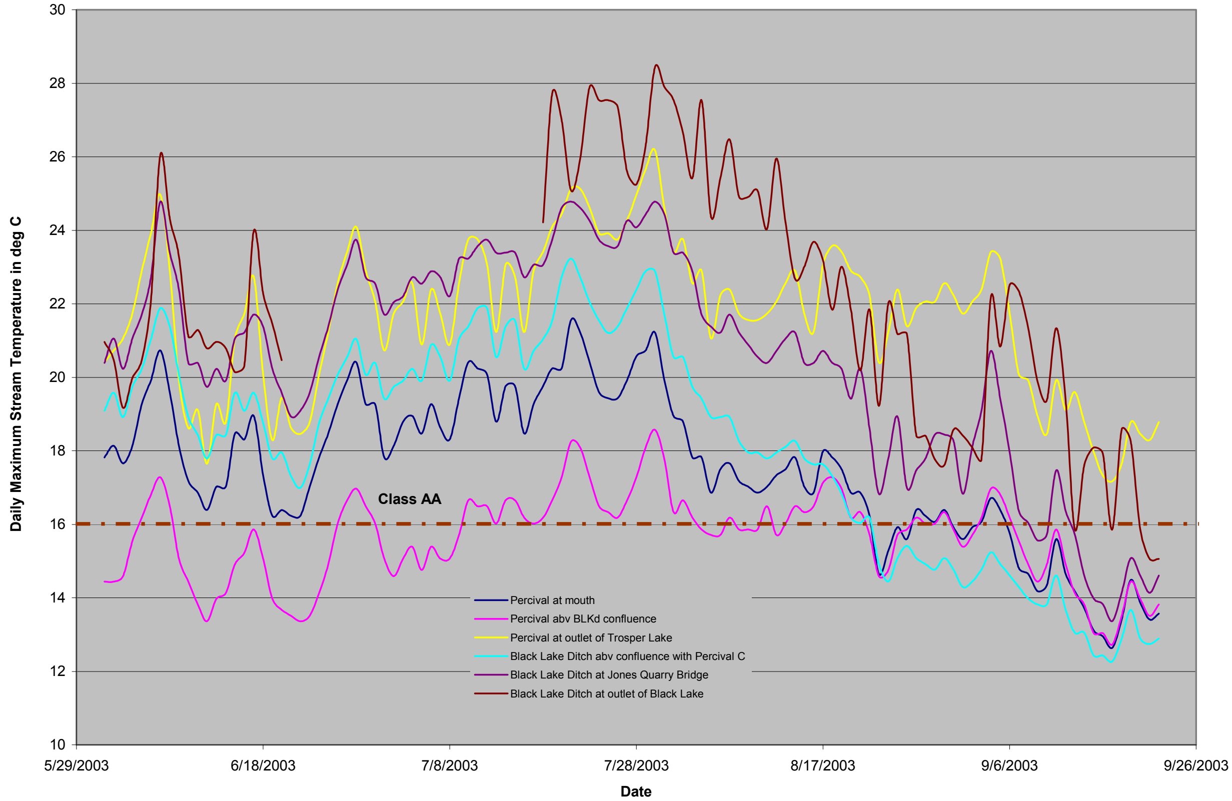

Figure C-12. Daily Maximum Stream Temperatures in the Percival Creek Watershed.

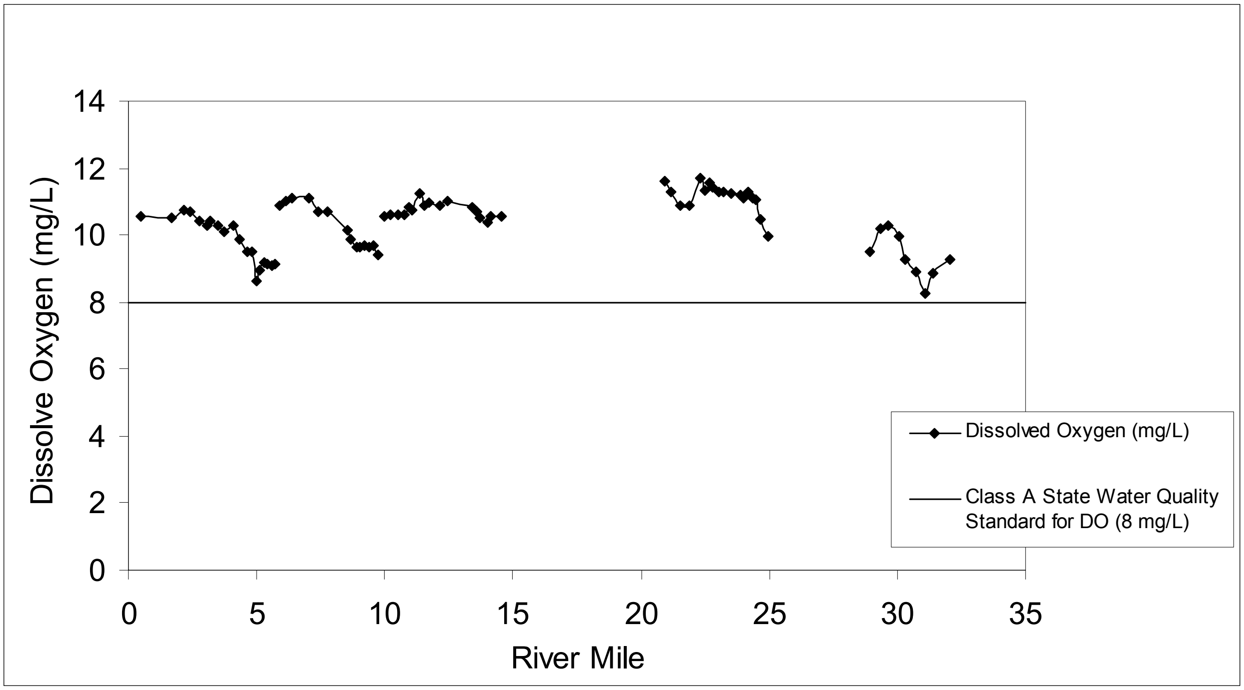

Figure C-13. Dissolved Oxygen (mg/L) Profile of Part of the Deschutes River During the Week of August 18, 2003.

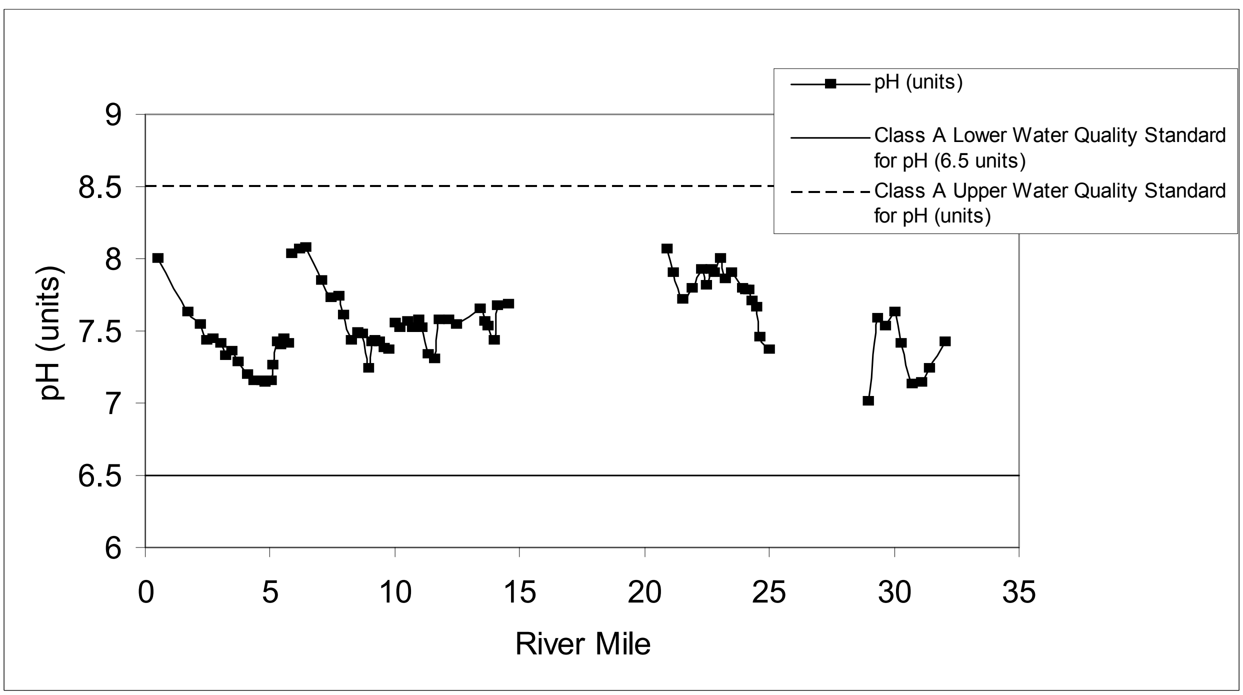

Figure C-14. pH Profile of Part of the Deschutes River During the Week of August 18, 2003.

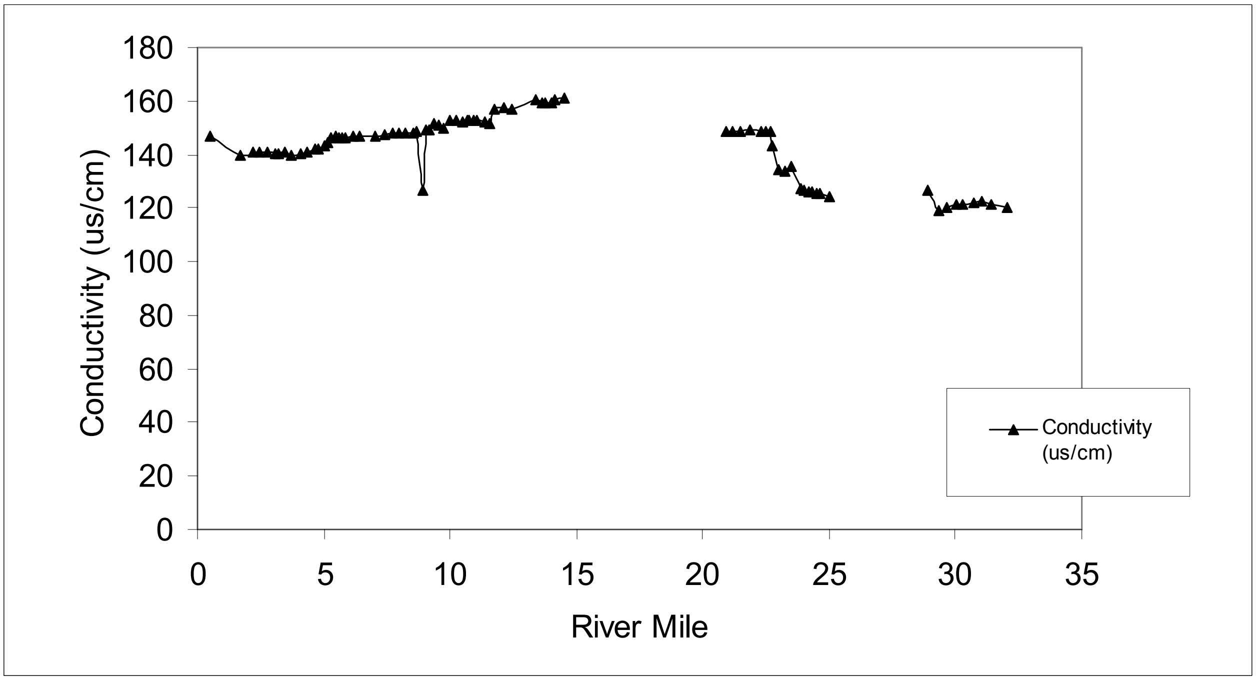

Figure C-15. Conductivity (us/cm) Profile of Part of the Deschutes River During the Week of August 18, 2003.

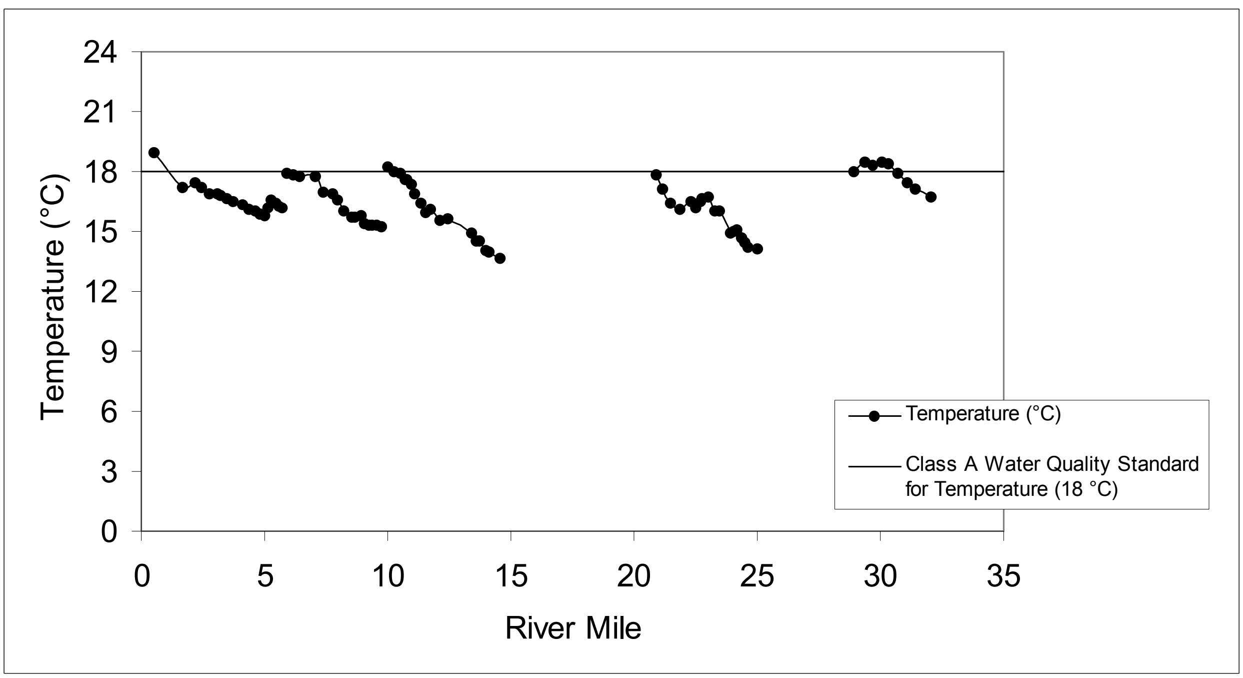

Figure C-16. Temperature (°C) Profile of Part of the Deschutes River During the Week of August 18, 2003.

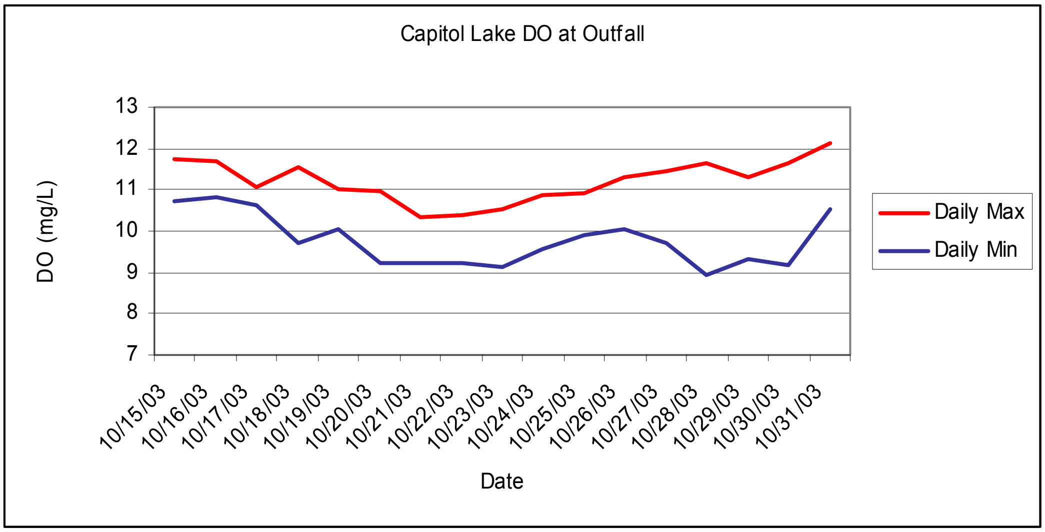

Figure C-17. Dissolved Oxygen Levels at the Outlet from Capitol Lake.