Attachment 7
Water Quality Discipline Report

CAPITOL LAKE – DESCHUTES ESTUARY

Long-Term Management Project Environmental Impact Statement

Water Quality Discipline Report

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June 2021

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Executive Summary

This Water Quality Discipline Report describes the potential impacts of the Capitol Lake – Deschutes Estuary Long-Term Management Project on water resources in the area surrounding the project. The Capitol Lake – Deschutes Estuary includes the 260-acre Capitol Lake Basin, located on the Washington State Capitol Campus, in Olympia, Washington. Long-term management strategies and actions are needed to address issues in the Capitol Lake – Deschutes Estuary project area. An Environmental Impact Statement (EIS) is being prepared to document the potential environmental impacts of various alternatives and determine how these alternatives meet the long-term objectives identified for the watershed.

The analysis examines the No Action Alternative, as well as three action alternatives: Managed Lake, Estuary, and Hybrid. Water resource impacts of the alternatives are described in this Discipline Report for construction and operation. The impacts from construction are primarily related to those from dredging activities that would occur under all but the No Action Alternative. Operational impacts are described primarily in terms of water quality standards and the aesthetic values of water quality (i.e., populations of algae and aquatic plants). The water quality standards assessment specifically focuses on dissolved oxygen (DO) because low DO concentrations have been a long-term problem in Budd Inlet and it has been the focus of water quality improvement planning efforts, including those of this project. Adequate DO concentrations are important to aquatic habitat, particularly for cold water fish. The assessment also addresses effects on algae blooms and aquatic plants (where applicable) since they are directly related to state water quality standards for aesthetics.

Under the No Action Alternative, it is unlikely that Enterprise Services would be able to procure funding and approvals to manage sediment, control aquatic plants, implement water quality protection measures, improve ecological functions, or enhance community use. Over time, DO concentrations below the dam would more closely reflect the DO in the Deschutes River. There would eventually be significant impacts to aesthetic values of the lake basin as the aquatic plant community in the nearshore zone transitions to emergent aquatic plants and as the zone of open water moves further away from the shoreline. Eventually there may be impacts on Budd Inlet water quality due to increased nutrient and sediment loads (derived from the river) when the lakes capacity to retain sediments is lost.

Under all action alternatives, areas of Capitol Lake would be dredged during construction and most, or all, of the dredge material would be used to create habitat areas within the lake basin. Once operational, there would be routine dredging to maintain target depths in the North Basin under the Managed Lake Alternative or impacted areas of West Bay under the Estuary and Hybrid Alternatives. Impacts to water quality from this in-water work would be minimized through implementation of protective conditions and best management practices (BMPs) which would be included in the water quality permits that would be obtained prior to dredging.

Under the Managed Lake Alternative, pollutant sources would eventually be reduced through implementation of the Deschutes TMDL and through pollution control activities in the lake basin. The aquatic plant community would also be reduced through aquatic plant control activities. While these activities would reduce nutrient sources to the lake and the inlet, within the planning horizon for this project, DO concentrations in the lake basin and Budd Inlet would be expected to be similar to what currently exists. Within the lake basin, there would be no expected change in DO concentrations. The decreased nutrient supply may result in decreased algae blooms, providing some water quality benefits. In lower Budd Inlet, there would be no change in impact on water quality compared to existing conditions based on there being no changes in DO or general condition of habitat for cold water fish and no change in the extent or frequency of algae blooms. Aquatic plant control activities would represent an immediate and substantial benefit to aesthetic values of the lake.

The Estuary and Hybrid Alternatives would result in removal of the 5th Avenue Dam, thereby reintroducing saltwater to the lake basin and creating an estuarine environment in the current lake basin. As is typical of these estuarine environments in Puget Sound, the water would have seasonally low DO. This water would replace the water currently in the lake basin, which is generally well oxygenated. Although DO reductions would be significant compared to existing conditions, they would reflect conditions that are similar to what is experienced in other inlets in South Puget Sound and reflect typical estuary conditions. Possible increases in algae blooms that might be expected due to the quality of the incoming tidal waters will be offset by Deschutes River flows; thus, overall algae blooms may be similar to existing conditions in the basin. In Budd Inlet there is expected to be modest improvement in DO conditions due to changes in circulation patterns and potential changes in nutrient loading after the dam is removed. Algae bloom occurrence in Budd Inlet is expected to be similar since there will continue to be an adequate nutrient supply.

Under the Hybrid Alternative a barrier would be constructed to retain a smaller saltwater reflecting pool in the North Basin. The reflecting pool of the North Basin (i.e., the eastern portion of the basin) is expected to be well flushed using only high tide waters that generally can be expected to have more DO and fewer algae than water at lower tides but will still have less DO than the current lake basin. Water quality in the western portion of the basin would be similar to what is described for the Estuary Alternative given the introduction of tidal flow from Budd Inlet. A freshwater reflecting pool concept was also evaluated; refer to Appendix E for more detail on this analysis. If a freshwater reflecting pool were chosen over a saltwater reflecting pool, it would require active management to avoid impacts to public health and visual quality.

Construction and operation impacts of the No Action and action alternatives are summarized in Tables ES.1 and ES.2.

Table ES.1 Summary of Construction Impacts and Mitigation Measures.

	Impact Finding	Mitigation Proposed for Significant Adverse Impacts	Significant and Unavoidable Adverse Impact
Managed Lake Alternative			
Short-term impacts to water quality from construction activities	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits	No
Estuary Alternative			
Short-term impacts to water quality from construction activities	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits.	No
Short-term impacts to water quality from initial release of sediment and nutrients after 5th Avenue Dam removal	**Significant**	Slow introduction of tidal exchange as coffer cell is removed	Yes
Hybrid Alternative			
Short-term impacts to water quality from construction activities	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits	No
Short-term impacts to water quality from initial release of sediment and nutrients after 5th Avenue Dam removal	**Significant**	Slow introduction of tidal exchange as coffer cell is removed	Yes

Table ES.2 Summary of Operational Impacts (including benefits) and Mitigation Measures.

Impact	Impact Finding	Minimization and Other Mitigation Measures	Significant and Unavoidable Adverse Impact
No Action Alternative			
Long-term water quality in Capitol Lake Basin – *DO concentrations and algae blooms*	**Minor-to-moderate benefit**	N/A	No
Long-term water quality in Capitol Lake Basin – *Aquatic plants*	**Significant impact**	N/A	**Yes**
Long-term water quality in Budd Inlet – *DO concentrations and algae blooms*	No Change in Impact	N/A	No
Managed Lake Alternative			
Long-term water quality in Capitol Lake Basin – *Aquatic plants*	**Substantial benefit**	Implementation of measures outlined in the Adaptive Management Plan, which is part of the alternative	No
Long-term water quality in Capitol Lake Basin – *DO concentrations and algae blooms*	No Change in Impact	N/A	No
Long-term water quality in Budd Inlet – *DO concentrations and algae blooms*	No Change in Impact	N/A	No
Short-term water quality from long-term management actions	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits	No
Estuary Alternative			
Long-term water quality in Capitol Lake Basin – *Aquatic plants*	**Substantial benefit**	N/A	No

Impact	Impact Finding	Minimization and Other Mitigation Measures	Significant and Unavoidable Adverse Impact
Long-term water quality in Capitol Lake Basin – *DO concentrations*	**Significant impact** (when a comparison is made to existing lake water quality, but estuarine water would be inherently different)	N/A	Yes
Long-term water quality in Capitol Lake Basin – *Algae blooms*	No Change in Impact	N/A	
Long-term water quality in Budd Inlet – *DO concentrations*	**Minor-to-moderate benefit**	N/A	No
Long-term water quality in Budd Inlet – *Algae blooms*	No Change in Impact	N/A	
Short-term water quality from long-term management actions	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits	No
Hybrid Alternative			
Long-term water quality in Capitol Lake Basin – *Reflecting Pool and Estuary Aquatic plants*	**Substantial benefit**	N/A	No
Long-term water quality in Capitol Lake Basin – *Estuary DO concentrations*	**Significant impact** (when a comparison is made to existing lake water quality, but estuarine water would be inherently different)	N/A	Yes
Long-term water quality in Capitol Lake Basin – *Estuary Algae blooms*	No Change in Impact	N/A	

Impact	Impact Finding	Minimization and Other Mitigation Measures	Significant and Unavoidable Adverse Impact
Long-term water quality in Capitol Lake Basin – Reflecting Pool *DO concentrations*	**Significant impact** (when a comparison is made to existing lake water quality, but estuarine water would be inherently different)	N/A	No
Long-term water quality in Capitol Lake Basin – Reflecting Pool *Algae blooms*	No Change in Impact	N/A	
Long-term water quality in Budd Inlet – *DO concentrations*	**Minor-to-moderate benefit**	N/A	No
Long-term water quality in Budd Inlet – *Algae blooms*	No Change in Impact	N/A	
Short-term water quality from long-term management actions	Less-than-significant	Implementation of BMPs and adherence to conditions provided in environmental permits	No

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List of Acronyms and Abbreviations

Acronyms/ Abbreviations	Definition
˚C	degrees Celsius
˚F	degrees Fahrenheit
µg/L	micrograms per liter
µS/cm	microseimens per centimeter
σ	standard deviation
BMPs	best management practices
BOD	biochemical oxygen demand
CFU/100 mL	colony forming unit per 100 milliliters
CI	confidence interval
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CSL	cleanup screening level
DBOD	dissolved biochemical oxygen demand
DIN	dissolved inorganic nitrogen
DO	dissolved oxygen
DOC	dissolved organic carbon
E. coli	*Escherichia Coli*
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
Enterprise Services	Washington State Department of Enterprise Services
FC	fecal coliform
gpm	gallons per minute
HCV	human caused variation
Herrera	Herrera Environmental Consultants
LOTT	Lacey, Olympia, Tumwater and Thurston County Wastewater Management Partnership
m	meter
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter
MPN/100 mL	most probable number per 100 milliliters
NHC	Northwest Hydraulic Consultants

NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
POC	particulate organic carbon
SCO	sediment cleanup objective
SMP	Shoreline Master Program
SMS	Washington State Sediment Management Standards
SQDR	Sediment Quality Discipline Report
SQS	sediment quality standard
SRP	soluble reactive phosphorus
SVOC	semi volatile organic carbon
TDG	total dissolved gases
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
USGS	Unites States Geological Survey
VSS	volatile suspended solids
WQ	water quality
WQMPP	water quality monitoring and protection plan
WSDOT	Washington Department of Transportation

1 Introduction and Project Description

1.1 PROJECT DESCRIPTION

The Capitol Lake – Deschutes Estuary includes the 260-acre Capitol Lake Basin, located on the Washington State Capitol Campus, in Olympia, Washington. The waterbody has long been a valued community amenity. Capitol Lake was formed in 1951 following construction of a dam and provided an important recreational resource. Historically, the Deschutes Estuary was used by local tribes for subsistence and ceremonial purposes. Today, the expansive waterbody is closed to active public use. There are a number of environmental issues including the presence of invasive species, exceedances of water quality (WQ) standards, and inadequate sediment management.

The Washington State Department of Enterprise Services (Enterprise Services) is responsible for the stewardship, preservation, operation, and maintenance of the Capitol Lake Basin. The 260-acre Capitol Lake Basin is maintained by Enterprise Services under long-term lease agreement from the Washington Department of Natural Resources.

In 2016, as part of Phase 1 of long-term planning, a diverse group of stakeholders, in collaboration with the state, identified shared goals for long-term management and agreed an Environmental Impact Statement (EIS) was needed to evaluate a range of alternatives and identify a preferred alternative. In 2018, the state began the EIS process. The EIS evaluates four alternatives, including a Managed Lake, Estuary, Hybrid, and a No Action Alternative.

The long-term management alternatives are evaluated against the shared project goals of: improving water quality; managing sediment accumulation and future deposition; improving ecological functions; and enhancing community use of the resource. Refer to Figure 1.1 for the project area for long-term management. The Final EIS will identify a preferred environmentally and economically sustainable long-term management alternative for the Capitol Lake – Deschutes Estuary.

The EIS process maintains engagement with the existing Work Groups, which include the local governments, resource agencies, and tribe. It also provides for expanded engagement opportunities for the public, such as a community sounding board.

Figure 1.1 Project Area

1.2 SUMMARY OF PROJECT ALTERNATIVES

1.2.1 Managed Lake Alternative

The Managed Lake Alternative would retain the 5th Avenue Dam in its existing configuration. The 5th Avenue Dam would be overhauled to significantly extend the serviceable life of the structure. The reflecting pool within the North Basin would be maintained, and active recreational use would be restored in this area. Sediment would be managed through initial construction dredging and recurring maintenance dredging in the North Basin only. Sediment from construction dredging would be used to create habitat areas in the Middle Basin to support improved ecological function, habitat complexity, and diversity. Sediment would continue to accumulate and over time would promote a transition to freshwater wetlands in the South and Middle Basins. Boardwalks, a 5th Avenue Pedestrian Bridge, a dock, and a boat launch would be constructed for community use.

If selected as the Preferred Alternative, adaptive management plans would be developed to maintain water quality, improve ecological functions, and manage invasive species during the design and permitting process.

1.2.2 Estuary Alternative

Under the Estuary Alternative, the 5th Avenue Dam would be removed, and an approximately 500-foot-wide (150-meter-wide) opening would be established in its place. This would reintroduce tidal hydrology to the Capitol Lake Basin, returning the area to estuarine conditions where saltwater from Budd Inlet would mix with freshwater from the Deschutes River. Sediment would be managed through initial construction dredging in the Capitol Lake Basin and recurring maintenance dredging within West Bay. Dredged materials from construction dredging would be used to create habitat areas in the Middle and North Basins to promote ecological diversity, though tideflats would be the predominant habitat type. Boardwalks, a 5th Avenue Pedestrian Bridge, a dock, and a boat launch would be constructed for community use. This alternative also includes stabilization along the entire length of Deschutes Parkway to avoid undercutting or destabilization from the tidal flow. Existing utilities and other infrastructure would be upgraded and/or protected from reintroduced tidal hydrology and saltwater conditions.

If selected as the Preferred Alternative, adaptive management plans would be developed to improve ecological functions and manage invasive species during the design and permitting process.

1.2.3 Hybrid Alternative

Under the Hybrid Alternative, the 5th Avenue Dam would be removed, and an approximately 500-foot-wide (150-meter-wide) opening would be established in its place. Tidal hydrology would be reintroduced to the western portion of the North Basin and to the Middle and South Basins. Within the North Basin, a curved and approximately 2,600-foot-long (790-meter-long) barrier wall with a walkway would be constructed to create an approximately 45-acre saltwater reflecting pool adjacent to Heritage Park. A freshwater (groundwater-fed) reflecting pool was also evaluated for this EIS. Construction and maintenance of this smaller reflecting pool, in addition to restored estuarine conditions in part of the Capitol Lake Basin, gives this alternative its classification as a hybrid. Sediment would be managed through initial construction dredging in the Capitol Lake Basin and recurring maintenance dredging within West Bay. In the Middle and North Basins, constructed habitat areas would promote ecological diversity, though tideflats would be the predominant habitat type. Boardwalks, a 5th Avenue Pedestrian Bridge, a dock, and a boat launch would be constructed for community use. This alternative also includes stabilization along the entire length of Deschutes Parkway to avoid scour or destabilization. Existing utilities and other infrastructure would be upgraded and/or protected from reintroduced tidal hydrology and saltwater conditions.

If selected as the Preferred Alternative, adaptive management plans would be developed before operation of the alternative to improve ecological functions and manage invasive species during the design and permitting process. Adaptive management would also be needed for a freshwater reflecting pool, but not for a saltwater reflecting pool.

1.2.4 No Action Alternative

The No Action Alternative represents the most likely future expected in the absence of implementing a long-term management project. The No Action Alternative would persist if a Preferred Alternative is not identified and/or if funding is not acquired to implement the Preferred Alternative. A No Action Alternative is a required element in a SEPA EIS and provides a baseline against which the impacts of the action alternatives (Managed Lake, Estuary, Hybrid) can be evaluated and compared.

The No Action Alternative would retain the 5th Avenue Dam in its current configuration, with limited repair and maintenance activities, consistent with the scope and scale of those that have received funding and environmental approvals over the past 30 years. In the last 30 years, the repair and maintenance activities have been limited to emergency or high-priority actions, which occur sporadically as a result of need and funding appropriations.

Although Enterprise Services would not implement a long-term management project, current management activities and ongoing projects in the Capitol Lake Basin would continue. Enterprise Services would continue to implement limited nuisance and invasive species management strategies.

In the absence of a long-term management project, it is unlikely that Enterprise Services would be able to procure funding and approvals to manage sediment, improve water quality, improve ecological functions, or enhance community use. The No Action Alternative does not achieve the project goals.

1.3 CONSTRUCTION METHODS FOR THE ACTION ALTERNATIVES

This impact analysis relies on the construction method and anticipated duration for the action alternatives, which are described in detail in Chapter 2 of the EIS.

2 Regulatory Context

2.1 RESOURCE DESCRIPTION

This report describes the water quality in the study area and evaluates the potential impacts of each project alternative on the water quality in Capitol Lake and in Inner Budd Inlet, including the areas of West Bay and East Bay and area to the north of the study area shown in Figure 1.1. These areas are included because impacts associated with project alternatives have been predicted to impact them. Upstream areas in the Deschutes River and Percival Creek are not part of the study area because these areas would not be impacted by the project alternatives.

Although the relative contribution to ecosystem functions from water quality are considered in the analysis, this report is focused on water quality and does not specifically evaluate impacts to fish and wildlife (including ESA-listed species), invasive species, or sediment disposal. Those evaluations are addressed in other discipline reports.

2.2 RELEVANT LAWS, PLANS, AND POLICIES

Several federal, state, and local government policies, regulations, and ordinances relating to the water quality of the Deschutes River, Capitol Lake, and Budd Inlet apply to this project. Table 2.1 summarizes federal regulations for water quality.

Table 2.1 Federal Laws, Plans, and Policies.

Regulatory Program or Policies	Lead Agency	Description
Clean Water Act (CWA)	Washington State Department of Ecology	Regulates water quality, maintaining standards by controlling pollutant discharges.

While USEPA has responsibility for overseeing implementation of the CWA nationwide, Ecology has been authorized for its implementation in Washington, including establishing WQS, identifying impaired waterbodies, conducting Total Maximum Daily Load (TMDL) studies, and issuing water quality permits.

Table 2.2 summarizes the applicable Water Quality Standards based on the waterbody designated use for Surface Waters in Washington State for Capitol Lake and Budd Inlet. Outer and Inner Budd Inlet are held to "Excellent" and "Good" water quality standards, respectively. The designated use of Capitol Lake was determined to be "Salmonid Spawning, Rearing, and Migration," the same as the upstream stretch of the Deschutes River (USEPA 2020). However, under the Estuary and Hybrid Alternatives, the geographic area of the lake basin would then be considered a part of Inner Budd Inlet and held to the applicable standards. Although Outer Budd Inlet is outside of the immediate project area, it is within the area of interest for the water quality assessment; and therefore the water quality standards for this section of the Inlet have also been included in Table 2.2.

Table 2.2 Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A).

Waterbody	Parameter	Description
Capitol Lake[a]	Temperature	7-day average of the daily maximum temperatures (7-DADMax) must not exceed 17.5˚C (63.5˚F). If the system's natural condition is above this criterion, HCV must not cause the 7-DADMax to increase more than 0.3˚C.
	Dissolved Oxygen	1-day minimum should not exceed 8.0 mg/L. If the system natural condition is below this criterion, HCV must not exceed 0.2 mg/L.
	Turbidity	Turbidity must not exceed 5 NTU over background when background is 50 NTU or less, or a 10% increase in turbidity when the background turbidity is more than 50 NTU.
	Total Dissolved Gas	Total dissolved gas shall not exceed 110% saturation at any point of sample collection.
	pH	pH shall be within the range of 6.5 to 8.5 with an HCV within the above range of less than 0.5 unit.
	E. Coli	Organism levels within the averaging period must not exceed a geometric mean value of 100 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 320 CFU/100 mL.
	Fecal Coliform	Organism levels within the averaging period must not exceed a geometric mean value of 100 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 200 CFU/100 mL.
Inner Budd Inlet[b]	Temperature	1-day maximum should not exceed 19˚C (66.2˚F). If the system's natural condition is above this criterion, HCV must not cause the 7-DADMax to increase more than 0.3˚C.
	Dissolved Oxygen	1-day minimum should not exceed 5.0 mg/L. If the system natural condition is below this criterion, HCV must not exceed 0.2 mg/L.

Waterbody	Parameter	Description
	Turbidity	Turbidity must not exceed 10 NTU over background when background is 50 NTU or less, or a 20% increase in turbidity when the background turbidity is more than 50 NTU.
	pH	pH must be within the range of 7.0 to 8.5 with an HCV within the above range of less than 0.5.
	Enterococci	Organism levels within the averaging period must not exceed a geometric mean of 30 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 110 CFU/100 mL.
	Fecal Coliform	Organism levels within the averaging period must not exceed a geometric mean of 14 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 43 CFU/100 mL.
Outer Budd Inlet[c]	Temperature	1-day maximum should not exceed 16°C (60.8°F). If the system's natural condition is above this criterion, HCV must not cause the 7-DADMax to increase more than 0.3°C.
	Dissolved Oxygen	1-day minimum should not exceed 6.0 mg/L. If the system natural condition is below this criterion, HCV must not exceed 0.2 mg/L.
	Turbidity	Turbidity must not exceed 5 NTU over background when background is 50 NTU or less, or a 10% increase in turbidity when the background turbidity is more than 50 NTU.
	pH	pH must be within the range of 7.0 to 8.5 with an HCV within the above range of fewer than 0.5.
	Enterococci	Organism levels within the averaging period must not exceed a geometric mean of 30 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 110 CFU/100 mL.
	Fecal Coliform	Organism levels within the averaging period must not exceed a geometric mean of 14 CFU/100 mL, with no more than 10% of all samples obtained within the averaging period exceeding 43 CFU/100 mL.

a Capitol Lake is classified as a river (USEPA 2020) and under "Salmonid Spawning, Rearing, and Migration" (WAC 173-201A-200).

b Inner Budd Inlet (waters south of Priest Point) is held to "Good Quality" criteria (WAC 173-201A-210).

c Outer Budd Inlet (waters north of Priest Point) is held to "Excellent Quality" criteria (WAC 173-201A-210).

d Human Caused Variation (HCV): Cumulative impact of human actions on the water quality parameter.

e The Fecal Coliform criteria will expire December 31, 2020, then *E. coli* and Enterocci will be the new criteria.

NTU: Nephelometric Turbidity Units   CFU: Colony Forming Unit

In July 2020, the U.S. Environmental Protection Agency (USEPA) approved a TMDL for the Deschutes River. (A TMDL is a formal plan that outlines discharge limits of problematic pollutants to improve water quality in an impaired system.) Table 2.3 summarizes the applicable Total Maximum Daily Loads (TMDLs) for the various parts of the Deschutes watershed. These areas are all upstream of the study area and are not impacted by project alternatives; however, as the TMDLs are implemented, water quality will improve in the project area. A TMDL is also currently being prepared for Budd Inlet but is not yet available and not summarized.

Table 2.3 TMDLs applicable to the Deschutes River Watershed.

Parameter	Waterbody
Fine Sediment	Deschutes River
Bacteria	Reichel Creek
	Spurgeon Creek
	Indian Creek
	Moxlie Creek
	Schneider Creek
	Mission Creek
	Ellis Creek
	East Adams Creek
	West Adams Creek
Temperature	Deschutes River
	Black Lake Ditch
	Percival Creek
	Huckleberry Creek
	Reichel Creek
	Tempo Lake Outlet
	Unnamed Spring to Deschutes River
	Ayer (Elwanger) Creek
DO	Deschutes River
	Black Lake Ditch
	Percival Creek
	Lake Lawrence Creek
	Reichel Creek
	Ayer (Elwanger) Creek
pH	Black Lake Ditch
	Ayer (Elwanger) Creek
	East Adams Creek

There are numerous discharges to the watershed that are regulated through the National Pollutant Discharge Elimination System (NPDES). Each permit includes specific requirements to control the quality of the water discharged from each site. The permits also include requirements for monitoring and reporting. Table 2.4 outlines the primary permits that set forth the discharge requirements (USEPA 2020). Most of these sources result in discharge of stormwater or effluents upstream of the study area but could still have an indirect impact on water quality in the study area. The key exceptions are the City of Olympia's municipal stormwater permit, the Port of Olympia's industrial stormwater permit, and LOTT's wastewater treatment plant permit; these discharge directly to the lake and/or Budd Inlet. Table 2.5 lists the key the regulatory programs and policies implemented by the study area communities.

Table 2.4 NPDES Permitted Sources in the Deschutes River (USEPA 2020).

Permittee	Permit Type
WSDOT	WSDOT Municipal Stormwater Permit
City of Olympia	Western Washington Phase II Municipal Stormwater Permit
City of Tumwater	
Thurston County	
City of Lacey	
Tumwater Falls Hatchery	N/A
Pioneer Park Hatchery	
Lakeside Industries (Olympia Airport)	Sand and Gravel
Alpine Sand and Gravel (Rixie Rd)	
Lakeside Industries (Waldrick Rd)	
O'Neill and Sons Trucking Inc	Industrial Stormwater General Permit
K and M Quarry	
Pepsi Northwest Beverages LLC	
Truss Components of Washington	
Pacific NW Bulkhead Yard	
Olympia Service Center	
Port of Olympia	
Construction Stormwater (Multiple)	Construction Stormwater Permit
Lacey, Olympia, Tumwater and Thurston County Wastewater Management Partnership (LOTT)	Wastewater Treatment Plant Permit

Table 2.5 Local Laws, Plans, and Policies.

Regulatory Program or Policies	Lead Agency	Description
Storm and Surface Water Plan	City of Olympia	This Code was created based on Washington State Standards for surface water management, water quality of surface waters, and aquatic habitat, all of which are applicable to Capitol Lake and Budd Inlet.
Shoreline Master Program (SMP)	City of Olympia	The City of Olympia SMP requires jurisdictions to manage and protect shorelines of the State. It is a set of local policies and regulations under Washington State's Shoreline Management Act that applies to Budd Inlet and Capitol Lake.
Noxious Weed Control	Thurston County Noxious Weed Control Board	The Thurston County Noxious Weed Control Board fulfills the requirements of RCW 17.10 and establishes policies and procedures in accordance with statutes and state regulations, adopts rules and regulations for noxious weed control, and prepares the annual Noxious Weed List (Thurston County 2020).

3 Methodology

3.1 SELECTION OF THE STUDY AREA

The study area for the water quality analysis includes Capitol Lake and its major inflow sources of the Deschutes River and Percival Creek, as well as West Bay and East Bay of Budd Inlet (Figure 3.1). These areas are included because they would be impacted (beneficially or adversely) by the project alternatives. Upstream areas in the Deschutes River and Percival Creek are not part of the study area because these areas would not be impacted by the project alternatives. The area of interest includes the study area and all areas discussed in this report that extend as far as the northernmost Budd Inlet monitoring station (Figure 3.1).

3.2 DATA SOURCES AND COLLECTION

A substantial amount of data has been made available due to numerous previous studies conducted on the Deschutes River System and Budd Inlet. Relevant data were used from these sources in addition to recent data collected for the project in 2019 and 2020.

Figure 3.1 Areas of Interest to Water Resources Discipline Report.

3.2.1 Key Studies

Key studies were reviewed to describe physical characteristics of the waterbodies and to summarize historical and existing water quality in the study area. The primary studies that are used in the evaluation that provided relevant information include:

- **Capitol Lake Restoration Analysis (Entranco 1984):** Preliminary study conducted to characterize the water quality conditions in Capitol Lake. Data from this study were not used, but the methods and results are referenced in some places in this report.
- **Budd Inlet Scientific Study Final Report (LOTT 1998):** Analyzed field data to quantify circulation patterns and nutrient loading to Budd Inlet. Results from this report were used to generally characterize the conditions in Budd Inlet.
- **Deschutes River, Capitol Lake, and Budd Inlet Temperature, Fecal Coliform Bacteria, Dissolved Oxygen, pH, and Fine Sediment Total Maximum Daily Load Technical Report: Water Quality Study Findings (Ecology 2012):** Reported data and modeling results for Capitol Lake and the Deschutes River using historical data from Budd Inlet (LOTT 1998) and Capitol Lake from 2003–2005.
- **South Puget Sound Dissolved Oxygen Study: Water Quality Model Calibration and Scenarios (Ecology 2014):** This study identified anthropogenic causes of DO depletion in South Puget Sound, providing an overview of the conditions between inlets. It was used in this study for a high-level comparison of Budd Inlet to other South Puget Sound Inlets.
- **Deschutes River, Capitol Lake, and Budd Inlet Total Maximum Daily Load Study Supplemental Modeling Scenarios (Ecology 2015b):** This study used data from LOTT (1998) and from monitoring in 2003–2004 to model scenarios that predict causes of poor water quality in Budd Inlet. Study results and data were used to describe existing conditions in Budd Inlet and to evaluate impacts of potential management alternatives.
- **Total Maximum Daily Loads (TMDLs) for the Deschutes River and its Tributaries:** Sediment, Bacteria, Dissolved Oxygen, pH, and Temperature (USEPA 2020): This study established TMDLs for the Deschutes River watershed. USEPA approved Ecology's temperature TMDLs but put forth revised TMDLs for fine sediment, bacteria, DO, and pH.

Ecology is currently developing a TMDL for Budd Inlet. This report and its findings was not available for this report.

3.2.2 Historical and Current Monitoring Data

The following is a description of the historical monitoring data available and used for this study. Appendix A provides a full summary of the data sources available for use in this analysis and also provides detail on the monitoring that occurred during 2019 to support this effort. Appendix B provides the data from the 2019 monitoring conducted for this project.

The following lists the key data sources for each waterbody and how they were used.

Deschutes River:

- **Stream Flow 2004–2014:** United States Geological Survey (USGS) has a continuous gaging station on the Deschutes River at the E Street Bridge, just upstream of Tumwater Falls. Flows are recorded at 15-minute time intervals. The data period selected for the analysis was selected to correspond with the data period used to assess Capitol Lake data. These data were used to develop water and phosphorus budgets for the lake.
- **Water Quality 2004:** For the TMDL water quality study (Ecology 2012), data were collected in the Deschutes River 0.5 river mile upstream from Tumwater Falls. Analytes included temperature, dissolved oxygen (DO), pH, conductivity, alkalinity, total nitrogen (TN), ammonia (NH4), nitrate plus nitrite (NO3+NO2), total organic carbon (TOC), dissolved organic carbon (DOC), fecal coliform (FC) bacteria, total phosphorus (TP), soluble reactive phosphorus (SRP), and total suspended solids (TSS). These data were used to augment the 2019 data to support this alternatives analysis.
- **Water Quality 2004–2014:** Thurston County conducts year-round monitoring of the river, in monthly intervals, at Tumwater Falls Park for temperature, FC bacteria, turbidity, TP, NO3+NO2, and NH4. Although monitoring continued past 2014, the analysis was constrained to this data set to coincide with the data set used in the assessment of Capitol Lake. This data set was used to identify long-term trends, and to develop the phosphorus budget and to support the alternatives analysis.

Capitol Lake:

- **Water Quality 2004:** For the TMDL water quality study (Ecology 2012), data were collected year-round on a monthly basis from the North Basin of Capitol Lake near the 5th Avenue Dam. Analytes included temperature, DO, pH, conductivity, TN, NH_4, NO_3+NO_2, TOC, DOC, FC bacteria, TP, SRP, and TSS. These data were used to augment the 2019 data to support the alternatives analyses.
- **Water Quality 2004–2014:** Thurston County conducted summertime (May through October) monthly sampling of the lake. This monitoring ended in 2014. Parameters include temperature, DO, pH, conductivity, TP, TN, Secchi depth, chlorophyll, and pheophytin (degraded chlorophyll). Data were collected at two locations near the deepest part of both the Middle Basin and North Basin. This data set was used for identifying long-term trends, comparison to water quality standards, comparison to other lakes, and river/lake comparisons.

Budd Inlet:

- **Water Quality 2000–2020:** Ecology conducts monthly water quality monitoring year-round at two locations within Budd Inlet. Station BUD005 is located in Outer Budd Inlet and station BUD002 is located in Inner Budd Inlet in the area known as West Bay. Profiles record physical data including depth, temperature, salinity, DO, pH, and fluorescence. Laboratory analyses include NO_3, SRP, and chlorophyll. These data are used to compare the observed water quality conditions to surface water quality standards.

3.2.3 2019 Water Quality Study for the Project

Capitol Lake:

- **Water Quality 2019:** As part of the EIS Project Team, Herrera Environmental Consultants collected water quality samples in Capitol Lake to compare current and historical water quality conditions to determine if current conditions are within the range of previous observations. Samples were collected from May–October to be consistent with Thurston County-collected data. Capitol Lake was sampled near the surface and bottom at the same two stations Thurston County used in the past in the Middle and North Basin. An additional site located close to the eastern shore of the North Basin was monitored for FC and *E. coli* bacteria only. At the two main stations water samples were collected at the surface and bottom (less than 1 m above the bottom depending on water level) and analyzed for TP, TN, SRP, NO_3+NO_2, NH_3, chlorophyll, pheophytin, phytoplankton, FC bacteria, *E. coli*, TSS, VSS, TOC, DOC, and BOD. Temperature, DO, pH and conductivity were measured at 1-meter intervals from the surface to the bottom. A Secchi depth measurement was also taken during each sampling event.

Deschutes River:

- **Water Quality 2019:** As described above, Thurston County has a long-term monitoring station on the Deschutes River near Tumwater Falls. During July through October of 2019, the County collected additional data during their routine monitoring to augment the sampling effort in Capitol Lake. In addition to the parameters analyzed from 2004–2014, the following analytes were added: SRP, TN, TSS, VSS, TOC, BOD, and dissolved BOD.

3.3 ANALYSIS OF IMPACTS

Potential adverse impacts and beneficial effects related to both construction and long-term operation are evaluated, with a focus on comparatively evaluating the alternatives. In general, construction-related impacts are associated with lake sediment dredging, dredged material placement for constructing habitat areas, and dam construction (repair or removal) because these activities represent the major construction impacts. Future long-term adverse impacts and beneficial effects associated with water quality conditions and management actions for each of the four project alternatives are evaluated using a combination of information on long-term trends, current conditions, and model predictions of environmental factors affecting water quality. These adverse impacts and beneficial effects are described for both the lake basin area (currently Capitol Lake) and for Budd Inlet. Consistent with SEPA requirements, this analysis acknowledges where there are gaps in relevant information associated with projected water quality changes, and areas of scientific uncertainty (WAC 197-11-080). As such, it considers a worst-case outcome, which can mean lower levels of water quality improvement from implementation of the long-term management alternatives.

The focus of the water quality impact assessment is on DO, algae blooms, and depending upon alternative, aquatic plants. (Aquatic plants refers to visible (not microscopic) rooted and floating plants that grow in the water and does not in this context include algae, which by strict definition is also a type of aquatic plant.) DO is critical because low DO concentrations have been a long-term problem in Budd Inlet, and it has been the focus of water quality improvement planning efforts for many years, including those of this project. Adequate DO concentrations are important to aquatic habitat, particularly for cold water fish. Algae blooms and aquatic plants are important because they directly impact DO concentrations and they address qualitative water quality standards associated with protecting aesthetics. There are a number of other water quality parameters that would typically be evaluated in a standard water quality assessment report and that are also parameters addressed in the Deschutes TMDL. These include bacteria, sediments, pH, and temperature. While these and other parameters are summarized in the description of the affected environment (Section 4), they are not used in the impact assessment (Section 5) because they are not key to describing differences between management alternatives and SEPA (WAC 197-11-030 (2)(b)) requires that the analysis emphasize important environmental impacts.

Evaluating the magnitude of beneficial effects and the significance of adverse impacts to water quality involves both assessment of water quality standards as well as a qualitative evaluation of the functional value of those benefits or impacts. A predicted benefit or impact needs to be weighed against the magnitude as well as the temporal and spatial extent of that change as it is experienced by the biological endpoint. For DO, the biological endpoint is cold water fish (e.g., salmon) because they are sensitive to DO and their needs are the core of the state water quality standards. For algae and aquatic plants, the biological endpoint is humans due to aesthetic impacts. (Note: algae and aquatic plants can also be harmful to aquatic life because they can result in decreased DO; however, because of this relationship that impact is embedded in the DO assessment.)

3.3.1 Identification of Construction Impacts

Sediment dredging, dredged material placement for constructing habitat areas, and dam construction (repair or removal) are the primary construction activities affecting water quality. Other construction activities potentially affecting water quality for action alternatives include construction of the boardwalks and docks and the 5th Avenue Pedestrian Bridge. These activities have the potential to cause temporary adverse impacts to water quality through increases in turbidity and release of nutrients or contaminants at the dredging site and placement sites.

Water quality impacts related to disposal of dredged sediments at an upland or open-water placement site are also evaluated for the Estuary and Hybrid Alternatives since a small portion of the sediments dredged during construction cannot be reused onsite and require offsite disposal. (The *Sediment Quality Discipline Report* [Herrera 2021] contains details on sediment quantities.)

For this analysis, the magnitude of short-term impacts is considered less-than-significant or significant, as follows:

- **Less-than-significant**—Impacts are considered less-than-significant if they meet the conditions defined by the water quality permit (i.e., Section 401 Water Quality Certification under the federal Clean Water Act).
- **Significant**—Impacts are considered significant if they would not be expected to meet the conditions defined by the water quality permit (i.e., Section 401 Water Quality Certification under the federal Clean Water Act).

The adverse impacts of construction on water quality are described for each alternative in Section 5.0 Impacts and Mitigation Measures.

3.3.2 Identification of Operational Impacts

As described previously, assessment of water quality impacts has been limited to a qualitative assessment of the functional value of predicted changes in DO and expected changes in the extent or frequency of algae blooms and, depending upon the alternative, changes in the aquatic plant community. Impacts are evaluated in terms of the functional value of any expected change, whether beneficial or adverse, to habitat for sensitive aquatic life (i.e., cold water fish) and aesthetics (as related to algae and aquatic plant populations). These values are incorporated into the water quality standards for DO and aesthetic values.

For this analysis, the magnitude of long-term (operational) adverse impacts on water quality are considered less-than-significant or significant, as follows:

- **No Change in Impact**–There is no expected adverse change over existing conditions.
- **Less-than-significant**–Adverse impacts are considered less-than-significant if the project would result in the following:
    - Minor changes in DO that do not substantively change habitat conditions for cold water fish and no noticeable increase in either extent or frequency of algae blooms or areal extent of aquatic plants over existing conditions.
- **Significant**–Adverse impacts are considered significant if the project would result in the following:
    - Substantive changes in DO that significantly degrade habitat conditions for cold water fish relative to existing conditions and/or result in a measurable increase in either the extent or frequency of algae blooms or areal extent of aquatic plants.

Long-term beneficial effects on water quality based on long-term operations are evaluated in terms of minor to moderate, or substantial beneficial effects where:

Minor-to-moderate benefits:

- Beneficial effects on water quality are minor to moderate if there is an expected limited to modest improvement in DO and limited or modest improvement in the extent or frequency of algae blooms, as determined using standard analytical techniques, and/or limited to modest improvement in the areal extent of aquatic plants. These water quality improvements would be expected to result in limited to modest improvements in habitat conditions for cold water fish.

Substantial benefits:

- Beneficial effects on water quality are substantial if there is expected to be a substantive improvement in DO and a visually noticeable decrease in the extent or frequency of algae blooms and/or decrease in the areal extent of aquatic plants. These improvements would be expected to result in a substantial increase in habitat conditions for cold water fish.

The impact of the alternatives on Water Resources is described in Section 5.0 Impacts and Mitigation Measures. Because benefits and impacts are not the same within the project area, they are described separately for both the lake basin area (currently Capitol Lake) and for Budd Inlet.

4 Affected Environment

The following sections describe the existing conditions in Capitol Lake (Section 4.1) and Budd Inlet (Section 4.2). Previous studies, historical monitoring data, and recent data collected for this analysis were used to characterize the conditions in both Capitol Lake and Budd Inlet. Both sections describe the existing condition of the respective waterbody and act as the basis for supporting conclusions regarding the potential adverse impacts or beneficial effects of the project alternatives in Section 5. The analysis of existing conditions provides information on a variety of water quality parameters to provide an overview of general conditions. However, the focus of the analysis is on DO and the analytes that most influence DO concentrations as identified by Ecology's modeling of the lake's influence on DO in Budd Inlet (Ecology 2014, 2015a, 2015b). Ecology's model focused on nitrogen, because it typically drives algae production in marine waters and on TOC, as an indicator of organic matter that, when decomposed, contributes to DO depletion.

The following paragraphs provide additional description of the key parameters discussed in this report and their relationship to Budd Inlet DO conditions:

- **Phosphorus:** Phosphorus is typically the limiting nutrient for algae growth in freshwater systems, meaning that if there is an adequate supply then algae (and some aquatic plants) can continue to reproduce. In addition to potentially leading to visible algae blooms, the algae (and aquatic plants) also create DO during photosynthesis, and use up DO during respiration and when they die and decompose. Therefore, algae (and aquatic plants in lake settings) often drive DO conditions; this is true for both fresh and marine waters. The algae in Capitol Lake eventually enter Budd Inlet as organic matter (often measured as carbon) and their decomposition contributes to the DO depletion in Budd Inlet.
- **Nitrogen:** Nitrogen is typically the nutrient that limits algae growth in marine waters. Dissolved inorganic nitrogen (DIN) is the form of nitrogen that is the focus of Ecology's modeling efforts because it is the form that immediately feeds algae growth. Similar to phosphorus in freshwater, increased nitrogen (especially as DIN) can lead to algae blooms as well as the fluctuations in DO caused by photosynthesis, respiration, and decomposition as described above for phosphorus. For this reason, DIN from Capitol Lake that is discharged to Budd Inlet is of interest because it can support additional algae growth in Budd Inlet, which in turn impacts DO concentrations.

- **Carbon:** Carbon is a measure of the organic content of water and is often measured as Total Organic Carbon (TOC). Algae and aquatic plants are sources of carbon as are any other decomposing plants and animals such as trees and leaves. Carbon (or organic matter) eventually needs to be decomposed, a process that typically requires oxygen and therefore leads to oxygen depletion. Therefore, TOC can be used as an indirect indicator of the amount of oxygen that might be required to decompose organic matter. In this study specifically it is used to represent the organic matter produced in Capitol Lake, that eventually settle and decompose in Budd Inlet. However, not all sources of TOC are equal in terms of their potential or near term impact on DO. TOC includes refractory constituents; refractory constituents are sources that do not decompose at relevant time scales. A good example of a refractory constituent is the lignin from trees, which is very resistant to decomposition.
- **Oxygen Demand:** Oxygen demand refers to the oxygen required for processes such as respiration, decomposition, and chemical processes (e.g., oxidation reactions in the sediments) to occur. As alluded to in the above descriptions, oxygen demand in Budd Inlet is high during late summer months, causing a decrease in oxygen concentrations. Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen required for respiration and decomposition of non-refractory (easily decomposable) organic matter. It is measured in this study to augment TOC data and to evaluate how much of the TOC discharged from Capitol Lake to Budd Inlet is non-refractory and therefore likely to contribute to more immediate oxygen demand.

To describe existing conditions for Capitol Lake (Section 4.1), the first step was to evaluate whether there have been any trends in water quality that should be considered to ensure the data used for the analyses are representative of existing conditions. The water quality of Capitol Lake was then compared to state water quality standards and trophic state criteria to evaluate its current status. Sediment quality and algae composition is also described. Lake conditions were compared to nearby lakes to provide perspective for water quality conditions in the region. A summary of data collected in 2019 to support this study is provided. This and a water and phosphorus budget provide further insight into the current interactions between the Deschutes River and Capitol Lake. Lastly, a summary of some of the previous studies relevant to this report is provided to include important context for the alternatives analysis.

The previously described analyses for Capitol Lake required several different data sets that did not necessarily have overlapping timescales. Water quality data collected by Thurston County from 2004 through 2014 for Capitol Lake (eliminating the years between 2000 and 2004 when the brewery was in operation (and therefore discharging nutrients and other pollutants to the lake) were used for the trend analysis. The fact that there were strong trends for key parameters indicates that data from earlier in the data record is not representative of current conditions and therefore is not appropriate to use to evaluate current conditions. Therefore, only the most recent 5-year period (2010–2014) was used to evaluate water quality criteria, trophic status, and in comparisons to nearby lakes. For the water and phosphorus budgets, WY 2008–2012 was analyzed because it was the most recent 5-year period that contained flow, storage and phosphorus data for the Deschutes River, Capitol Lake, and Percival Creek.

Budd Inlet (Section 4.2) was also evaluated based on available data using similar methods as for Capitol Lake. The current conditions within Budd Inlet were characterized by comparing existing water quality to applicable state criteria. Sediment quality was also analyzed, largely referencing the findings from the *Sediment Quality Discipline Report* (SQDR) (Herrera 2021). Several studies and modeling efforts conducted in Budd Inlet were used to compare the waterbody to similar inlets in South Puget Sound and to evaluate interactions between Capitol Lake and Budd Inlet under different project alternatives. These too are summarized.

4.1 CAPITOL LAKE

4.1.1 General Description

Capitol Lake was formed in the 1950s when the 5th Avenue Dam was built near the mouth of the Deschutes River. The lake is approximately 267 acres in size with a mean depth of 9 feet and maximum depth of 20 feet with an approximate volume of 2,400 acre-feet. (Thurston County 2006). The lake is divided into three basins (Figure 1.1). The South Basin has formed where the Deschutes River discharges over Tumwater Falls and enters a wide shallow area. The Middle Basin is a long, somewhat narrow, and slightly deeper area, and the North Basin is both wider and deeper than the Middle Basin. Water from the North Basin discharges through tide gates in the 5th Avenue Dam into the West Bay area of lower Budd Inlet. There is little development in the immediate shoreline of Capitol Lake other than well-used parks and trails along the west side of the lake and around the North Basin. Steep slopes comprise much of the east side of the lake.

There are numerous (over 50) stormwater outfalls that discharge typical urban contaminants such as bacteria, metals, and petroleum products into Capitol Lake. Both the Deschutes River and Percival Creek, the two main inflows to the lake, have experienced serious spills over the past few years. There was a spill of PCB contaminated transformer oil to the Deschutes River in 2019, and three sewage spills in Percival Creek, one associated with a construction project and breakage of a sewer main in 2019, and two associated with a tree falling and crushing a pedestrian bridge that carried a sewer line in 2019.

Since Capitol Lake is an impoundment of the Deschutes River, it is highly influenced by the river. Due to the high inflow from the river and relatively small storage of the lake basin, the lake has a low detention time. It is estimated that during low flow periods water that enters the lake basin is retained for no more than 14 days before it is discharged over the dam (Ecology 2020). In Washington State, detention time is used to define the difference between lakes and rivers. A waterbody with a mean detention time greater than 15 days is treated as a lake for use designation. Therefore, by definition, Capitol Lake is classified as a river and held to the applicable water quality criteria (USEPA 2020). Detention time was also calculated during development of the water budget for this study (Section 4.1.3). The calculation was aimed at average conditions rather than low flow; and therefore, calculated detention times were much lower: ranging from 0.6–7.9 days. The storage estimate was based on 2013 lake bathymetry data. Since the lake will have filled-in to some extent with sediment since 2013, the detention time may be slightly lower than calculated.

From a management perspective, Capitol Lake displays many lake-like characteristics including higher nutrient concentrations, algae blooms, and extensive aquatic plant habitat. Additionally, it is considered a lake and treated as a lake by the public and resource managers. Therefore, this water quality assessment includes comparisons to lake trophic thresholds and comparisons to other local lakes to provide perspective.

Based on historically observed depths and calculated detention times (CH2M-Hill 1978), Capitol Lake has always been well-mixed. This is also supported by monitoring data collected in the early 1980s (Entranco 1984) that showed little or no temperature differences with depth and plentiful oxygen in the bottom waters. The lake does experience localized stratification near the dam. During high tides (>14 feet) marine water can enter the lake over the fish ladder. When this occurs, the denser water sinks to the deepest potion of the lake causing temporary salinity driven stratification until the marine water is flushed out (Thurston County 2014).

The lake's algal community is largely dominated by diatoms; this is unlike other eutrophic lakes in the region, which are dominated by cyanobacteria (i.e., blue-green algae) (Thurston County 2014). This was attributed to the influence of the river. While blooms of cyanobacteria (and green algae) do sometimes occur, the lake has not experienced toxic algae blooms to date. A dense community of aquatic plants has existed in the lake for decades. In the past, saltwater flushing was used to control the aquatic plants but this was discontinued due to concerns about adverse impacts to lake ecology. In 2004, the herbicide triclopyr was applied to the lake to control the infestation of Eurasian watermilfoil (*Myriophyllum spicatum*). At that time, it was estimated that the plants covered approximately 260 acres of the lake and had an average biomass of 65.3 g/m^2 and represented 72 tons of dry weight (Ecology 2012). Two months following the treatment the Eurasian watermilfoil was nearly eliminated, but the native aquatic plant biomass had returned to 62.1 g/m^2 and the primary plant was Common waterweed (Elodea *canadensis*). Although there have been no recent plant biomass estimates, it is expected that the coverage and density of plants is similar to what existed in 2004.

Since 2007, the management of aquatic plants has been limited to invasive species, which has primarily included hand pulling of Eurasian watermilfoil. The lake is currently dominated by coontail (*Ceratopyhyllum demersum*) (Thurston County 2014), a native floating plant (not rooted) that obtains its nutrients directly from the water (similar to algae) and therefore competes with algae for the available nutrients. In this sense it may be considered a more beneficial plant than others because it reduces the supply of nutrients available for algae growth. Most aquatic plants extract their nutrients from the sediments.

The following sections describe water quality conditions for the lake in terms of long-term trends, existing conditions, comparison to other local lakes, and a comparison to the Deschutes River. As stated previously, although the focus of the impact assessment is on DO, algae, and aquatic plants, the following sections provide data on other parameters as a means of providing a more complete characterization of lake conditions.

4.1.1.1 Assessment of Long-Term Water Quality Trends

Water quality data collected by Thurston County from 2004 through 2014 for Capitol Lake and the Deschutes River was compiled to evaluate existing conditions. (The year 2004 was selected as the starting date to eliminate water quality data collected before 2004 when the brewery was still in operation. The year 2014 was selected as the end date because the County discontinued monitoring the lake after 2014.) This data set, which represents interannual variation associated with approximately 10 years of data, was used to assess recent long-term trends in annual and summer conditions to ensure that the data used in the analysis is reflective of existing conditions.

During 2004 through 2014 period of interest, the Deschutes River was monitored year-round, whereas Capitol Lake was monitored only during summer months (May–October). Consequently, Deschutes River trends were evaluated on both a full year scale and a seasonal (May–October) scale. Capitol Lake trends were evaluated using all the available data (May–October) as well as separating data into seasons, i.e., spring (May–June), summer (July–August), and fall (September–October). (Note: Data collected in 2019 were not included in the trend analysis. As is described later (Section 4.1.1.2.2), a number of spills in 2019 contributed to significantly different conditions for some key analytes. This data is summarized in Section 4.1.1.2.2.

Temporal trends were evaluated using Kendall's Tau rank correlation coefficients (Kendall 1938) and the associated p-value. Kendall's Tau is a nonparametric test (i.e., a test applicable to non-normally distributed data) that is not strongly impacted by small sample sizes or irregular values (Helsel and Hirsch 1992). For trends to be considered significant, the associated p-values must be less than 0.05. The trends are determined to be positive or negative from the calculated Tau for the related time series. The Tau value indicates the sign of the trend and can be either positive (increasing) or negative (decreasing). For water quality variables a positive or negative trend can signify improving or worsening conditions depending upon the variable. For example, a positive trend in temperature would signify that temperature is increasing and that would represent a worsening trend in water quality conditions. Conversely, a positive trend in DO would also signify that DO is increasing but would represent an improving trend in water quality. In the data summary that follows, trends are described as either improving or worsening and the direction of the trend is noted in parentheses.

Key results from the trend analysis are summarized for Capitol Lake and the Deschutes River in Table 4.1 and Table 4.2, respectively. Graphs showing the identified significant trends for several key variables in Capitol Lake are displayed in Figure 4.1. (Note, the best fit line shown on the figures is calculated separately from the Kendall's Tau and is only displayed to better visualize the temporal trend).

Table 4.1 Kendall's Tau Trend Analysis Results for Capitol Lake (2004–2014).

Parameter	All (May–Oct) Tau	All (May–Oct) p-value	Spring (May–June) Tau	Spring (May–June) p-value	Summer (July–Aug) Tau	Summer (July–Aug) p-value	Fall (Sept–Oct) Tau	Fall (Sept–Oct) p-value
Temperature (Surface)	**-0.14**	0.128	-0.24	0.146	**-0.5**	**0.006**	-0.18	0.33
Temperature (Bottom)	0.03	0.783	0.02	0.922	0.06	0.752	-0.03	0.881
pH (Surface)	**-0.28**	**0.003**	-0.32	0.054	**-0.49**	**0.010**	-0.34	0.056
pH (Bottom)	-0.06	0.515	-0.07	0.694	-0.16	0.413	-0.18	0.289
DO (Surface)	-0.11	0.254	0.05	0.773	-0.27	0.165	**-0.36**	**0.039**
DO (Bottom)	0.16	0.086	0.22	0.186	-0.11	0.558	0.15	0.41
Conductivity (Surface)	**0.33**	**0.000**	0.253	0.128	**0.38**	**0.041**	**0.37**	**0.032**
Conductivity (Bottom)	**0.23**	**0.012**	0.242	0.146	0.30	0.116	0.294	0.096
TP (Surface)	**-0.31**	**0.001**	**-0.39**	**0.019**	-0.11	0.558	**-0.59**	**0.001**
TN (Surface)	-0.01	0.976	-0.32	0.055	0.36	0.053	0.20	0.26
Chlorophyll-a	**-0.21**	**0.027**	**-0.34**	**0.040**	-0.19	0.32	**-0.48**	**0.006**
Pheophytin-a	**-0.27**	**0.005**	-0.22	0.183	-0.20	0.279	**-0.38**	**0.033**
Secchi Depth	**0.24**	**0.012**	0.28	0.091	0.28	0.169	0.30	0.087

Bold and shaded values indicate a significant trend (p-value<0.05).

The sign of Tau (+ or -) indicates the trend direction. A positive trend does not necessarily depict improving conditions and a negative trend does not necessarily depict worsening conditions; this interpretation varies by parameter.

Table 4.2 Kendall's Tau Trend Analysis Results for the Deschutes River (2004–2014).

Parameter	May–Oct Tau	May–Oct p-value	Year-Round Tau	Year-Round p-value
Temperature	0.06	0.483	0.03	0.665
pH	**-0.22**	**0.012**	**-0.23**	**0.000**
DO	0.05	0.578	0.03	0.656
Conductivity	0.02	0.853	0.02	0.684
TP	-0.04	0.625	0.04	0.455
Nitrate + Nitrite	-0.09	0.264	-0.07	0.209
Turbidity	-0.06	0.519	0.02	0.718
FC Bacteria	**-0.22**	**0.015**	-0.10	0.134

Bold and shaded values indicate a significant trend (p-value <0.05).

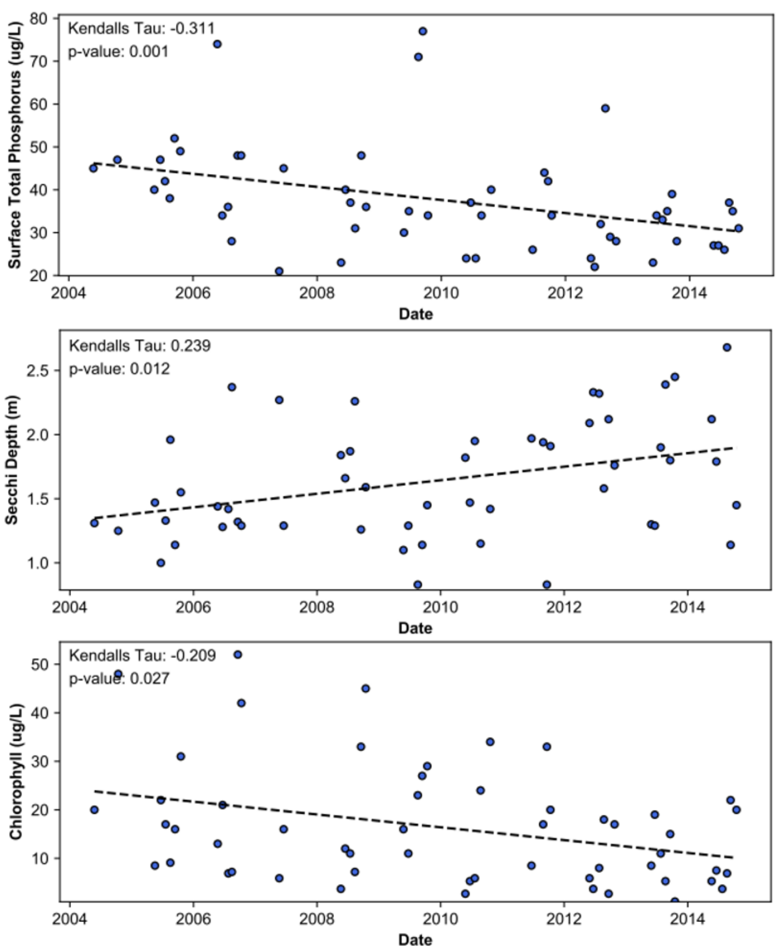

Figure 4.1 Kendall's Tau Trend Analysis Results for (a) TP (Surface), (b) Secchi Depth, (c) Chlorophyll-a, Based on Data Collected in Capitol Lake from May to October of 2004–2014.

Capitol Lake Trends

- All (May–October): Seven water quality parameters exhibited significant trends over this period: surface pH, surface and bottom conductivity, surface TP, chlorophyll-a, pheophytin, and Secchi depth. Of these parameters, surface pH (negative Tau), surface TP (negative Tau), chlorophyll-a (negative Tau), and Secchi depth (positive Tau) all indicate lower productivity and an improving water quality trend. Surface and bottom conductivity also exhibited a significant increasing trend. The observed trends in conductivity are indicative of saltwater intrusion through the dam. (As a result of historical backflushing events, a scoured crater exists at the mouth of the 5th Avenue Dam where saline water has previously induced stratification and stagnation [Entranco 1984]).
- Spring (May–June): During the spring, TP and chlorophyll-a exhibited significant improving water quality trends (negative Tau).
- Summer (July–August): Surface temperature, surface pH, and surface conductivity all had significant trends during summer months. The trend in surface temperature (negative Tau) and pH (negative Tau) indicate improving water quality. Surface conductivity also had a positive trend during this period, again indicating the influence of saltwater intrusion.
- Fall (September–October): During this period TP, chlorophyll-a, and pheophytin all had significant improving water quality (negative Tau). Surface DO exhibited a worsening (negative Tau) trend, potentially due to a decrease in algae or aquatic plants, which is supported by the negative trend in chlorophyll-a and pheophytin and lower pH. Surface conductivity also had a positive trend during this period, again indicating the influence of saltwater intrusion.

Deschutes River Trends

- Year-Round (January–December): pH exhibited an improving trend (negative Tau) and was the only significant trend. Lower pH is often an indicator of lower productivity.
- Summer (May–October): FC bacteria and pH exhibited significant improving trends (negative Tau).

Together the results from the temporal trend analyses indicate that Capitol Lake exhibited improving water quality from 2004–2014 based on significant improving trends in temperature, TP, chlorophyll-a, Secchi depth, and FC bacteria. These trends appear to be most evident in fall and spring. Due to the observed trends, evaluation of existing water quality data (Section 4.1.1.2) was limited to the most recent 5-year period of data (2010 through 2014) to better reflect current conditions in the lake and river, while still reflecting interannual variability. The improvements measured in this and other studies (Ecology 2012) are indications that watershed improvement activities carried out over the past 25 years have been effective at improving overall water quality in the Deschutes River system.

4.1.1.2 Assessment of Existing Water Quality

4.1.1.2.1 Comparison to Water Quality Standards and Trophic State Indicators

The first step in assessment of existing conditions is to compare lake water quality to state water quality standards. Capitol Lake presents an unusual situation because the lake's detention time is less than the 15-day mean detention time used by the state (WAC 173-201a-020) to define a lake. For this reason, Capitol Lake is characterized as a river (USEPA 2020) and is held to the applicable freshwater criteria. Therefore, these criteria are described below and compared to existing lake conditions. However, since the lake would be managed as a lake under the Managed Lake Alternative, lake specific standards or indicators are also described.

The state standards include an Action Level for total phosphorus that is only applied to lakes for assessing impairment from excess nutrients. This Action Level is also described since phosphorus is important to consider for managing a lake and one of the alternatives being considered is a Managed Lake Alternative. According to the state standards, if the Action Level is exceeded, then a lake-specific study is recommended to determine the appropriate nutrient criteria for meeting the specific uses of the lake.

Table 4.3 provides a comparison of recent lake water quality data with state surface water standards (WAC 173-201A-602). As shown in Table 4.3, during the summer the lake occasionally exceeds (i.e., does not comply with) the state standards for temperature, pH, DO, and TDG, and continually exceeds the trophic-state Action Level for TP for Puget Sound lowland lakes.

Figure 4.2 visually displays some of these results using box and whisker plots. In these figures, the top and bottom of the boxes represent the 75th and 25th percentiles, respectively, the middle line indicates the median, and the two whiskers represent the maximum and minimum values. The mean is indicated by an "X"; and if outliers are present, they are shown as points above and below the 75th percentile line.

Table 4.3 Comparison of Capitol Lake Data to Washington State Surface Water Quality Standards (WAC 173-201A-230). (Based on 2010–2014 Data from the North Basin).

Parameter	Mean	Median	Min	Max	Surface Water Quality Standard/ Action Level
Temp. (˚C) (Surface)	16.5	17.1	9.3	**21.1**	17.5[a]
Temp (˚C) (Bottom)	16.2	16.9	9.7	**20.1**	17.5[a]
DO (mg/L) (Surface)	12.2	12.2	9.2	16.3	8.0[a]
DO (mg/L) (Bottom)	10.7	10.6	**7.7**	13.1	8.0[a]
TDG[c] (%) (Surface)	**124.8**	**124.8**	95.3	**168.5**	110.0[c]
TDG[c] (%) (Bottom)	108.1	109.8	83.0	**133.3**	110.0[c]
pH (Surface)	8.2	8.2	7.4	**9.2**	6.5–8.5[a]
pH (Bottom)	7.7	7.7	6.6	**8.8**	6.5–8.5[a]
TP (µg/L) (Surface)	**32.3**	**32.0**	**22.0**	**59.0**	20.0[b]

Data is from monthly summer (May through October) grab samples collected by Thurston County. **Bold and shaded values** indicate excursions from the standard or action level.

a Washington State Surface Water Quality Standards (WAC 173-201A: Salmonid Spawning. Rearing, and Migration).

b Action Level listed in WAC 173-201A-230.

c WAC 173-201A standard for total dissolved gases (TDG).

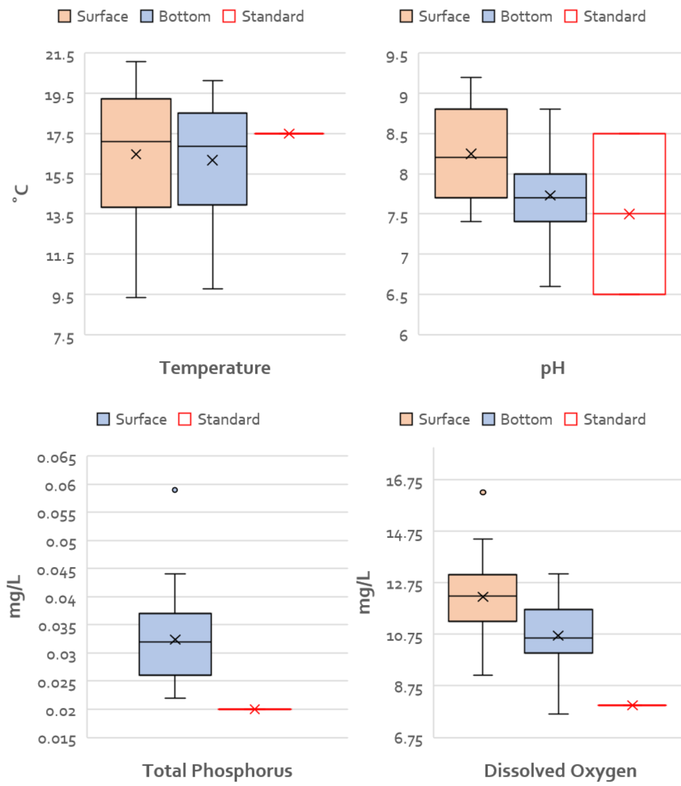

Figure 4.2 Box and Whisker Plots of Key Parameters with the Water Quality Standard or Action Level (WAC 173-201A) Shown in Red.

As indicated by Figure 4.2, there is almost no difference in temperature between surface and bottom waters; and pH and DO are only slightly lower in the bottom waters, indicating that this is a well-mixed system. Although the numeric DO standard is slightly and infrequently exceeded in the bottom waters of the lake, from a typical lake perspective these results signify well-oxygenated bottom waters. (Many lakes become thermally stratified in the summer (warm water on top and cool water on the bottom), which inhibits mixing between layers and results in bottom waters that are anoxic (low or no oxygen). Since Capitol Lake does not thermally stratify and remains well mixed throughout the summer, oxygen remains in the bottom waters.

DO can also be too high and result in supersaturated conditions that can also be a hindrance to aquatic life. This is measured as total dissolved gas or TDG. The TDG standard was established due to concerns with super-saturated conditions at dam spillways and the impact on fish. However, supersaturated DO is also common in eutrophic lakes and is associated with high rates of photosynthesis by plants and algae. (It should be noted that these DO concentrations are from daytime measurements and do not reflect the lowest DO concentrations that would occur. The most critical time period for DO concentration, in rivers, lakes and marine waters, is typically just before dawn. For the purposes of this report [to summarize and compare conditions between the river, lake, and inlet], daytime measurements represented by the available data are appropriate.)

Water temperature also exceeds standards for surface and bottom samples with some frequency. Again, from a lake perspective these water temperatures are low when compared to other lakes. (This is described further in Section 4.1.1.3). Since the main incoming water sources (Deschutes River and Percival Creek) also experience temperature exceedances; therefore, the high values in the lake can be attributed to both the incoming water and the slower moving, more sunlight-exposed water that is characteristic of a lake. There are also exceedances of surface and bottom pH that are a result of high primary productivity from photosynthesis by algae and aquatic plants.

Although Capitol Lake meets the definition of a river, it has many lake characteristics and would be managed as a lake if it is retained (i.e., under the Managed Lake Alternative). Therefore, it is reasonable to evaluate it against common lake attributes. Table 4.4 compares Capitol Lake conditions to criteria commonly used for assigning a trophic state to lakes. Based on TP, chlorophyll, and Secchi depth, the lake would continue to be classified as eutrophic even with the improved trends in these parameters observed in recent years. As stated previously, the TP concentrations measured in Capitol Lake exceeded the Action Level set for lakes (>20 µg/L) in all samples. However, as shown in Table 4.4, by definition all eutrophic lakes would exceed the Action Level concentration. This Action Level is not a standard, but WAC 173-201A-230 recommends that a study be initiated to develop a lake specific standard for TP when the Action Level is exceeded.

Table 4.4 Comparison of Capitol Lake Data and Trophic State Criteria for Lakes.

Trophic State	Secchi[a,b] (m)	Chlorophyll-a[a,b] (µg/L)	TP [a,b] (µg/L)	TN[a,c] (mg/L)
Capitol Lake	1.8	12.3	32.3	0.60
Oligotrophic	>4	<2.6	<12	<0.35
Mesotrophic	2–4	2.6–7.2	12–24	0.35–0.65
Eutrophic	1–2	7.1–20.1	24–48	0.65–1.2
Hypereutrophic	<0.5	>56	>96	>1.2

a Summer mean value for surface water measurements taken between 2010 and 2014.

b Carlson 1977

c Welch and Jacoby 2004

Table 4.5 provides a summary of bacteria data from the 2019 field study. In addition to the two main lake monitoring stations, a third site near the eastern shore of the North Basin was monitored for bacteria to evaluate nearshore conditions. Until recently, the state water quality standards for lakes and rivers (WAC 173-201A-200) used FC bacteria and *Escherichia coli* (*E. coli*) as alternative indicators of bacterial contamination. Both were measured during the 2019 monitoring to evaluate lake conditions. As of this year (2021) only *E. coli* bacteria will be used to determine compliance. Both standards are provided in Table 4.5 for comparison.

Table 4.5 Comparison of Bacteria Concentrations in Capitol Lake Data in 2019 to Washington State Surface Water Quality Standards (WAC 173-201A-230).

Sample Date	Middle Basin		North Basin – Center		North Basin – Shore	
	FC Bact. (CFU/100 mL)	*E. Coli* (CFU/100 mL)	FC Bact. (CFU/100 mL)	*E. Coli* (CFU/100 mL)	FC Bact. (CFU/100 mL)	*E. Coli* (CFU/100 mL)
5/28/2019	16	11	**540**	**335**	115	68
6/26/2019	<10[a]	<10[a]	<2[a]	<2[a]	–	–
7/24/2019	2	2	<2[a]	<2[a]	–	–
8/22/2019	<2[a]	<2[a]	4	4	78	66
9/24/2019	64	54	7	7	9	4
10/22/2019	171	171	35	35	44	44
Geometric Mean	14	13	11	10	43	30
Geometric Mean Standard[b]	100	100	100	100	100	100
Maximum Standard[b]	200	320	200	320	200	320

Bold and shaded values indicate excursions from the standard or action level.

a Values with a < indicate sample was below the detection limit.

b WAC 173-201A-200: Table 200 (2)(b) Criteria based on datasets where there are fewer than ten sample points.

Overall, bacteria concentrations were low and geometric means values were well below the standard (Table 4.5). However, there was one sample from the North Basin (from May 28, 2019) that exceeded the maximum standard. A large sewage spill was identified in Percival Creek on the same day and resulted in very high bacteria concentrations in Percival Creek. This was coincidental with the monitoring of Capitol Lake and the only day when the bacteria standards were exceeded in the lake. This spill is the likely cause for high bacteria concentrations since concentrations were not high at the Middle Basin sampling site, which is located upstream of where Percival Creek flows into Capitol Lake. Elevated bacteria concentrations were also measured that were associated with a rain event, but did not result in exceedances of the water quality standard. With the exception of the monitoring event that occurred during the spill that impacted the North Basin only, the Middle and North Basin stations had similar concentrations and geometric mean values. The station located near the eastern shoreline of the North Basin had elevated bacteria concentrations when compared to the other lake stations, but still met water quality standards.

4.1.1.2.2 Assessment of 2019 Data

4.1.1.2.2.1 Water Quality

The Budd Inlet modeling study (Ecology 2015b) indicated that the largest human-caused contributor to low DO problems in Budd Inlet was loading of nutrients and TOC from Deschutes River and Capitol Lake. For the parameters of most interest (e.g., biological indicators such as TOC and DOC), the Ecology report was based on data collected in Capitol Lake more than 15 years ago. Therefore, to provide more recent data and to augment the historical dataset with additional analytes, limited additional monitoring was conducted in Capitol Lake from May–October 2019 and the routine monitoring of the Deschutes River performed by Thurston County was expanded to include some key analytes. The 2019 data also allowed the EIS Project Team to verify trends that were observed in the 2004-2014 dataset, and confirm that that dataset is representative of existing conditions. Monitoring details are summarized in Section 3.2 and provided in detail in Appendix A.

Three events occurred in 2019 that may have affected water quality results. The first event occurred on February 25, 2019, when there was a spill of transformer oil, just below Tumwater Falls. The oil entered the Deschutes River from several storm drains and entered Capitol Lake. Ecology immediately launched an extensive cleanup that involved removing oil from the system by skimming the surface, cleaning the shoreline vegetation, and vacuuming contaminated sediment. The removal efforts occurred from March through July 2019. Water quality may have been affected by both the transformer oil and the site disturbances from cleanup operations. The cleanup effort caused a small but important delay in the start of the sampling planned to support development of this discipline study; the first sampling day occurred at the end of May rather than the middle of the month. The remaining two events were associated with sewage pipe spills on Percival Creek near in early February and near the end of May in 2019. As described previously, the spill impacted bacteria concentrations in Percival Creek and Capitol Lake.

Due to concerns that these events may have impacted water quality, 2019 data were compared with those from previous years (2010–2014) (Table 4.6). The data comparison indicates that there were only minor differences in surface TN, chlorophyll, and phaeophytin; and there appears to have been a decrease in Secchi depth (a measure of transparency) in the Middle Basin, which could likely be a reflection of cleanup activity disturbance. However, the TP increased substantially; the average TP concentration in the Middle Basin in 2019 was seven times higher than the average measured in previous years, and in the North Basin concentrations were twice as high as the average measured in previous years (Figure 4.3). The high TP concentrations appeared to coincide with high SRP concentrations in both basins but this did not result in a large increase in algae growth; chlorophyll and pheophytin concentrations were only slightly elevated when compared to averages from previous years. Thus, suggesting that the lake was nitrogen limited at the time. The oil spill, or more likely cleanup efforts associated with the spill (e.g., phosphorus release from sediment disruption and plant die-off), appears to have been the most likely source of increased nutrients, since the largest increase was in the Middle Basin, which would have been impacted by the oil spill but not the sewage spill. Additionally, the Deschutes River does not appear to have been the cause of increased TP and SRP (Figure 4.3), providing supporting evidence that the high values measured in 2019 were caused by the spill. Due to this issue, TP and SRP data from 2019 is not used in this analysis. Data from other parameters collected in 2019 was generally within the expected range of historically observed values (Table 4.6) and was accepted for use in this analysis.

Overall, the lake data (2010–2014 and 2019) indicate that Capitol Lake currently has relatively good water quality in terms of physical characteristics important to aquatic life; there are occasional exceedances of water quality standards such as temperature and DO but these are tempered by the Deschutes River. Chlorophyll concentrations are also relatively low, especially in light of the lake's eutrophic condition. (Section 4.1.1.3 provides more perspective on the lakes condition by its comparison to other lakes.) The extensive aquatic plant community remains a concern. These findings may be contradictory to popular perception of the lake. This may be because the public's perception is largely driven by the extensive aquatic plant population and that is equated to poor water quality. Also, because algae will "pile up" along the shore in the direction of the prevailing wind, this can influence perceptions of the magnitude or frequency of algae blooms.

Table 4.6 Comparison of 2019 Capitol Lake Water Quality Data to 2010–2014 Data.

Parameter	2010–2014 Average (North Basin)	2019 Average (North Basin)	2010–2014 Average (Middle Basin)	2019 Average (Middle Basin)
TN (mg/L) (Surface)	0.60	0.49	0.69	0.65
TP (mg/L) (Surface)	0.032	0.069	0.032	0.22
SRP (mg/L) (Surface)	0.010[a]	0.024	0.014[a]	0.115
Chlor-a (µg/L) (Surface)	12.3	14.1	5.2	3.8
Phae-a (µg/L) (Surface)	3.0	3.3	3.1	1.7
Secchi (m)	1.8	1.6	2.4	1.9

[a] These values are based on the 2004 dataset because SRP was not measured from 2010-2014

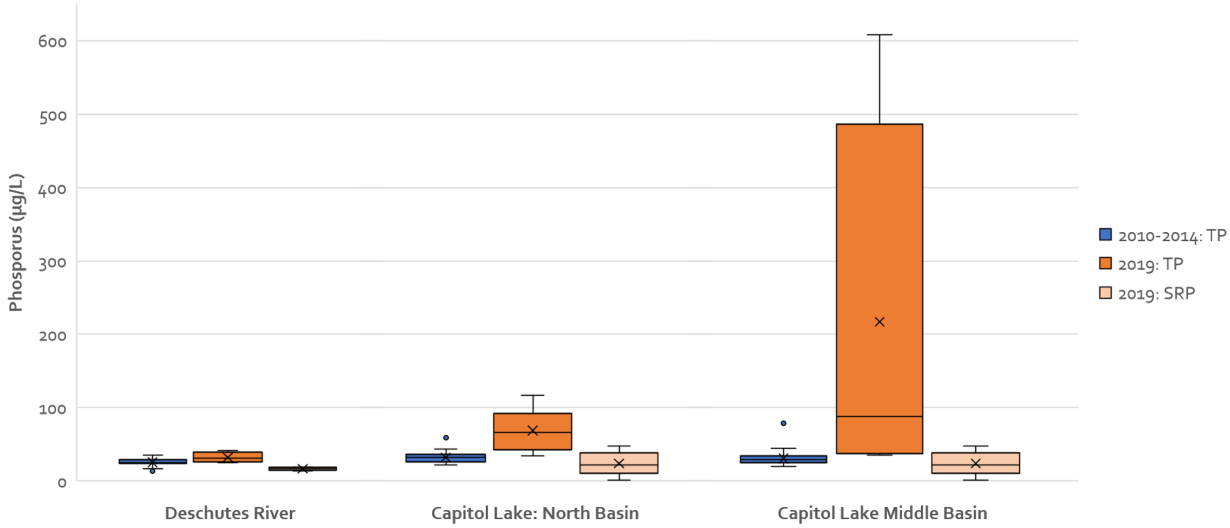

Figure 4.3 Comparison of 2019 Phosphorus Data in the Deschutes River and Capitol Lake with Data from Previous Years (2010–2014).

4.1.1.2.2.2 Algae Community Composition

Figure 4.4 summarizes algae composition and biovolume data from the samples collected in 2019. As shown, in 2019 diatoms dominated the algae biomass and represented 80% or more of the biomass at both monitoring sties during 6 of the 7 monitoring events and always represented more than 70% of the biomass. Bluegreen algae (the algae associated with the potential for toxic algae blooms) were sometimes present and were present more frequently in the North Basin but they never represented more than approximately 10% of the biovolume. In 2004 the lake algae population was also dominated by diatoms; however, there were two algae blooms: one caused by green algae (July) and one caused by blue-green algae (August) (Ecology 2012).

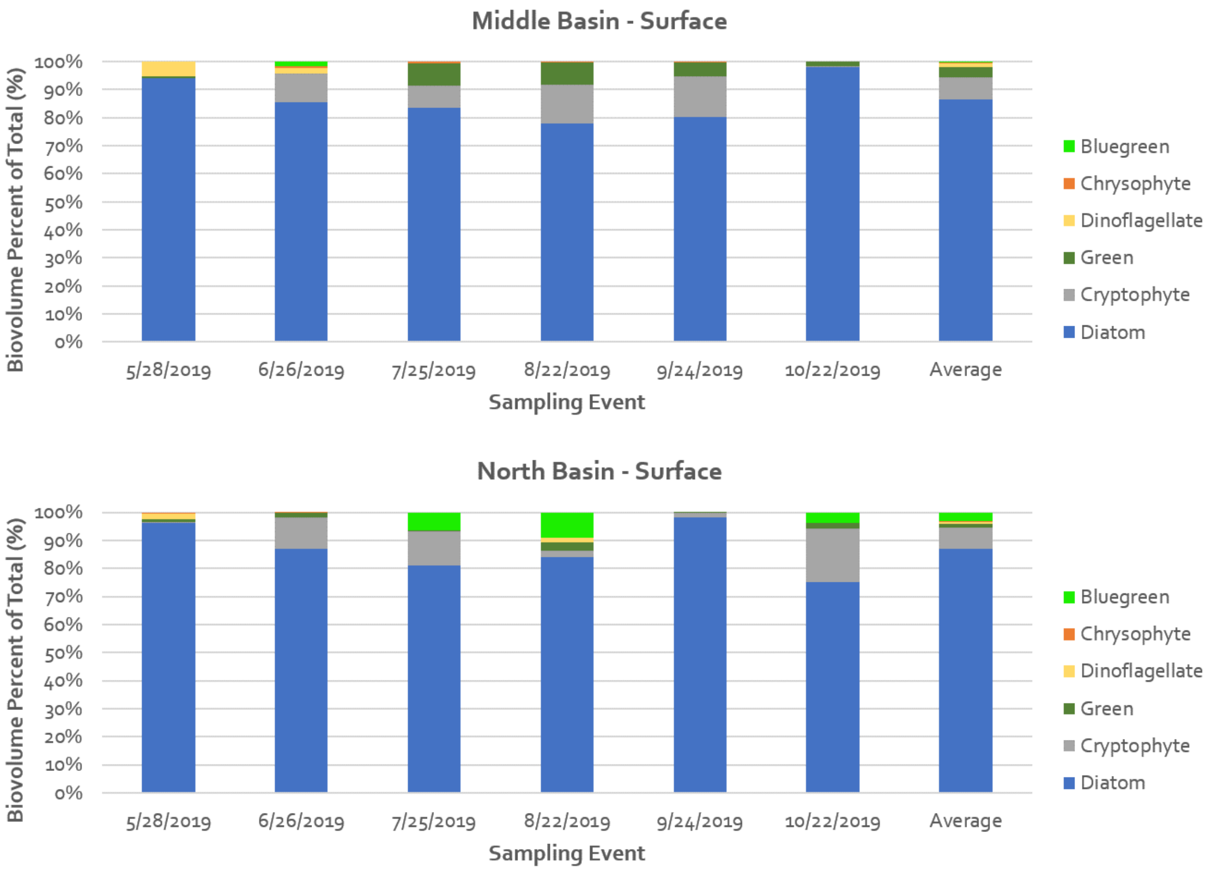

Figure 4.4 Summary of Phytoplankton Species Biovolume by Group collected in 2019 from the Middle and North Basin of Capitol Lake.

4.1.1.3 Comparison to Other Local Lakes

Figure 4.5 compares average measured conditions in Capitol Lake to other lakes in Thurston County using data from 2010–2014. Black Lake and Long Lake are similar to Capitol Lake since they are considered eutrophic, while Ward Lake is likely mesotrophic. As shown, Capitol Lake is cooler and has more oxygen than the other lakes. It has higher concentrations of both TP and TN; however, this is coupled with only moderate chlorophyll concentrations and Secchi depths relative to the other lakes. (Note, Secchi depth is a common lake measurement used an indicator of transparency and/or algae growth). These differences are likely due to the atypical hydrodynamics of Capitol Lake: the large inflow from the river and low residence time. Capitol Lake is typically well mixed and therefore does not stratify into a layered system with warm, oxygenated upper layers and cooler, low oxygen lower layers as is common in most lakes in the Puget Sound lowlands. Overall, Capitol Lake exhibits relatively good water quality when compared to other lakes in the area. The chlorophyll concentrations are low and Secchi depths are moderately good, especially considering the concentrations of phosphorus and nitrogen. Ecologically, the low temperatures and high DO are more supportive of cold water fish than other lakes.

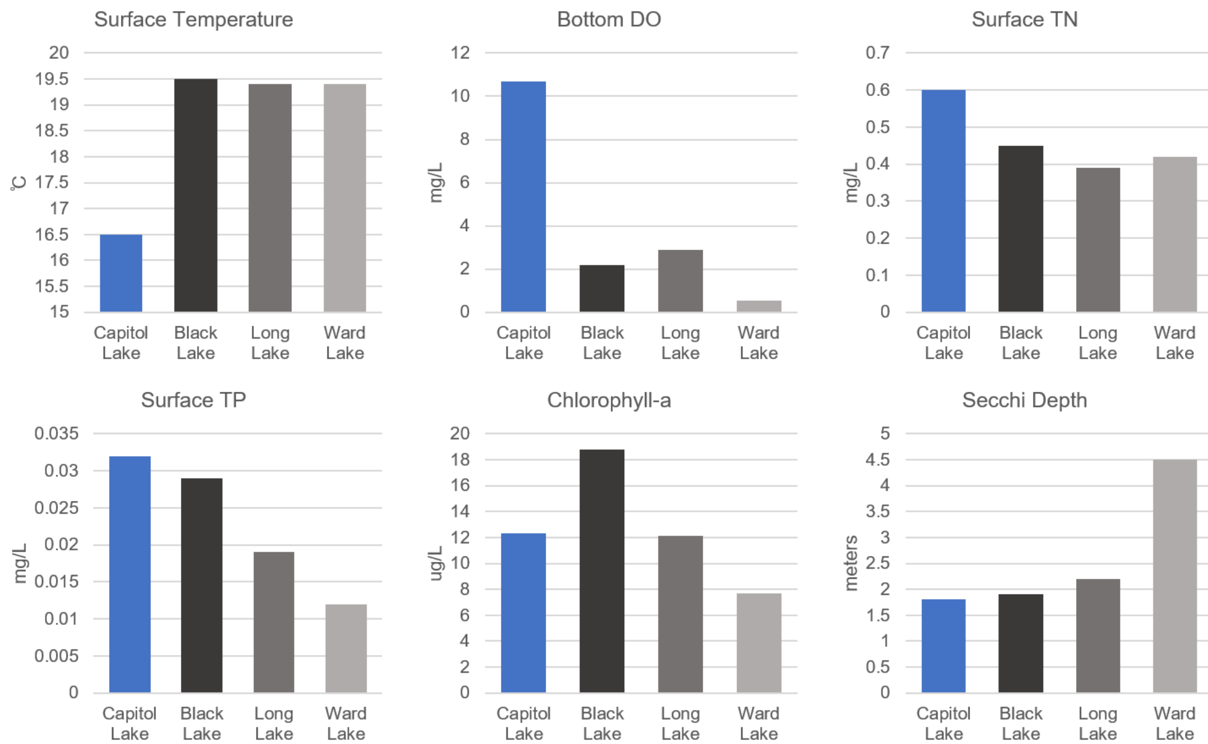

Figure 4.5 Capitol Lake Comparison to Local and Similar Lakes Using Data from Summer Months in 2010–2014 for All Lakes.

4.1.1.4 Comparison to the Deschutes River

One of the main objectives of the 2019 data collection effort was to compare BOD, TN, and TOC between the lake and river to evaluate the extent to which the lake is a principal contributor of the loads of these constituents to Budd Inlet, and therefore a principal contributor to low DO in Budd Inlet. Before this comparison could be made, it was necessary to first evaluate the extent to which the spill and/or spill related activities may have resulted in increases in BOD, TN, or TOC due to either increased algal biomass and/or release or movement of additional organic matter that would increase carbon. As described above and shown in Table 4.6, there appeared to be no impact on algal biomass from the spill; chlorophyll concentrations in 2019 were similar to 2010 to 2014 data. Further, TOC concentrations measured in 2019 were lower than those measured in 2004. TN was also nearly the same in 2019 as it was in 2010–2014. Based on this, it was assumed that BOD, TN, and TOC appeared to be unaffected by the spills; and therefore, comparisons to Deschutes River data could reasonably be made.

Table 4.7 provides a comparison of Deschutes River and Capitol Lake data from recent (2019) monitoring. As depicted in the table, there was a small decrease in average TN between the river and lake. Although the soluble fractions of nitrogen that comprise DIN (i.e., NH_3 and NO_3+NO_2) were not measured in the river in 2019, a comparison of concentrations in the Middle Basin with the North Basin also indicates that concentrations decrease as the water flows through the Capitol Lake Basin. The data indicates that there were increases in BOD, TSS, VSS, and TOC between the river and lake (Table 4.7

and Figure 4.7), but these were generally small in relation to the overall low concentrations measured. (At low concentrations small changes can equate to large percent increases. For example, TOC increased by approximately 1 mg/L between the Deschutes River and North Basin which represents a 50% increase, but when compared to the range of TOCs measured in this system of (i.e., up to approximately 30 mg/L (LOTT 1998)), the 1 mg/L can be put into perspective. A further indicator that TOC concentration increases in Capitol Lake are not driving large changes in BOD are the BOD values themselves. BOD was below detection limits much of the time in both the Deschutes River and Capitol Lake. Chlorophyll was not measured in the river, but a comparison between the Middle and North Basin results indicates that chlorophyll increases as the water moves from the river through the lake. And thus, the increases in BOD, TSS, VSS and TOC are likely due in part to increased algae growth.

Table 4.7 Summer Mean Values for Key Water Quality Data Collected in 2019.

Parameter	Deschutes River	Middle Basin Surface	North Basin Surface	North Basin Bottom
TP (mg/L)	0.033	0.031[b]	0.032[b]	–
SRP (mg/L)	0.017	0.014[c]	0.010[c]	ND[d]
TN (mg/L)	0.79	0.65	0.49[b]	0.51
NH3 (mg/L)	–	0.075	<0.055[a]	<0.030[a]
NO3+NO2 (mg/L)	–	0.42	<0.20[a]	0.22
Chlorophyll (µg/L)	–	3.83	14.1	10.1
Pheophytin (µg/L)	–	1.7	3.3	3.0
TSS (mg/L)	1.70	1.81	2.63	2.83
VSS (mg/L)	<1.00	1.11	1.70	<1.66[a]
TOC (mg/L)	1.83	2.22	2.55	2.94
DOC (mg/L)	–	2.00	2.44	2.10
BOD5 (mg/L)	<2.00[a]	<2.06[a]	<2.25[a]	<2.08[a]

[a] Values with a < indicate the sample set had at least one sample below the detection limit: (BOD = 2 mg/L; VSS = 0.5 mg/L; NH3 = 0.01 mg/L; NO2+NO3 = 0.01 mg/L)

[b] For these parameters, 2019 data were determined to be different than data from 2010–2014 data. In these cases, average values from 2010–2014 are shown.

[c] For these parameters, 2019 data were determined to be different than data from 2010–2014 data. In these cases, average values from 2004 are shown

[d] ND = No Data. SRP data that was collected in 2019 did not represent typical conditions due to extensive spill clean-up efforts.

Previous modeling studies concluded that Capitol Lake increased the load of TOC and decreased the DIN load to Budd Inlet as compared to the river, and this is supported by the data. Figure 4.6 provides a comparison of TN and DIN concentrations in the river and lake. As shown, the concentrations are consistently lower in the lake during the growing season; and they steadily decrease relative to the river as the growing season progresses. The decrease in DIN over the growing season has been attributed to uptake by plants and algae in the lake (Ecology 2015b).

The conversion of DIN into organic material in the lake corresponds to higher TOC concentrations in the lake relative to the river (Figure 4.7). Each year for which there is data there were notable peaks in TOC in late summer (2004) or fall (2019). These peaks have been attributed to aquatic plant die-off. Unfortunately, 2004 was not a typical year for plant die-off because two herbicide applications had been conducted in the summer of 2004 to kill aquatic plants. This would have resulted in atypical spikes in TOC in terms of both concentration and the timing of the spike. (The herbicide applications would have resulted in nearly immediate die off of the majority of the plants resulting in a large release of TOC in the few days or week after the applications, which were done in mid-summer (Figure 4.7). Under natural conditions, aquatic plants would die off slowly over an extended period and this would happen in late summer and fall, similar to timing of increased TOC was observed in 2019 (Figure 4.7).

These results along with the previous studies indicate that Capitol Lake may increase the load of TOC but decrease the load of TN and DIN to Budd Inlet when compared to the Deschutes River input without the lake. While the differences in nitrogen between the river and lake are clear, there is less distinction in TOC concentrations. While TOC in the lake is consistently higher than the river through most of the summer, they are both generally low overall (below 3 mg/L), with the important exception of the peak that occurs in the lake during late summer or early fall due to plant die-off.

Although an increase in TOC was noted in the lake it did not appear to result in a commensurate increase in BOD. Theoretical relationships related to stoichiometry and respiration can be used to estimate potential DO demand from TOC (Welch and Jacoby 2004). Based on these relationships, the mass ratio between oxygen and carbon is 3.89. Therefore, if the 2 to 3 mg/L of TOC measured in the lake in 2019 had exerted its full potential DO demand, it would have required approximately 7 to 12 mg/L of oxygen for decomposition. Instead, the measured oxygen demand (as BOD) was only approximately 2 mg/L. This indicates that that the BOD concentrations measured in 2019 were quite low in comparison to TOC concentrations in both the lake and the river, and therefore that the TOC was largely composed of organic matter that is resistant to decomposition.

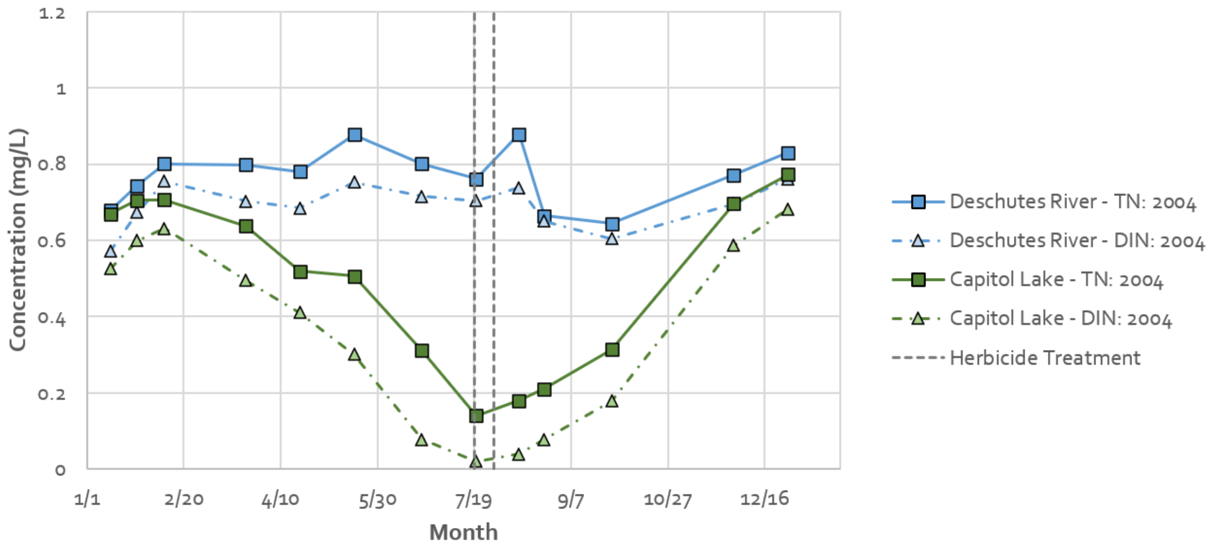

Figure 4.6 **TN and DIN Concentrations for the Deschutes River Near Tumwater Falls and the North Basin of Capitol Lake.**

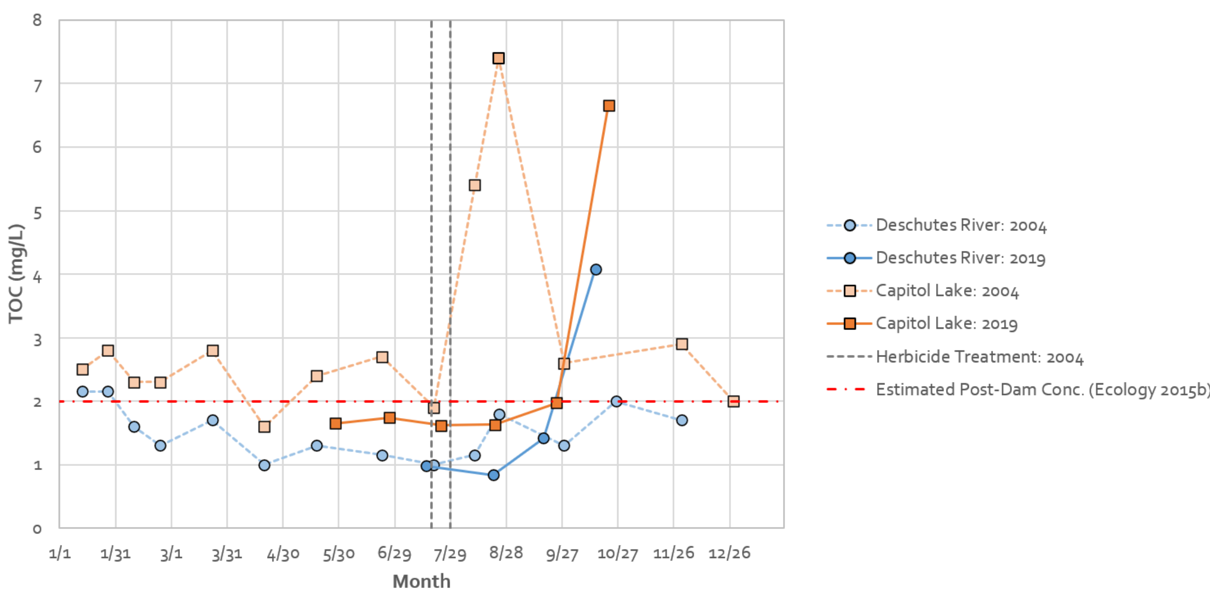

Figure 4.7 **Deschutes River and Capitol Lake TOC Concentrations From 2004 and 2019. (Red line indicates the approximate TOC concentration of 2 mg/L estimated by Ecology [Ecology 2015b] to reflect conditions without the 5th Avenue Dam in place during summer months in 1997. The 2 mg/L estimated from the model output (See Figure 4-14) corresponds to Ecology's estimate of 5 mg/L TOC with the 5th Avenue Dam in place.)**

4.1.2 Sediment Quality

The information presented in this section describes lake sediment quality in the context of the water quality of Capitol Lake. Sediment samples were collected from the Middle and North Basins of Capitol Lake by the EIS Project Team in March 2020 and analyzed for multiple chemicals of potential concern. Sediment sampling included collection of surface sediment grab samples to a depth of 4 inches (10 cm), and sediment cores to the proposed initial dredge depths ranging from 4 to 12 feet and including an extra 2 feet into the z layer (the term used for the sediments located below the dredge depth that would become the new surface layer to be colonized by benthic invertebrates when dredging is completed). Sampling methods and results are provided in the *Sediment Quality Discipline Report* (Herrera 2021) and summarized below for chemical concentrations, elutriate metals, and phosphorus fractions.

4.1.2.1 Chemical Concentrations

The sediment chemical concentrations were compared to Washington State Sediment Management Standards (SMS) (WAC 173-204) for protection of benthic communities in freshwaters. SMS criteria include a sediment cleanup objective (SCO), which is equivalent to the sediment quality standard (SQS), and a cleanup screening level (CSL) for various chemicals. Sediment chemical concentrations at or below the SCO/SQS are predicted to have no adverse effects on the benthic community. Sediment chemical concentrations above the SCO/SQS and below the CSL are expected to have minor adverse effects on the benthic community, while sediment chemical concentrations above the CSL are expected to have significant effects on the benthic community.

Sediment quality was good with low chemical concentrations in all three layers of both sampled lake basins. Total sulfide was the only chemical found to exceed the CSL and expected to have minor adverse effects on the benthic community in the near surface and dredge layers, but not below the dredge layer where organic matter content is much lower. Sulfide is common in lake sediments due to microbial decay of natural organic matter present in algae and aquatic plants. No metals or organic chemicals exceeded SMS criteria except for nickel, which was less than the CSL and less than the average concentration in Washington soils (Herrera 2021).

4.1.2.2 Elutriate Metals

In addition to evaluating sediment chemical concentrations, elutriate tests were performed to evaluate the potential for the release of chemicals into the water during sediment dredging and construction of the habitat areas. (Sampling and testing methods and more detail on findings are provided in the *Sediment Quality Discipline Report* [Herrera 2021].) Elutriate tests measure the effects of suspending sediments in water on chemical concentrations in the water. The elutriate tests followed the synthetic precipitation leaching procedure (SPLP), which extracts 5% of sediment (1 part solids to 20 parts water) at an acidic pH of 5.0 with constant agitation for 18 hours, which is a lower pH and longer duration than would be expected during dredging. The elutriate was filtered, the filtered elutriate and water portions of the samples were analyzed separately for total dissolved metals, and the volume-weighted average concentrations for the solid and liquid phases were reported. The SPLP results are presented in the

Sediment Quality Discipline Report (Herrera 2021) and summarized in Table 4.8 with comparison to the aquatic life freshwater acute criterion of the Washington State Surface Water Quality Standards (WAC 173-201A).

Table 4.8 Sediment Elutriate Metals Analysis Average Concentrations for Capitol Lake.

	Aquatic Life Freshwater Acute Criterion	Middle Basin (µg/L)			North Basin (µg/L)		
		Surface Layer	Dredge Layer	Z Layer	Surface Layer	Dredge Layer	Z Layer
Arsenic	360	<10	<10	<10	<10	<10	<10
Cadmium	1.6	<10	<10	<10	<10	<10	<10
Chromium	285	<10	<10	<10	<10	<10	<10
Copper	80	3 J	6 J	5 J	12	19 J	9 J
Lead	2.7	**8 J**	**11 J**	**17**	**12**	**13 J**	**16**
Mercury	2.1	<1	<1	<1	<1	<1	<1
Nickel	720	3 J	4 J	5 J	4 J	4 J	5 J
Selenium	20	<20	<20	6	<20	<20	<20
Silver	0.9	<20	<20	**1.0 J**	<20	<20	0.8 J
Zinc	58	<20	<20	<20	<20	<20	<20

Bold values exceed Aquatic Life Freshwater Acute Criterion (WAC 173-201A).
J = Average value based on one or more estimated values below the detection limit

Metals were either not detected or detected at low concentrations in the sediment elutriate samples. The freshwater acute criterion for lead (2.7 µg/L for dissolved lead based on a hardness of 45 mg/L) was exceeded in all samples. Dissolved lead concentrations in the dredge layer elutriate samples (11 and 13 µg/L) were four to five times the acute criterion (see Table 4.8). However, much lower dissolved lead concentrations would be expected during sediment dredging because: 1) the lake pH would be much higher than the 5.0 used for the test and lead solubility decreases with increasing pH in low alkalinity waters such as those in Capitol Lake, and 2) the period of sediment-water mixing during dredging would be much shorter than the 18 hours of constant agitation applied to the elutriate test. These results indicate that it is possible the acute criterion for lead would be temporarily and locally exceeded by minor amounts during the placement of dredged sediments in the habitat areas within Capitol Lake.

Although silver was not detected in the dredge layer samples, the detection limit for those samples (20 ug/L) exceeded the acute criterion (0.9 ug/L) (see Table 4.8). A lower detection limit was achieved for elutriate tests of sediments collected below the dredge layer (in the z-layer) where silver concentrations in the elutriate samples were near the acute criterion at 0.8 ug/L for the North Basin and 1.0 ug/L for the Middle Basin. Given the differences in pH and mixing between the elutriate tests and dredging, it is not expected that acute criterion for silver would be temporarily exceeded during the placement of dredged sediments in the habitat areas within Capitol Lake.

4.1.2.3 Sediment Phosphorus Fractions

For the analysis of sediment phosphorus fractions for each sampled lake basin, the separate samples collected from the surface and z layer were each composited into one sample (one composite sample for each layer). The results are presented with solids analysis results in Table 4.9. Total phosphorus concentrations in surface sediment samples were much higher in the North Basin (1,710 mg/kg) than the Middle Basin (1,035 mg/kg), and much higher than those observed in the z layer samples (less than 600 mg/kg in both basins). In addition, the bioavailable fraction (sum of loosely bound, iron bound, and biogenic phosphorus fractions) in surface sediment samples was slightly higher for the North Basin (34%) than the Middle Basin (27%), and much higher than those observed in the z layer samples (less than 20%).

The differences in sediment phosphorus concentrations appear to be due to differences in the amount of organic matter present in the two basins and two sediment layers. Total volatile solids concentrations in surface sediments were higher in the North Basin (12.5%) than in the Middle Basin (9.0%), and z layer sediments did not exceed 5% in either basin. Thus, amounts of bioavailable phosphorus for potential release and algal uptake in the lake are currently higher in the North Basin than the Middle Basin.

Table 4.9 Sediment Phosphorus Fraction Analysis Results for Capitol Lake.

	Middle Basin		North Basin	
	Surface Layer	Z Layer	Surface Layer	Z Layer
Total solids (percent)	40	64	25	62
Total volatile solids (percent)	9.0	3.1	12.5	5.0
Total phosphorus (mg/kg)	1,035	564	1,710	521
Loosely bound phosphorus (mg/kg)	<2	<2	<2	11
Iron bound phosphorus (mg/kg)	139	61	208	35
Aluminum bound phosphorus (mg/kg)	353	86	646	72
Calcium bound phosphorus (mg/kg)	249	276	300	289
Organic phosphorus (mg/kg)	293	142	557	114
Biogenic phosphorus (mg/kg)	136	42	378	24
Bioavailable fraction (percent)	27%	19%	34%	14%

4.1.3 Water and Phosphorus Budgets

Water and TP budgets were developed to quantify sources of TP to the lake. The budgets were developed using data from water years 2008–2012 as this was the most recent 5-year period containing data for all of the key sources (e.g., both rivers and lake). Both budgets were formulated in accordance with the methods described in Appendix A. There were some modifications to the methods used, which are described in an addendum to Appendix A.

The results of both the water and TP budgets are summarized in Table 4.10. The annual and monthly variability, in millions of cubic meters for water and in kilograms for TP, are also displayed in Figures 4.8 and 4.9. As shown in Table 4.10, there were calculated inputs from sources such as precipitation, stormwater, and groundwater; together, they would have accounted for approximately 1% of the water volume on both an annual and summer average. Those same sources would have accounted for approximately 5% of the summer TP input. Internal loading of phosphorus (derived from release from the sediments) was not calculated or accounted for as part of the phosphorus budget. In many lakes this is a significant source of summer TP loading (Nürnberg and LaZerte 2016), but in Capitol Lake the high DO and relatively low phosphorus concentrations measured in the bottom waters indicate that loading from sediments was not significant. TP discharged over the dam represents 79% of the TP loss during summer, leaving 21% as a residual. A positive residual is an indication that there is net loss of phosphorus, which occurs primarily through sedimentation. A negative residual is an indication of internal sources of loading such as through release from sediments or aquatic plant and algae decay. Sedimentation appears to be largely a function of the initial load of phosphorus generated from the Deschutes.

Table 4.10 Summary of Hydrologic and Phosphorus Budgets Results Using Data from 2008 Through 2012.

	Hydrologic Budget				Phosphorus Budget	
Source	Annual Average (m3)	Annual Average Percent	Summer Average (m3)	Summer Average (percent)	Summer Average (kg)	Summer Average (percent)
Deschutes River	375,249,359	89%	94,765,49	87%	4,019	86%
Percival Creek	43,019,991	10%	12,991,747	12%	442	10%
Precipitation	1,372,345	0%	362,292	0%	9	0%
Stormwater	1,418,419	0%	374,455	0%	82	2%
Groundwater	994,807	0%	298,443	0%	96	2%
Total Input	422,722,348	100%	108,792,431	100%	4,648	100%
Storage Change	0	–	-127,947	–	10	–
Evaporation	-332,574	0%	-196,343	0%	–	–
Tide Gate Outlet	-421,722,348	100%	-108,724,035	100%	-3,660	79%
Residual (net sedimentation)	–	–	–	–	-978	21%

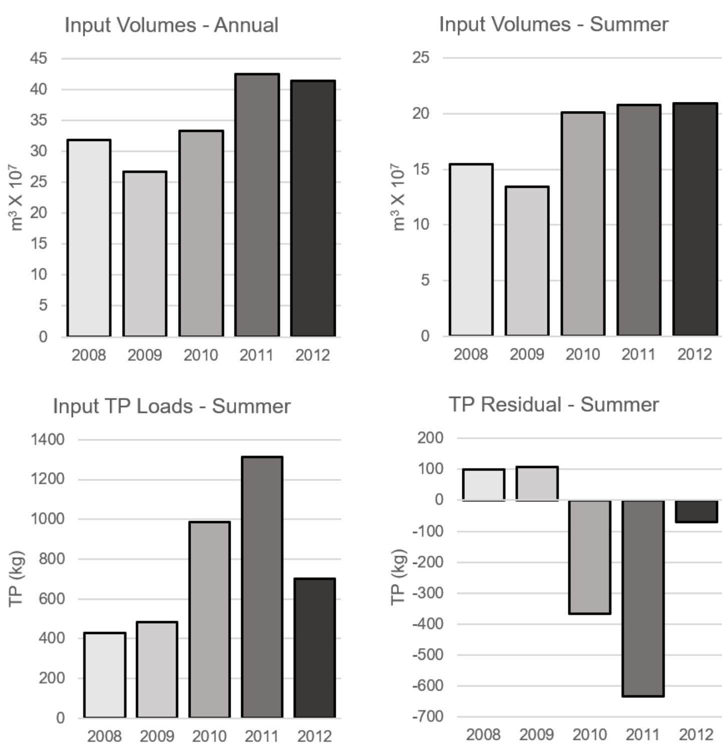

Figure 4.8 Bar Plots of the Annual and Summer Average Input Volumes and TP Loads and Residual TP Load Calculated from the Hydrologic and Phosphorus Budgets by Year.

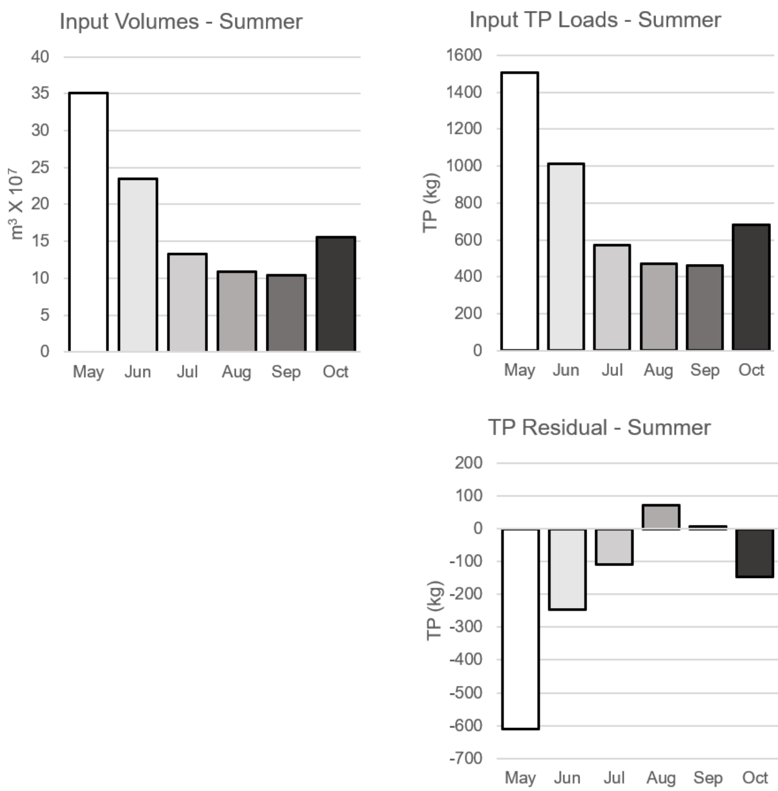

Figure 4.9 Bar Plots of the Average Input Volume, TP Load, and Residual TP Load Calculated from the Hydrologic and Phosphorus Budgets for Summer Months.

There was a substantial amount of variability that is not captured in the 5-year average values shown in Table 4.10 that are displayed in Figures 4.8 and 4.9. Annually (Figure 4.8), the differences between years were a function of Deschutes inflow. During 2008 and 2009, Deschutes input and TP load were relatively low on an annual and summer basis. This led to positive residuals in summer due to minimal sedimentation. The years with the higher TP load had the largest magnitude negative residuals, suggesting net sedimentation.

During summer (Figure 4.9), during the period of lowest flows and therefore TP loads (August and September), the calculated residual was lowest and calculated as both positive and negative values. These relationships with flows and the residual suggest that there were likely relatively constant inputs of TP to the system that were not specifically represented in the TP budget. These sources may include internal loading, macrophyte decay, and waterfowl excretion. Similar results were attained in previous budgets developed for the lake (Entranco 1984). These more recent budgets support the notion that the Deschutes River strongly influences Capitol Lake physically and ecologically.

4.1.4 Summary of Modeling Studies

There have been numerous modeling studies of the Deschutes River system over the past 10 to 15 years. Although they have primarily been focused on the river and its watershed, each has predictions and assumptions that are applicable to Capitol Lake and to Budd Inlet. The findings and predictions related to both Capitol Lake and Budd Inlet from the key reports are summarized here and discussed further in Section 4.2. A TMDL is currently being prepared for Budd Inlet that will address loadings and allocations associated with Capitol Lake and will likely supersede some of the findings from the studies.

These modeling studies are focused on understanding the relative contributions of anthropogenic sources to the Deschutes River, Capitol Lake, and Budd Inlet, so that those human-caused impacts can potentially be regulated. That is a different objective and focus than this analysis, which evaluates changes to water quality as a result of the long-term management alternatives, reflective of both naturally occurring conditions and human-caused impacts. However, despite the different objectives, the modeling studies still provide important information for this water quality evaluation.

4.1.4.1 Deschutes River TMDL-Water Quality Findings

In 2012, Ecology submitted the "Water Quality Study Findings" report (Ecology 2012). The primary goal of the study was to provide the technical basis to support development of the Deschutes River TMDL. The water quality variables addressed by the TMDL include FC bacteria, temperature, DO, pH, and fine sediment. The study used historical data, as well as supplemental data collected from July 2003 to December 2004, to develop a computer model of the system.

The supplemental data collected represents a comprehensive data set for some of the analytes such as TOC, BOD, and DIN that are key to the modeling predictions. As documented in the study, an herbicide treatment was performed in the summer of 2004 to eliminate Eurasian watermilfoil. This resulted in immediate die off of a large stand of the milfoil as well as other aquatic plants. The resultant decomposition would have increased TOC and nutrients and produced immediate algae growth, as was noted by the researchers. This affected nutrient and TOC concentrations throughout the summer. As documented in the same study, the aquatic plant biomass grew back entirely over the summer and therefore was present to decompose in the fall and again result in TOC release from the lake. Thus, the magnitude and seasonal relationships for nutrient and TOC discharges to Budd Inlet in 2004 would not have been typical.

This 2012 study served as a precursor to future studies for this system because it calibrated and validated the QUAL2kw model for the mainstream Deschutes River as well as a GEMSS model applied to Capitol Lake. Although the focus of the TMDL was the Deschutes River, Capitol Lake and Budd Inlet were also modeled under current conditions and with removal of the dam. The calibration process for water quality results in Capitol Lake and Budd Inlet are both detailed in the study.

Conclusions from the modeling in relation to pollutant loads generated from the Deschutes watershed were that the combined effects of nonpoint and point sources currently exceed the pollutant loading capacity of Budd Inlet and Capitol Lake for nutrients, and pollutant load reductions are required to meet water quality standards for DO. The report also concluded that with continued operation of the 5th Avenue Dam, less of Budd Inlet will meet water quality standards under critical conditions, and that existing nonpoint sources exceed the loading capacity of Capitol Lake. Model results predicted that, "If the lake were to revert to an estuary, a smaller portion of Budd Inlet would violate standards for DO, and the geographic area that is currently Capitol Lake would meet marine water quality standards for

DO under all nutrient loading alternatives" (Ecology 2012). (It is assumed that the water quality standards Ecology is referring to are those associated with allowed human depletion of DO, since their graphics indicate numeric standards will not be consistently met in all areas.)

4.1.4.2 Deschutes River TMDL

In 2015 Ecology submitted the "Deschutes River, Percival Creek, and Budd Inlet Tributaries TMDL" (Ecology 2015a). The parameters assessed in the TMDL included fine sediment, bacteria, DO, pH, and temperature. In 2018, the USEPA disapproved some portions of the TMDL and released a revised version in 2020 (USEPA 2020). USEPA (2020) is the source of information provided in this section unless otherwise indicated.

For this assessment the TMDL results are primarily of interest because of what the results signify in terms of characterizing the quality of water entering the lake. Additionally, the TMDL aids in identifying upstream sources of pollutants that need to be controlled to improve water quality downstream in Capitol Lake and Budd Inlet. The TMDL set allocation targets for TN and TP as a means of improving DO. The TMDL target concentrations for TN and TP for the Deschutes River and Percival Creek are listed in Table 4.11.

To put the TP target concentration into perspective in terms of its potential impact to Capitol Lake, it was used in the phosphorus budget prepared for this discipline study as described previously (Section 4.1.3). The Deschutes River and Percival Creek currently comprise 86% and 9% of the summer TP load to Capitol Lake, respectively. By replacing the existing concentrations of TP in these streams with the target concentrations recommended by the TMDL, the summer load from these sources would decrease by over 30%. If achieved, this decrease is expected to result in significant changes in water quality in the lake. Limited data are available for comparing the TN target, but the Deschutes River had a summer 2019 average of 0.784 mg/L, which is very near the target set by the TMDL (0.763 mg/L). Implementation of the TMDL is predicted to contribute to the continuation of declines in phosphorus in the lake and an improvement in lake water quality conditions in the future.

Table 4.11 Summary of TMDL Target Concentrations for Average TP and TN (USEPA 2020).

Impaired Waterbody	Target TP (mg/L)	Target TN (mg/L)
Deschutes River (Upstream of Offutt Lake)	0.0060	0.175
Deschutes River (Downstream of Offutt Lake)	0.0190	0.763
Percival Creek	0.0195	0.340
Black Lake Ditch	0.0195	0.340

4.1.4.3 Deschutes River TMDL Supplemental Scenarios

In Ecology (2015b), additional modeling using the model from Ecology (2012) was completed in order to evaluate different management scenarios that had been identified and prioritized with stakeholders as potential management actions. Fifteen different scenarios were evaluated for Budd Inlet that ranged from removing wastewater treatment plant (WWTP) sources to removing the 5th Avenue Dam. Additionally, five scenarios for management of the lake included such things as alum treatments to control phosphorus or reducing Deschutes River inflow temperature. All of the scenarios relied upon establishing a "natural" condition as a baseline for comparing management scenarios. The "natural" condition was defined by assuming nutrient concentrations and loadings from the rivers, tributaries, and Puget Sound are at background (pre-development) levels and that WWTP discharges and other human-caused pollutant sources such as stormwater are at natural background river concentrations. Lastly the "natural" condition was defined by assuming that there was no dam at 5th Avenue. The model focused on nitrogen, because it typically drives algae production in marine waters, and algae production and decomposition in Budd Inlet is believed to be the major driver of DO problems in Budd Inlet. The model also focused on TOC, as an indicator of organic matter that, when decomposed, contributes to DO depletion.

The scenario of most interest to this discipline study was removal of the 5th Avenue Dam. The model predicted "widespread and continuous depletion of around 1 mg/L in the bottom layer of the water column throughout Inner Budd Inlet south of Priest Point for extended periods during July–September" due to the existing dam (Ecology 2015b). This depletion of DO caused by the dam was attributed to a combination of factors (Ecology 2015b):

- The dam creates a pulsed flow that alters circulation in southern Budd Inlet
- The dam and lake alter concentrations and loads of carbon
- The dam and lake alter concentrations and loads of nitrogen. The assimilation of inorganic nitrogen by freshwater plants (e.g., phytoplankton) in the lake with resultant production of organic carbon alters discharges to Budd Inlet

The model predicts that much of the DIN is converted to organic nitrogen in plants and algae as the water moves through Capitol Lake. The model, which was based on 1997 data and conditions, predicts TOC and DIN concentrations in the lake, estuary, and river. Based on review of the model output as shown in Figure 4-14, the TOC was higher with the dam in place than without the dam, likely due to predicted growth of algae and aquatic macrophytes in the lake. Based on Figure 4-14, Ecology estimated that concentrations would be approximately 2 mg/L without the dam as compared to approximately 5 mg/L with the dam. (These estimated concentrations appear to represent an approximation of average conditions during the summer months.) Conversely, the model predicted higher loads of DIN to Budd Inlet during summer months without the dam (Section 4.2.4). The model predictions for the DIN load to Capitol Lake and impacts to Budd Inlet are supported by field data. Figure 4.5 shows concentrations of TN and DIN in the river and lake as measured in 2004. Generally, the concentrations of nitrogen are higher in the river than in the lake. Similarly, in 2019 (Table 4.7), the mean TN concentration in the lake was only 62% of what was measured in the river. Field data and model results both support the conclusion that Capitol Lake decreases the TN and DIN load to Budd Inlet during the summer and therefore that removal of the dam will increase the TN and DIN load to Budd Inlet. (Table 4.7 also shows DIN and TN for comparison). Increased DIN load will supply additional nutrients for algal production in Budd Inlet.

4.2 BUDD INLET

4.2.1 General Description

The hydrodynamics of Budd Inlet are dominated by tides but are also influenced by inflow from the Deschutes River/Capitol Lake (LOTT 1998). Seventy-five percent of the water in Budd Inlet originates from Puget Sound, and the remaining 25% is from freshwater sources. The Inlet has a relatively short residence time ranging from 8–12 days. The rate of discharge over the 5th Avenue Dam is highly variable and depends on Deschutes River discharge. On some days, no water is released and on other days high volumes of water are released for several hours. The combination of tides and Capitol Lake inflow support a counterclockwise circulation pattern within Budd Inlet.

Budd Inlet circulation and water quality have been altered due to filling of much of the historical estuary (the Port peninsula and much of downtown Olympia is part of the historical estuary), the 5th Avenue Dam, Puget Sound conditions, point and nonpoint sources of pollution, and watershed modifications. Studies over the past 20 years or more have focused on the relative importance of many of these factors and how they influence the low DO problems in much of Budd Inlet.

4.2.2 Assessment of Existing Water Quality

4.2.2.1 Assessment of Water Quality Standards

The current conditions of Budd Inlet were evaluated using data collected from Ecology's Marine Waters Monitoring program at two stations in Budd Inlet: BUD005 (outer inlet) and BUD002 (inner inlet) (Figure 3.1).

Budd Inlet is divided into two water quality categories for protection of aquatic life. Inner Budd Inlet (south of Priest Point) is categorized as "Good Quality" whereas waters north of Priest Point are categorized as "Excellent Quality." These categories are associated with different water quality criteria (Table 2.2). For DO there are two parts to the standard; the first is a 1-day minimum DO standard that applies to most marine waters. However, the developers of the state standards recognized that many marine waters, including the long narrow inlets that comprise much of South Puget Sound, have naturally low DO concentrations that are all below the criteria. For these areas, a second part to the standard was developed to limit the amount of decrease in DO that could be caused by human activity. Both parts of Budd Inlet are limited to a human caused DO depletion of no more than 0.2 mg/L.

For consistency with the evaluation of existing conditions presented for Capitol Lake (Section 4.1), water quality characteristics from the same period (May–October from 2010–2014) were used for Budd Inlet (Table 4.12). Additionally, summer is typically when temperature, DO, and pH are the worst making it an important period to evaluate. For this date range, only data collected in 2014 were available for BUD002.

Both stations exceeded the water quality standards for temperature and DO and the Outer Budd Inlet site (BUD005) also exceeded the pH standard (Table 4.12). Median and minimum surface DO concentrations in West Bay (BUD002) were more than 3 mg/L lower than in the outer inlet (BUD005). DO problems normally occur late summer to early fall at both stations (Figures 4.10 and 4.11). There are no TDG standards for marine waters but as shown, TDG was also very high in the Inlet during summer (as was also documented for the lake), this and elevated pH, indicate the influence of increased algae growth.

Figures 4.10 and 4.11 provide perspective on the spatial and temporal extent of DO problems. The figures display DO concentrations as measured from the top of the water column to the bottom. As shown, the range in DO concentrations at BUD005 is very wide during the months of May through October. There appears to be plentiful DO in the upper portions of the water column during those months but in the lower water column concentrations can be well below the standard of 6 mg/L from July and lasting through November (Figure 4.10). At the inner station (BUD002) (Figure 4.11), DO concentrations do not range as widely (likely due to the shallower conditions and greater influence of the river). The period when DO in the bottom waters at station BUD002 does not meet DO standards appears to be of shorter, but this is primarily a function of the standard being set lower in this part of the Inlet. There are times at this station (i.e., September of 2014) when there appears to have been no place within the water column where the DO standard was met. There would have been very limited habitat available for cold water fish at that time.

Table 4.12 Comparison of Budd Inlet Water Quality with Applicable Standards (May–October).

Station	Parameter	Mean	Median	Min	Max	Standard[b]
BUD002 (2014)	Temp. (°C)	13.97	13.47	10.94	**19.64**	19
	Top DO (mg/L)[a]	7.21	6.10	**1.97**	13.54	5.0
	Bot. DO (mg/L)[a]	6.55	5.82	**3.05**	10.66	5.0
	TDG (% sat)[a]	69.70	59.50	19.65	125.54	NA[c]
	TDG (% sat)[a]	62.30	55.97	30.38	97.16	NA[c]
	pH	7.55	7.53	7.21	8.04	7.0–8.5
BUD005 (2010–2014)	Temp. (°C)	13.37	13.56	9.00	**19.36**	16
	Top DO (mg/L)[a]	10.23	9.95	**5.10**	18.08	6.0
	Bot. DO (mg/L)[a]	7.49	6.99	**4.83**	12.80	6.0
	TDG (% sat)[a]	98.02	92.15	50.87	183.35	NA[c]
	TDG (% sat)[a]	70.21	67.41	47.40	113.58	NA[c]
	pH	7.83	7.82	7.14	**8.87**	7.0–8.5

Bold and shaded values indicate excursions from the standard or action level.

a Top: 0.0–6.0 m; Bot: 6.5–12 m

b WAC 173-201A-210 for "Excellent" and "Good" water quality criteria for BUD005 and BUD002, respectively.

c There are no marine standards for TDG.

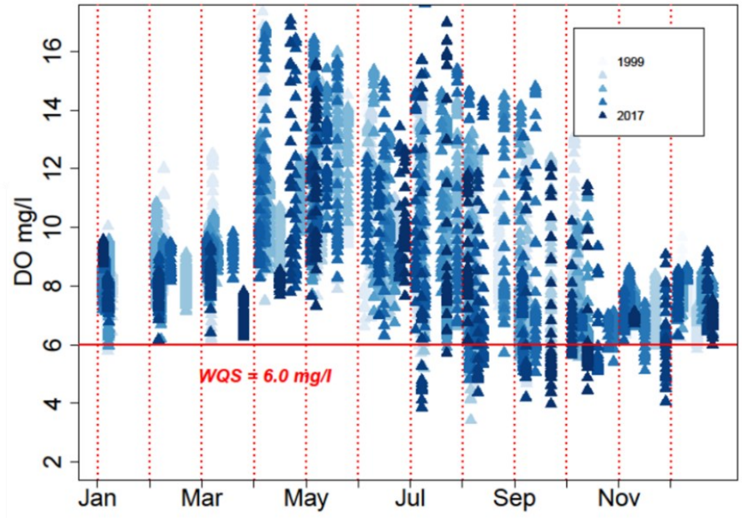

Figure 4.10 DO Concentrations from select years between 1999–2017, at BUD005. Red Line Indicates the 6.0 mg/L Water Quality Criteria for Outer Budd Inlet (Source: Ahmed et al. 2018).

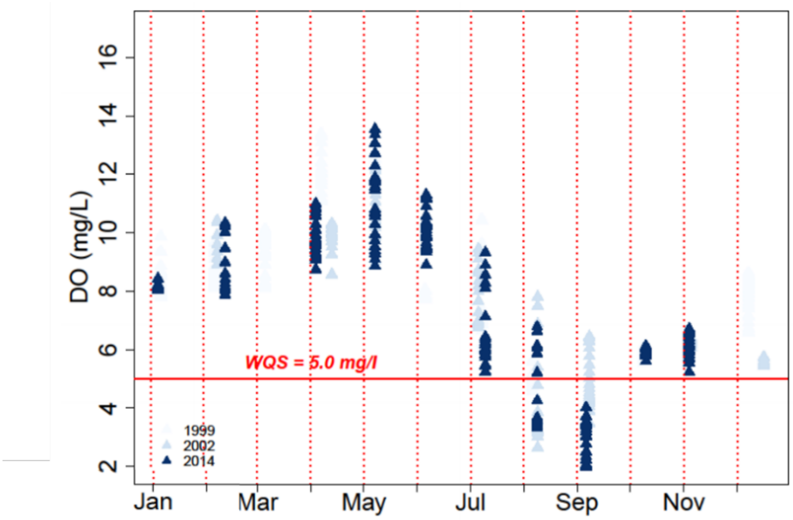

Figure 4.11 DO Concentrations from 1999, 2002, and 2014 at BUD002. Red Line Indicates the 5.0 mg/L Water Quality Criteria for Inner Budd Inlet (Source: Ahmed et al. 2018).

Nutrient and chlorophyll data from Ecology's ambient monitoring data for the Budd Inlet sites are summarized in Table 4.13. The two stations have similar nutrient concentrations; and the concentrations do not vary substantially between depths, indicating well mixed conditions. Chlorophyll concentrations appear to be higher at the outer station (BUD005) based on median and mean values, and the outer station experiences substantially higher maximum concentrations.

Table 4.13 Comparison of Nutrient and Chlorophyll Concentrations from Different Depths at the Two Budd Inlet Stations (May–October).

Station	Parameter	Mean	Median	Min	Max
BUD002 (2014)	0 m PO_4 – P(mg/L)	0.08	0.08	0.07	0.07
	10 m PO_4 – P (mg/L)	0.08	0.08	0.06	0.07
	0 m NO_3 – N (mg/L)	0.17	0.14	0.00	0.02
	10 m NO_3 – N (mg/L)	0.17	0.16	0.00	0.03
	0 m Chl. (µg/L)	13.07	12.31	9.67	17.24
	10 m Chl. (µg/L)	12.55	11.33	3.64	23.50
BUD005 (2010–2014)	0 m PO_4 – P (mg/L)	0.06	0.06	0.00	0.05
	10 m PO_4 – P (mg/L)	0.07	0.08	0.04	0.06
	0 m NO_3 – N (mg/L)	0.18	0.16	0.00	0.01
	10 m NO_3 – N (mg/L)	0.22	0.21	0.00	0.07
	0 m Chl. (µg/L)	17.66	15.09	1.54	49.35
	10 m Chl. (µg/L)	17.90	11.85	2.55	62.76

4.2.2.2 Comparison to other South Puget Sound Inlets

Figure 4.12 provides a comparison of Budd Inlet to other inlets and embayments in Puget Sound (Ecology 2019b) as predicted by Ecology's Salish Sea model. The figure shows the predicted number of days and areas in the Puget Sound that would not meet DO water quality standards during 2006, 2008, and 2014.

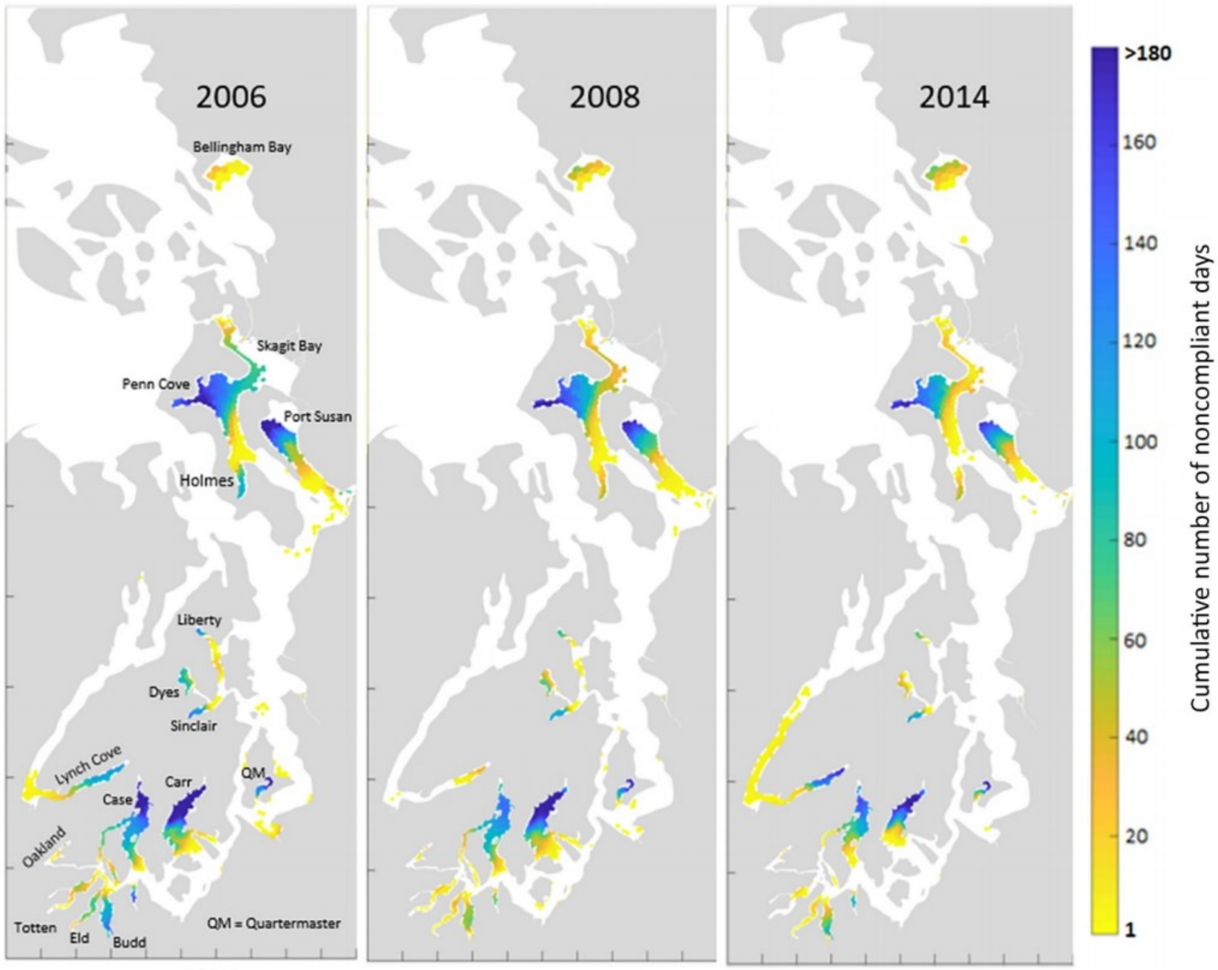

Figure 4.12 Cumulative days where depletion of dissolved oxygen results in noncompliance in 2006 (left), 2008 (middle), and 2014 (right) (Source: Ecology 2019b, Figure 27).

As shown, Budd Inlet, along with most inlets in South Puget Sound, frequently violates the DO standard (Figure 4.12). The model also showed that Budd Inlet had a relatively high maximum daily depletion of DO due to anthropogenic sources (Ecology 2019b) when compared to other South Sound inlets. These model results also indicate that the low DO issues of Budd Inlet are not atypical for Inlets in South Puget Sound and they also emphasize the importance of the Deschutes River in moderating DO conditions in Budd Inlet. (Note that these figures were generated by the Salish Sea Model and the depletions predicted are different than what is predicted by the Budd Inlet model [Ecology 2012 and 2015b]). Ecology considers the Budd Inlet model to be more accurate for predicting conditions in Budd Inlet (Ecology 2014). However, the relationships among inlets are assumed to be similar even if the values shown for Budd Inlet are not directly comparable between the models).

4.2.2.3 Nutrient Loading

Nutrient loading to Budd Inlet was documented in previous studies (LOTT 1998). DIN was specifically analyzed because it fuels algal growth and subsequently results in decreased DO concentrations as the algae die and decompose. Sources of DIN as calculated in the LOTT study are summarized in Table 4.14. Focusing on the summer months, which is the period of concern for DO, the results show that Puget Sound was the largest contributor of DIN to Budd Inlet and that the load from sediments was the next most significant source. These two sources together accounted for 66 to 118% of the summer DIN load to the Inlet (LOTT 1998). The predicted loads from Capitol Lake are slightly higher than those from LOTT (1998), but both were similar in magnitude, and minor sources compared to loads attributed from the Puget Sound and sediments. Both Capitol Lake and LOTT are predicted to have a larger influence in Inner Budd Inlet as would be expected due to their proximal locations.

Table 4.14 Percent of Total DIN Loading to Budd Inlet by Source and Season (reproduced from LOTT 1998).

Source	Whole Inlet		Inner Inlet	
	Winter	**Summer**	**Winter**	**Summer**
Puget Sound	78–83%	60–84%	73–78%	47–82%
Sediments	2–11%	6–34%	0.4–6.0%	0.7–37%
Capitol Lake	7–11%	1–8%	12–17%	3–14%
LOTT	2–5%	1–3%	3–7%	2–8%
Other Inputs	1–2%	1–3%	1–2%	1–5%

Winter: November–January
Summer: July–September

4.2.3 Sediment Quality

The information presented in this section is based on findings of the *Sediment Quality Discipline Report* (Herrera 2021). The sediment quality in Budd Inlet was characterized though the use of data from 2008–2019.

Based on recent studies, sediment chemical concentrations do not exceed Sediment Management Standards (SMS) and Dredged Material Management Program (DMMP) criteria in West Bay except for selected chemicals in some samples collected near stormwater outfalls in marinas and the Port of Olympia along the eastern shoreline of the West Bay. Some exceedances of Sediment Cleanup Objectives (SCOs) for Semi-Volatile Organic Carbons (SVOCs) (acenaphthene, phthalates, benzyl alcohol, and benzoic acid) and mercury were found in recent surface sediment samples collected near stormwater outfalls to West Bay. In general, lower concentrations of SMS parameters were found in the central and southwest areas of West Bay.

The spatially weighted, average dioxins/furans concentration for sediments in West Bay (15 ng/kg) did not exceed regional background (19 ng/kg), but did exceed the DMMP SL for dispersive disposal sites (4 ng/kg) and non-dispersive disposal sites (10 ng/kg). The average carcinogenic PAHs concentration for West Bay (87 ppb) exceeded regional background (78 ppb), indicating potential impacts to ecological and human health.

The benthic invertebrate community in West Bay currently is impacted from the high organic matter content of surface sediments, not the low chemical concentrations (PSP 2020). The average total organic carbon (TOC) concentration in Budd Inlet is 3.7%, which slightly exceeds the typical range of 0.5 to 3.5% for Puget Sound (Ecology 2019a).

4.2.4 Supplemental Modeling Scenarios

The most detailed information on existing conditions in Budd Inlet relevant to the project alternatives is from Ecology (2015b). This report was discussed previously (Section 4.1.4.3) but is expanded here specifically because it relates to the conditions in Budd Inlet. This Ecology model was used to predict current and natural conditions in Budd Inlet (see Section 4.1.4.3 for definition), as well as a wide variety of scenarios to quantify the effect of different anthropogenic sources on DO in Budd Inlet. The results focused largely on predicting the magnitude of human caused DO depletion in comparison to the modeled natural conditions.

The scenarios most relevant to this evaluation modeled the effects of the 5th Avenue Dam. The dam was estimated to cause 66% of the DO depletion in all of Budd Inlet, with the magnitude of the depletion varying based on location (Ecology 2015b). Modeled under current conditions, the worst water quality in Budd Inlet is predicted to occur in East Bay with a predicted DO depletion of up to 3.1 mg/L. Figure 4.13 shows the modeled spatial variability in DO depletion due to both the cumulative anthropogenic effects (a) and solely from the 5th Avenue Dam being in place (b). The DO depletion from the 5th Avenue Dam was attributed to the pulsed releases that alter Budd Inlet circulation and increased TOC load from Capitol Lake.

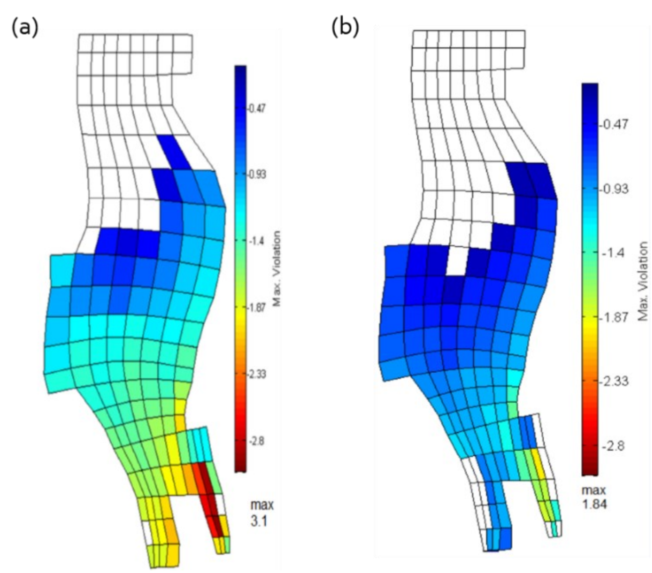

Figure 4.13 Model Predictions of DO Depletion (mg/L) From (a) the Cumulative Anthropogenic Effects and (b) Solely Due to the 5th Avenue Dam (Source: Ecology 2015b, Figures 8 and 9).

The findings by Ecology (2015b) also support those of LOTT (1998), suggesting that Capitol Lake converts much of the DIN load from the Deschutes River into organic nitrogen and TOC. This is exhibited in Figure 4.14, where an inverse relationship is shown between modeled concentrations of TOC and DIN. The TOC concentrations with the dam in place were predicted to be higher when compared to without the dam. The data collected in 2004 and 2019 also supports this prediction (Table 4.7).

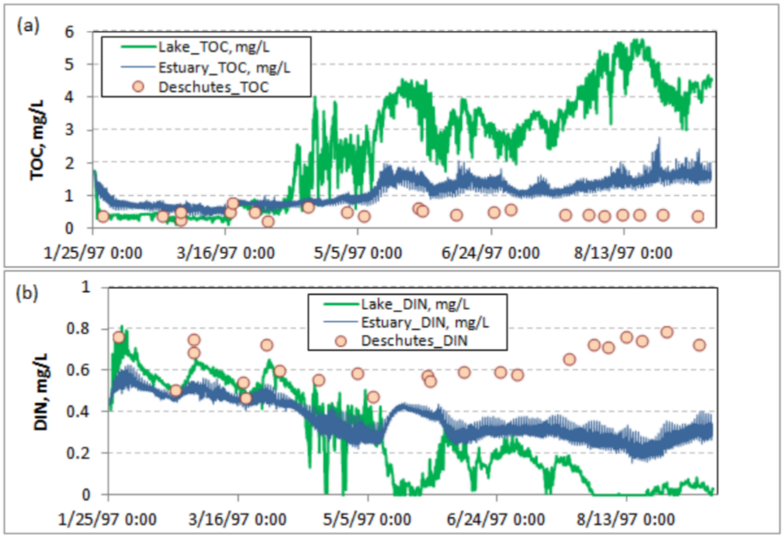

Figure 4.14 Modeled a) Total Organic Carbon (TOC) and b) Dissolved Inorganic Nitrogen (DIN) Concentrations at the Outflow from 5th Avenue Dam with the Dam (i.e., similar to Managed Lake Alternative) and Without the Dam (i.e., Estuary Alternative) Compared with Measured Concentrations in the Deschutes River at E Street (Source: Ecology 2015b, Figure 11).

The extent of the DO depletion allocated to the 5th Avenue Dam varies spatially across Inner Budd Inlet (Figures 4.13 and 4.15). Based on conditions in the bottom waters, DO concentrations in West Bay (BA-2 and BI-4, BI-5, BI-6) were predicted to improve by approximately 1 to 1.5 mg/L (Figure 4.15). The figure also indicates that the numeric DO standard (5 mg/L) would have been met (under 1997 conditions) at these cells in West Bay without the dam, i.e., under the Estuary Alternative. In East Bay (BI-1 and BI-2) the maximum differences attributed to depletion by the dam are predicted to be greater, approximately 1.5 to almost 2 mg/L. Although DO is predicted to improve if the dam is removed, the numeric water quality criteria would still not be met in East Bay (Figure 4.15).

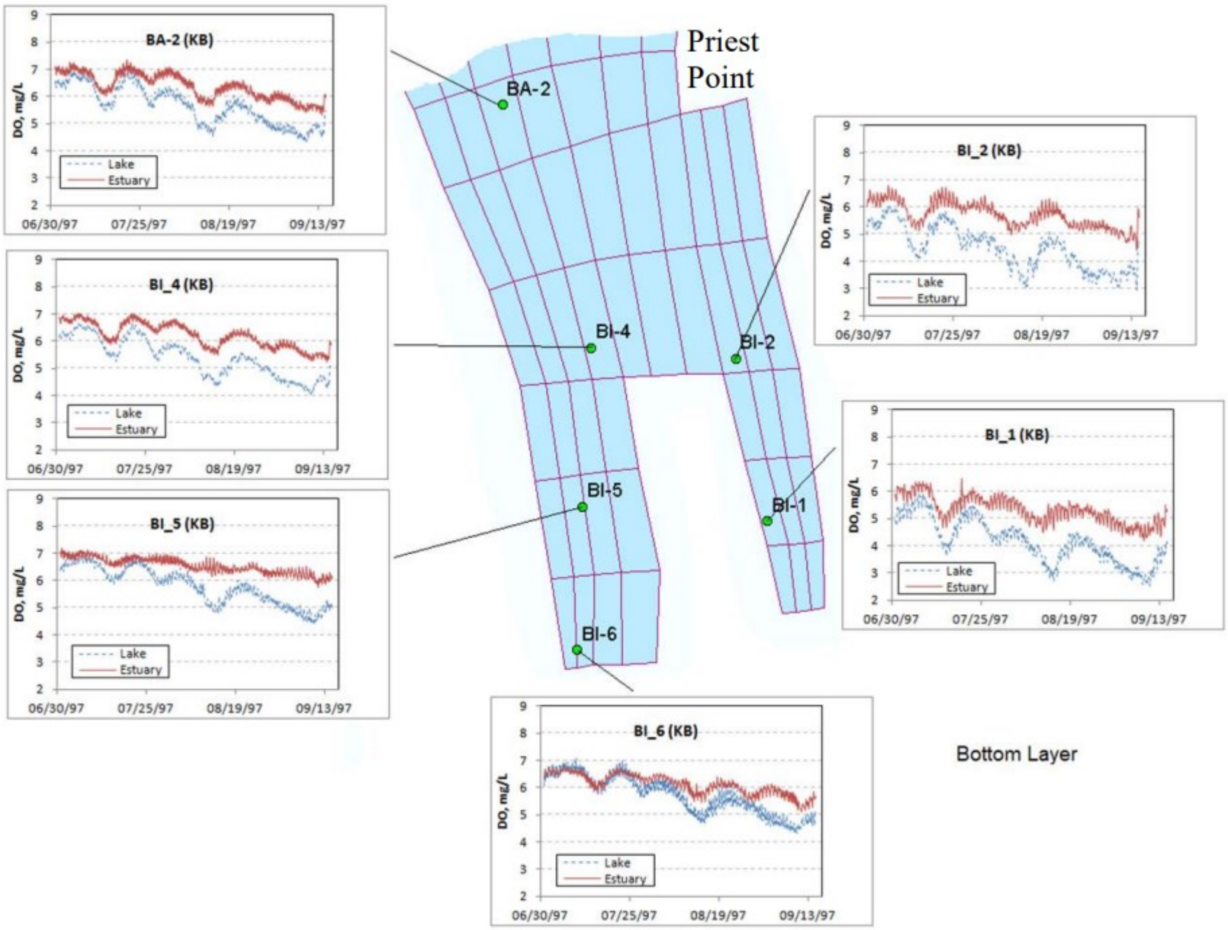

Figure 4.15 Model Predictions of DO in the Bottom Layer at Selected Locations in Budd Inlet with Current Anthropogenic Loading with the 5th Avenue Dam (Blue-Dashed Lines Labeled "Lake") and Without the 5th Avenue Dam (Red Line Labeled "Estuary") (Source: Ecology 2015b, Figure 15).

4.3 SUMMARY

Capitol Lake is a productive (eutrophic) lake that experiences dense aquatic plants and algae blooms, typical of many Puget Sound lowland lakes. Lake conditions are strongly influenced by the large inflow from the Deschutes River, which results in short residence times and a well-mixed system. Monitoring done as part of this study as well as past studies indicates some improving trends in water quality in the river and lake. Capitol Lake does not meet all applicable water quality standards; however, relative to other lakes in the region, Capitol Lake exhibits comparable or better water quality (based on temperature, DO, and chlorophyll levels). Lake TP concentrations are higher than the Action Threshold set by the state for eutrophic lakes, but as indicated by the phosphorus budget, the phosphorus load is primarily driven by input from the Deschutes River. As noted previously, the Action Threshold is higher than the phosphorus concentrations used to define eutrophic lakes.

Budd Inlet is also a productive system that supports extensive algae blooms. DO is routinely below the numeric minimum criteria (primarily in the lower water column) at both the outer and inner Inlet monitoring stations in the summer and early fall (Figures 4.10 and 4.11). To a large extent this is a natural condition that occurs in other inlets and embayments in South Puget Sound. The water quality standards acknowledge that DO concentrations may naturally be low, and in those cases the water quality standards are aimed at controlling only human induced sources of DO depletion. The standards allow for human induced depletion to account for no more than 0.2 mg/L of DO. Ecology modeling (Ecology 2015b) has indicated that human sources of DO depletion in Budd Inlet are responsible for a maximum of 3.1 mg/L depletion (based on daily minimum bottom water concentrations at the critical location in East Bay), and therefore Budd Inlet does not meet the applicable water quality standard.

Recent modeling has indicated that Capitol Lake and the 5th Avenue Dam are the primary cause of human induced depletion of DO in Budd Inlet, and that they may account for up to 1.8 mg/L depletion (based on daily minimum bottom water concentrations at the critical location in East Bay) (Ecology 2015b). The Ecology model attributes DO depletion from the lake as due to altered circulation caused by operations of the 5th Avenue Dam but more so due to altered loading of carbon (i.e., an increased TOC load). Ecology summarizes in reference to Capitol Lake "the production and decomposition of organic carbon is the process that is most responsible for depletion of DO in Budd Inlet" (Ecology 2015b).

Despite having different objectives, it was important for this water quality analysis to consider Ecology's modeling efforts because the modeling considered a variety of complex factors. The Ecology model synthesizes the existing relationship between Capitol Lake and Budd Inlet and provides estimates of the impact of the 5th Avenue Dam or dam removal on DO in Budd Inlet, with particular focus on anthropogenic inputs.

The approach for the water quality analysis in this EIS is to support a comparative evaluation of water quality conditions under the long-term management alternatives. Recent data evaluated within this analysis indicate that water quality conditions may have changed since the modeling effort, and that overall, there is a lack of field data for key parameters affecting modeling results. Consistent with SEPA requirements, when there are data gaps or uncertainties, an analysis should identify a worst-case outcome (WAC 197-11-080). In this case, "worst-case" can mean lower levels of water quality improvement than predicted by other analyses. Therefore, this analysis estimates impacts of the 5th Avenue Dam or improvements from dam removal conservatively relative to modeled results. The following paragraphs provide a summary of some of the findings from the evaluation of the recent field data that contribute to uncertainty.

The monitoring data (and the model) indicate that DIN is higher in the Deschutes River compared to Capitol Lake in the system's current condition. Conversely, the data and model also indicate that TOC is lower in the Deschutes River compared to Capitol Lake (Figure 4.14). This relationship is likely a result of the assimilation of inorganic nitrogen by phytoplankton in Capitol Lake that subsequently increases organic carbon (TOC), which is eventually discharged to Budd Inlet. Therefore, if the dam were removed, the water that enters Budd Inlet would have higher DIN concentrations and lower TOC concentrations due to the decrease in phytoplankton growth in the Capitol Lake Basin. Since the model predicts that overall these two changes will result in an improvement in DO in Budd Inlet, the implication is that the decreased TOC (predicted to occur with dam removal) is more important to DO conditions in Budd Inlet than the increased DIN concentrations. Therefore, a closer examination of the TOC data and modeling results was warranted considering field data.

Under the modeled conditions (Ecology 2015b) it was predicted that without the dam the TOC concentrations at the outflow from Capitol Lake would be substantively lower (2 mg/L) than with the dam (5 mg/L). Yet, field data from 2004 and 2019 both indicate that average TOC concentrations in the outflow are already close to 2 mg/L (Figure 4.7). The average concentration for 2004 was less than 3.0 mg/L, while the average for 2019 was less than 2.6 mg/L; and, in 2019 concentrations were below 2 mg/L until October. Thus, during the 2 recent years for which there are data, the TOC averages were well below the 5 mg/L estimated by Ecology to represent conditions with the dam and closer to the 2 mg/L Ecology estimated for conditions without the dam. This adds uncertainty to the model predictions related to TOC and its impacts. Further, for both years for which there is data, the differences between lake and river concentrations of TOC do not appear to be substantial (Figure 4.7), at least until the late summer or fall die-off of aquatic plants.

Another factor contributing to uncertainty is that data collected from the lake in 2003–2004 that was used to calibrate the model were not reflective of typical lake conditions. As noted by Ecology (Ecology 2012), a lake herbicide treatment to kill aquatic plants produced immediate algae growth in the lake and increased TOC concentrations in the period following the applications. Additionally, the aquatic plant biomass grew back entirely over the summer and therefore was present to decompose in the fall and contribute to another increase in TOC release from the lake (Ecology 2012). Thus, the magnitude and seasonal relationships for nutrient and TOC discharges to Budd Inlet in 2004 would not have been typical.

The TOC data for 2019 also do not indicate that there was a relationship between TOC in the lake and decreased DO in Budd Inlet. TOC concentrations were fairly consistent and low throughout the summer in the lake and then increased in late summer or fall (Figure 4.7). Low DO concentrations in Budd Inlet start in July (Figures 4.10 and 4.11), well before the TOC concentration in the lake increases. Further, the TOC did not exert the impact on DO demand that is predicted by stochiometric relationships.

Overall, the differences between predicted TOC concentrations and measured concentrations, the atypical year that was used to calibrate the model, and the apparent lack of a relationship between the onset of DO problems and changes in TOC, contribute to uncertainty in interpretation of TOC results. This is exacerbated by the general lack of TOC data, i.e., data from just 2 years that were separated by a period of over 10 years and during a time when lake conditions appear to have been changing.

Comprehensive monitoring of the lake was last completed over 15 years ago and there have been significant changes in water quality over the past decades. Ecology (2012) (based on data from 1988 to 2008) indicated there were measurable trends in water quality in the river. The analysis of more recent data (based on 2004 to 2014 data reported in this study) indicates there have been improving trends in both the lake and river during that time. This implies that the water quality conditions may have changed since the modeling effort.

Under SEPA, when there are gaps in relevant information or scientific uncertainty exists, that uncertainty needs to be acknowledged in the EIS and the analysis needs to identify the worst-case outcome. Therefore, to avoid potentially overstating improvements from the dam removal, lower levels of DO improvement were assumed in evaluating impacts in Section 5. This results in an independent synthesis and analysis of existing and newly collected data for this project. The data collected adds to the available information, but is by no means exhaustive.

5 Impacts and Mitigation Measures

5.1 OVERVIEW

This section describes the probable significant impacts or benefits related to water quality conditions from the No Action Alternative (Section 5.2), Managed Lake Alternative (Section 5.4), Estuary Alternative (Section 5.5), and Hybrid Alternative (Section 5.6). Because there are two distinctly different waterbodies that may be impacted by the alternatives, the description of impacts is further divided into those related to the existing Capitol Lake Basin and those within Budd Inlet. This section also identifies mitigation measures that could avoid, minimize, or reduce the identified impact below the level of significance.

As described in previous sections of this document, this water quality impact assessment is focused on impacts to DO (and the parameters that are used to predict DO) because 1) it is important to improving water quality and enhancing habitat which are two of the long-term management goals for the project, 2) this is the parameter that is the focus of Ecology's modeling, and 3) DO is the parameter that provides the most differentiation between alternatives for aquatic habitat (for cold water species). There are other parameters of concern in the project area in terms of water quality standards and human health criteria (for example, both the lake and the inlet are included in Ecology's impaired water list for bacteria and pH), but these are either not impacted by the selection of alternatives or would not have been informative for selecting between alternatives. This focus on DO also addresses SEPA requirements to "emphasize important environmental impacts" (WAC 197-11-030 (2)(b)). As described above, and consistent with SEPA requirements, this analysis ensures that benefits and/or impacts are not overstated.

5.2 NO ACTION ALTERNATIVE

Under the No Action Alternative, Enterprise Services would not implement a long-term management project. Enterprise Services would continue to implement limited nuisance and invasive species management strategies. In the absence of a long-term management project, it is unlikely that Enterprise Services would be able to procure funding and approvals to manage sediment, control aquatic plants, implement water quality protection measures, improve ecological functions, or enhance community use. Based on this, under the No Action Alternative, the lake basin would continue to fill with sediment, developing more wetland type conditions and loss of open water habitat around the perimeter and more riverine conditions along the path of the Deschutes River; submerged aquatic plants would continue to dominate the habitat, but it would slowly transition to emergent wetland type plants. This transition would occur more quickly in the shallow South and Middle Basins than the North Basin as described in the *Wetlands Discipline Report* (ESA 2021). This is expected to occur over a period of decades. Eventually, the lake's capacity to store sediments would be lost and at that time the river's sediment load would pass directly to Budd Inlet; this is not expected to happen within the 30-year planning horizon of this project. The quality of the water entering Budd Inlet would become increasingly more similar to that of the Deschutes River as the lake becomes more river-like: higher DIN, fewer algae, and less variable DO and pH but these changes would be small in comparison to the existing conditions in the inlet.

There would be **no change in impact** on DO and algae concentrations in Budd Inlet since any changes in water quality in the lake basin would be small in comparison to existing conditions in the inlet.

There would be **minor to moderate benefits** on DO and algae concentrations in the lake basin because conditions in the Deschutes may improve through implementation of the TMDL and establishment of wetlands around the lake perimeter may provide further pollutant buffering. The increase in aquatic plants and loss of open water habitat would represent **significant impacts**.

There are long term impacts associated with climate change. Climate change will result in increased water temperature in all three waterbodies described in this assessment: the Deschutes River, Capitol Lake, and Budd Inlet. The increase in temperature is likely to result in increased algae blooms, increased pH, and decreased DO and the attendant impacts on TOC and other nutrient dynamics. All of these changes will equate to changes in habitat conditions, which could favor new or different plant and animal species over those that currently exist, thus resulting in species shifts. The No Action Alternative will not affect the magnitude or extent of these impacts.

In addition to increased water temperatures, peak (flood) flows in the Deschutes River are expected to increase over time, therefore increasing flood impacts. Also, since sediment is transported most in flood events, total sediment delivery could also increase over time, accelerating the time required for the lake to fill in. At the same time summertime low flows will decrease, which could exacerbate the temperature effects described above.

5.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

The action alternatives have in common several adverse and beneficial impacts associated with construction and operation. The extent of these impacts on water quality may vary between alternatives and are addressed under the impacts and mitigation described for each alternative section.

5.3.1 Impacts from Construction

Project construction would last 4 to 8 years, depending on the alternative, and would entail multiple in-water work windows. This construction period for the Hybrid Alternative is the longest at 8 years and the Managed Lake Alternative is the shortest at 4 years. Each action alternative would involve initial dredging, construction of habitat areas in the Middle Basin of Capitol Lake and also in the North Basin under the Estuary and Hybrid Alternatives, and construction of a pedestrian bridge, boardwalks, dock and boat launch for public use. As these actions are planned for each, their respective impacts are discussed below for both Capitol Lake and Budd Inlet.

5.3.1.1 Initial Dredging

Under all action alternatives, hydraulic dredging would be conducted in the Capitol Lake Basin over several successive years during the allowable in-water work period (i.e., from June 1 through August 15 and from November 15 through February 15, equating to 183 days per year). Dredging would occur 12 hours a day, 5 days a week, at a rate of 124 cy/hour, resulting in a dredging rate of 1,500 cy/day. Thus, dredging durations for each alternative would approximately be 232, 351, and 333 work days, for the Managed Lake, Estuary, and Hybrid Alternatives, respectively. Therefore, dredging operations and associated impacts would occur over approximately 1.5 to 2 years for most of the allowable in-water work period. All dredging activities would be regulated under a water quality permit, which would define required Best Management Practices (BMPs), set allowable mixing zones, and set monitoring requirements. For dredging activities in the lake basin, the mixing zone for rivers and streams would apply, which is 300 feet as described in the *Sediment Quality Discipline Report* (Herrera 2021).

For the Managed Lake Alternative, 348,000 cubic yards would be dredged from the entire 127 acres of the North Basin, and all dredged sediments would be placed over approximately 35% of the 147-acre Middle Basin to construct habitat areas.

For the Estuary Alternative, 526,000 cubic yards would be dredged from the main channel, over approximately 30 acres of the North Basin, 30 acres of the Middle Basin, and fewer than 5 acres at the 5th Avenue opening, where the dam is currently in place. All but 3% of the dredged sediments would be used to construct habitat areas covering approximately 30% of both the Middle and North Basins. In addition, shoreline armoring would be placed along approximately 10 acres of the Middle and North Basins to minimize scour along Deschutes Parkway from reintroduced tidal flow. Hydraulic dredging would suspend the lake bottom sediments and the associated nutrients and metals. In addition, considerable amounts of submersed aquatic plants likely would be removed and deposited in the inland disposal cells because dredging would begin on June 1 when aquatic plant biomass is near its annual maximum and covers the lake sediment surface. The suspended sediments/plants would result in temporary and localized increased turbidity, decreased DO (due to increased BOD from suspended and dissolved organic matter), and reintroduction of previously buried nutrients to the waterbody.

Initial dredging for the Hybrid Alternative would be similar to that described for the Estuary Alternative, except less sediment would be dredged from the North Basin (approximately 499,000 cubic yards). Habitat would not be constructed on the eastern shoreline of the North Basin given the construction of a smaller reflecting pool, so approximately 20% of the dredged material would be exported compared to 3% for the Estuary Alternative.

5.3.1.1.1 Budd Inlet

No dredging of Budd Inlet would occur during construction. As described below, impacts to the lake basin from dredging within the lake basin would be less than significant and this would further limit potential impacts to Budd Inlet. However, dredging could the increase the load of nutrients (e.g., DIN) and TOC to the Inlet over the extended dredging period. This increase could result in increased algae growth and oxygen demand in Budd Inlet during construction. These impacts, if they occur, are not expected to be measurable or result in a noticeable change in algae conditions given the existing variability in DO concentrations and the dominant influence of marine water derived nutrients. Therefore, the impact is predicted to be **less than significant**.

Overall, Budd Inlet would experience **less-than-significant impacts** to its water quality due to standard BMPs that would be used during the dredging process in Capitol Lake, including water quality monitoring to ensure that water quality standards are maintained.

5.3.1.1.2 Lake Basin

Hydraulic dredging would suspend the lake bottom sediments and the associated nutrients and metals. In addition, considerable amounts of submersed aquatic plants likely would be removed and deposited in the inland disposal cells because dredging would begin on June 1 when aquatic plant biomass is near its annual maximum and covers the lake sediment surface. The suspended sediments/plants would result in temporary and localized (within the permitted mixing zone) increased turbidity, decreased DO (due to increased BOD from suspended and dissolved organic matter), and reintroduction of previously buried nutrients to the waterbody. Since Capitol Lake is classified as a river the mixing zone boundary that would likely be defined by the permit would be approximately 300 feet from the dredged area, beyond which water quality criteria are not to be exceeded (WAC 173-201A).

Water quality monitoring during sediment dredging and capping in West Bay was performed for an interim action cleanup pilot study for the Port of Olympia (Anchor 2009). The permit for the project required compliance with water quality standards at a mixing zone (compliance) boundary at 150 feet down current from the dredging and capping areas. No confirmed exceedances of turbidity or dissolved oxygen criteria were observed at the 150-foot compliance boundary throughout the dredging project. Initial increases in turbidity were detected inside the compliance boundary and dredging operations were modified such that turbidity decreased at that location from approximately 19 to 11 NTU within 30 minutes. Although this dredging occurred in Budd Inlet rather than Capitol Lake the impacts would be expected to be similar. These observations indicate that any potential impacts from the dredging occurring in Capitol Lake would be localized (i.e., inside the permit-defined compliance boundary) and would decrease quickly after dredging stops.

Concentrations of dissolved nutrients could increase in the lake during placement of dredging materials in the habitat areas. While dissolved nutrient concentrations are not monitored during dredging because there are no nutrient standards, permit limits on dissolved oxygen impacts would indirectly limit the amount of dissolved nutrients produced by dredging. Sediment phosphorus fractionation results show that less than 1% of the sediment phosphorus is in a dissolved state (i.e., less than 2 mg/kg of loosely bound phosphorus compared to over 1,000 mg/kg total phosphorus; see Table 4.9). As discussed in Section 4.1.1.2.2, hydraulic suction dredging of near-shore, PCB-contaminated surface sediments in 2019 did not result in a significant increase of algal biomass even though it resulted in increased lake phosphorus concentrations. These results suggest that dredging would not induce excessive algae growth in the lake.

As indicated by sediment sample elutriate analyses noted in Section 4.1.2.2, sediment suspension may result in temporary water quality impacts due to elevated concentrations of dissolved lead within the mixing zone boundary. Due to the higher pH and lower agitation period expected during dredging compared to the sediment elutriate tests described in Section 4.1.2.2, dredging is not likely to result in significant impact to water quality from dissolved lead. Fish and other wildlife can be expected to avoid the dredging area, which also reduces the potential for impact.

A pilot study of hydraulic dredging impacts in Lake Lawrence in Thurston County was conducted in the 1990s (Hartman 1995). During that study water quality measurements were taken from mid-depth in the water column approximately 5 feet from the cutter head. Measurements were made during dredging and 1 hour after dredging ceased. Turbidity increased from 2.4 to 14 NTU during dredging but decreased to 6 NTU within an hour. TSS increased from 4.6 to 24 mg/L during dredging and decreased to 10 mg/L within an hour. There was no measured impact on DO. It is unknown how long dredging had been ongoing when the samples were collected but operations were described as having been intermittent; therefore, the results likely do not represent worst-case conditions, and there were no observations of the extent of the turbidity plume. While there may be differences in sediment characteristics between Lake Lawrence and Capitol Lake, the primary difference between them is that Lake Lawrence is not influenced by the flow of a large river. Therefore, the extent of any turbidity plume in Capitol Lake would be expected to be longer but also dilution will be higher. Nonetheless, the results suggest that the impacts of dredging and habitat area construction would not visibly persist for more than a few hours after dredging operations have stopped each day and that the plume of impact is likely to be well within the 300 feet that would be allowed by the permit. As described in the previous section, previous dredge monitoring of Budd Inlet (Anchor 2009) provides further evidence of this. BMPs such as a turbidity curtain, could be implemented to further reduce impacts. Although the dredging would last for multiple months over multiple years the impacts are still expected to be temporary and localized from a working day perspective.

Considering the above information, it is expected that due to permit requirements and assuming effective implementation of BMPs, the existing lake basin would experience **less-than-significant impacts** during initial dredging due to the requirement that there is no measurable impact to water quality outside the mixing zone.

5.3.1.2 Constructed Habitat

As previously described in Section 5.3.1.1, the dredged sediments would be used for constructed habitat within the existing lake basin. The sediment-water slurry would be placed within temporary sheet piles installed to contain the slurry and allow the sediment to settle. During the process of sediment placement and when the sheet piles are removed, similar water quality impacts as described for dredging would occur as discussed above, including sediment disruption and resultant increase in turbidity and nutrients. However, the same types of permit requirements and BMPs would also be in place. Therefore, for both Capitol Lake and Budd Inlet there would be **less-than-significant impacts** to water quality due to habitat construction.

5.3.1.3 Construction of the 5th Avenue Pedestrian Bridge, Boardwalks, Dock, and Boat Launch

Construction of the pedestrian bridge, boardwalks, dock and boat launch is proposed for each action alternative to allow the public access to the waterbody. Construction of the pedestrian bridge would take 4 to 5 months to complete and in-water work would occur during the work window. Construction of the pedestrian bridge would occur in stages, so the area of disturbance in any particular year would be limited to the extent that could be completed within the work window or within 1 year. Construction of the boardwalks would occur over an approximately 4- to 6-month duration and would be staged from land or water. The dock and boat launch would be completed within one in-water work window. Construction of these structures would produce minor, temporary and localized increases in turbidity and sedimentation. These types of temporary impacts are reduced through BMPs required by the permits that would be applied. Specific construction materials have not been selected, but if concrete is used it would be expected that it would be pre-cured before placement as required by permit to eliminate concerns about pH. Since any construction would occur using necessary BMPs to reduce erosion and sediment suspension there is expected to be **less-than-significant impacts** to water quality during these construction activities.

5.3.2 Impacts from Operation

Long-term operations-related impacts common to all action alternatives are associated with recurring maintenance dredging to maintain target depths that would occur in the North Basin under the Managed Lake Alternative or in impacted areas of West Bay under the Estuary and Hybrid Alternatives. The risk of water quality degradation from maintenance dredging is considered low because dredged sediment quality in both the lake basins and West Bay is expected to be similar to the high quality sediment (i.e., having concentrations of contaminants below SMS criteria) currently present in Capitol Lake surface sediments (Herrera 2021). Long-term maintenance dredging of a portion of West Bay would be performed for only the Estuary and Hybrid Alternatives and would consist of removing only those sediments in the area of deposition from the Deschutes River and lake basins. Thus, chemical concentrations in those sediments are not likely to significantly change from what is presently in the lake sediments. Dredging BMPs would be implemented to reduce suspended sediments to the immediate dredge area. Considering these factors, maintenance dredging for all action alternatives would have **less-than-significant** impacts on water quality because operations are not anticipated to substantially affect water quality outside the project area.

Another impact associated with long-term operations is that associated with climate change. Climate change will result in increased water temperature in all three waterbodies described in this assessment: the Deschutes River, Capitol Lake, and Budd Inlet. The increase in temperature is likely to result in increased algae blooms, increased pH, and decreased DO and the attendant impacts on TOC and other nutrient dynamics. All of these changes will equate to changes in habitat conditions, which could favor new or different plant and animal species over those that currently exist, thus resulting in species shifts. None of the management alternatives considered will affect the magnitude or extent of these impacts.

In addition to increased water temperatures, peak (flood) flows in the Deschutes River are expected to increase over time. This could increase flood impacts associated with all of the alternatives. Also, since sediment is transported most in flood events, total sediment delivery could also increase over time. At the same time summertime low flows will decrease, which could exacerbate the temperature effects described above.

5.4 MANAGED LAKE ALTERNATIVE

5.4.1 Impacts from Construction

In addition to dredging impacts common to all action alternatives, construction impacts of the Managed Lake Alternative on water quality could be associated with maintenance and repairs to the 5th Avenue Dam. This process would last 6 months and include control house, spillway, and earthen dam repairs.

5.4.1.1 Budd Inlet

Construction activities associated with maintenance and repair of the dam would impact dam operation and water releases that affect the hydrodynamics of Budd Inlet. Subsequently, this could temporarily reduce DO in Budd Inlet if the inflow is reduced. However, repair times would be relatively short (4 weeks) and periodic, with at least one gate open at all times to allow for continual water release. All in-water work on the spillways and stoplogs would occur within the allowable work period and be contained behind a buttressing berm.

The construction could also have adverse impacts on water quality due to increased construction site stormwater runoff during dam repair. Additionally, placement of the buttressing berm armored with aggregate and riprap along the shoreline and in-water on the seaward side of the dam would temporarily increase turbidity when the material is placed. However, both of these impacts are expected to be minor due to required construction site BMPs.

In consideration of the temporary nature of the impacts, construction activities for the 5th Avenue Dam would have **less-than-significant impacts** on Budd Inlet water quality.

5.4.1.2 Lake Basin

Since dam repair activity would occur at the northernmost part of the basin, water movement would be away from the basin, and construction site BMPs would be in place, construction activities would have **less-than-significant impacts** on water quality within the lake basin.

5.4.2 Impacts from Operation

Impacts to water quality under the Managed Lake Alternative would depend upon management techniques implemented as part of this alternative. As the name implies, the Managed Lake Alternative includes an adaptive management approach that would be adopted to integrate water quality, aquatic plant, algae, invasive species, and habitat management. Management objectives for the lake would include:

- Meeting applicable water quality standards
- Controlling nuisance or toxic algae blooms
- Controlling aquatic plants to improve aesthetics, boating access, and reduce fall/winter nutrient release to Budd Inlet
- Controlling invasive species
- Supporting beneficial uses (fish and wildlife habitat, fishing, small non-motorized watercraft, aesthetics, reflecting pool, and other non-contact recreation uses)
- Supporting ongoing work to reduce nutrients and contaminants in as identified in the existing Deschutes River TMDL and future Budd Inlet TMDL
- Enhancing ecological value

An action threshold for the summer mean concentration of total phosphorus would be developed as recommended by the state water quality standards. This threshold would be used to identify when management actions are needed to reduce the frequency and extent of algae blooms causing recreation impacts from algae scum and cyanotoxins, and aquatic life impacts from high pH and dissolved gas in surface waters and low dissolved oxygen in bottom waters. Aquatic plant management objectives would be developed in conjunction with the aquatic invasive species management plan to maintain a healthy aquatic plant community that does not significantly impair recreation or aquatic life uses. The adaptive lake management plan would specify water quality and aquatic plant monitoring procedures for evaluating whether the objectives are being met or need to be modified based on changes in water quality conditions or lake uses.

Feasible water quality and aquatic plant management techniques would be identified and assessed for cost effectiveness and environmental impact. It is anticipated that water quality management needs would be limited, due to:

- The relatively low existing chlorophyll concentrations and DO conditions that support aquatic life and the generally improving water quality trends that have been documented over recent years.

- Reduced sediment phosphorus inputs by removing phosphorus rich surface sediments from the North Basin.
- Reduced watershed phosphorus inputs through implementation of the Deschutes TMDL and stormwater treatment.

Aquatic plant management needs may also be limited initially due to reduced growth as a result of deepening and removing phosphorus rich sediments from the North Basin, although there will be a continued need to manage Eurasian watermilfoil and other noxious weeds.

However, it is likely that the aquatic plant community will fully recover over time and ultimately require continued management. It is also possible that toxic algae blooms develop and restrict boating and other recreational uses of the lake despite efforts to control phosphorus sources. Therefore, the adaptive management plan would identify appropriate management techniques to be further evaluated and implemented if monitoring data show that management objectives are not being met.

Recurring maintenance dredging would also occur in the North Basin; refer to Section 5.3.2 for a description of anticipated impacts of that operational component of the Managed Lake Alternative.

5.4.2.1 Budd Inlet

Water quality conditions in lower Budd Inlet are expected to remain the same as existing conditions. Lake and watershed management activities may improve nutrient loading from these sources to the Inlet, including possible decreases in summer/fall TOC due to aquatic plant management activities. However, the majority of nutrient loading to Budd Inlet is from Puget Sound tidal waters and inlet sediment flux (LOTT 1998). Therefore, the ample nutrient supply would continue to feed algae blooms and drive continued low DO conditions, regardless of inputs from Capitol Lake. Although low DO concentrations are typical of inlets in South Puget Sound, a portion of the DO depletion that Budd Inlet experiences has been attributed to Capitol Lake and the 5th Avenue Dam and this lake/dam derived depletion would continue to occur.

The Managed Lake Alternative would have no change in impact on water quality in Lower Budd Inlet compared to existing conditions based on there being no changes in DO or general condition of habitat for cold water fish and no change in the extent or frequency of algae blooms. Budd Inlet would continue experience low DO concentrations that do not meet DO standards each summer especially in the lower water column.

5.4.2.2 Lake Basin

Active and adaptive management of the lake would likely result in substantive control of aquatic plants that would reduce aquatic plant biomass while continuing to provide habitat for aquatic life and to support recreational use. Establishment of a lake-specific action threshold for phosphorus is expected to promote improvements in treatment of stormwater that enters the lake by the various agencies that are responsible for the stormwater discharges. These activities and continuing work in the Deschutes watershed as a result of the adopted TMDL, would promote a continuing trend in water quality improvement. If the TMDL goal of 0.019 mg/L for TP in the Deschutes River is achieved, this would likely result in a substantive change to mesotrophic status (summer TP less than 0.020 mg/L) and notably decrease algal populations. However, achieving this goal will be difficult and take many years. To be conservative, it has been assumed that this goal would not be achieved within the 30-year planning horizon of this project. Therefore. in the near term, these potential improvements are not expected to result in enough decrease in lake nutrient concentrations to substantively change the trophic state of the lake; for example, it is not expected that it would change from a eutrophic to mesotrophic lake. The lake would continue to be productive (eutrophic) and to support an aquatic plant community, even if that community is largely controlled through aquatic plant management activities, such as mechanized harvesting. The lake would also continue to experience summertime algae blooms. While there could be measurable changes in the algal community and fewer occurrences of blooms due to decreased nutrients, the changes may not be noticeable to the general public. This finding is supported by scenarios modeled by Ecology (2015b). Ecology evaluated potential impacts to lake quality from watershed improvements, dredging to 13 feet, and alum treatments; the modeling indicated that none would have a significant impact on lake water quality.

Initial dredging and deepening of the North Basin is not expected to result in thermal stratification and development of low DO conditions in bottom waters. Most of the removed material would be replaced in the lake basin; therefore, the lake volume would not be significantly affected; and the residence time would continue to be very low.

Creation of habitat area in the Middle Basin would impact hydrodynamics and create localized areas of more stagnant water associated with the change to wetland conditions. This would promote algae and/or more plant growth, thereby causing localized areas of poorer water quality. This is not expected to substantially change the overall condition of the Middle Basin in terms of water quality.

As noted in Section 4.1.2.3, initial dredging of the North Basin would remove aquatic plants and upper layers of sediments that contain substantially higher concentrations of bioavailable phosphorus (phosphorus available for algae and plant growth). Although internal loading of phosphorus from sediments was not identified as a significant contributor to the lake's phosphorus budget on an annual basis (Table 4.10), it may be important seasonally (Figure 4.9). Therefore, the lower bioavailable phosphorus concentrations in the North Basin sediments that would be exposed after dredging may result in lower lake phosphorus concentrations and therefore a reduced nutrient supply for algae blooms.

There would be no change in DO concentrations under the Managed Lake Alternative. The decreased nutrient supply may result in decreased algae blooms, providing **minor-to-moderate benefits** on water quality. Even with implementation of the adaptive management plan, Capitol Lake would continue to experience summertime algae blooms; occasional exceedances of state standards for DO, pH, and temperature; and frequent violations of TDG, as is typical of lake environments.

This alternative will have **substantial benefits** on aquatic plants due to active control of aquatic plant communities and biomass.

Activities to control aquatic plants, algae, or invasive species could have localized, short-term impacts such as increased turbidity or application of approved pesticides that would vary depending upon the activity. However, permit requirements and associated BMPs would be in place to minimize potential impacts. Based on the frequent occurrence of these activities on many other area lakes and the underlying permit requirements, there is expected to be **less-than-significant** impact to water quality from lake management activities.

Maintenance dredging in the North Basin on one occasion at year 20 to maintain target depths would result in localized, short-term increases in turbidity and suspended material associated with both the dredging and the barge dewatering, as generally described in Section 5.3.1 related to dredging impacts during construction. BMPs would be deployed to reduce turbidity and ensure water quality permit compliance. Maintenance dredging would have **less-than-significant impacts** on water quality because those operations are not anticipated to substantially affect water quality outside the immediate project area, and temporary impacts within the project area would be managed using BMPs and other permit conditions.

Table 5.1 provides a summary of the impacts and benefits on the lake and Inlet of the Managed Lake Alternative.

Table 5.1 General Comparison of Key Impacts and Benefits from Operation of the Managed Lake Alternative on Water Quality.

	DO Concentrations	Algae Blooms	Aquatic Plants
Budd Inlet	No change	No change	NA
Lake Basin	No change	Minor to moderate benefit due to sediment removal and improvements in river water quality	Substantial benefit due to active plant control activities.

5.5 ESTUARY ALTERNATIVE

5.5.1 Impacts from Construction

The construction impacts of the Estuary Alternative on water quality are generally described in Section 5.3.1 and primarily involve impacts from sediment dredging and construction activities associated with the constructed habitat and construction of the pedestrian bridge, boardwalk, and boat launch. Construction impacts on water quality specifically associated with the Estuary Alternative primarily relate to the removal of the 5th Avenue Dam as discussed below for Capitol Lake and Budd Inlet.

5.5.1.1 Budd Inlet

Removal of the 5th Avenue Dam would result in altered discharge patterns that would impact the hydrodynamics and water quality of Budd Inlet. Impacts from dam demolition would be contained within a sealed cofferdam to prevent the spread of sediment beyond the mixing zone established by the water quality permit. When the cofferdam is removed and estuary waters first enter the lake, a substantial amount of disturbed sediment, organic matter, and nutrients from the lake basin would be transported into Budd Inlet. Budd Inlet would experience a **significant impact** to water quality during and immediately following dam removal due to increased sediment that may be transported outside the established mixing zone, increased TOC load to Budd Inlet that contributes to oxygen depletion and increased nutrient availability for algal uptake. These impacts would be expected to normalize after disturbed sediments from the lake basin are flushed out of the system, which may take several days to a few weeks.

Other construction activities include a new 5th Avenue Bridge, slope stabilization along Deschutes Parkway, stormwater outfall replacement along the Deschutes Parkway and the Arc of Statehood, and culvert replacement at the Interpretive Center. These construction activities would produce minor, temporary, and localized increases in turbidity and sedimentation. These types of temporary impacts would be reduced by implementing BMPs specified in the water quality permit. If concrete is used, it would be subject to typical permit requirements to eliminate high pH concerns. These disturbances will have less impact than dredging and habitat construction, and because BMPs would be required and monitored during construction activities, impacts on water quality would be **less-than-significant**.

5.5.1.2 Lake Basin

Following the completion of dredging and habitat area construction, the 5th Avenue Dam would be removed, allowing the Capitol Lake Basin to become partially filled with marine water creating an estuary within this basin. Therefore, the applicable water quality criteria for this geographic area would transition to those of Inner Budd Inlet. By design, this process would result in a dramatic shift in water quality as the basin transitions from freshwater to saltwater. The change in hydrodynamics and flushing patterns would result in redistribution and transport of existing sediments, which would increase turbidity in the lake basin until equilibrium is restored. The Capitol Lake Basin would experience **significant impacts** to water quality during this transition period due to dramatic shifts in environmental conditions and a temporary increase in turbidity. This would result in loss of remaining aquatic plants and change in algal communities and possibly transition from a high DO to low DO environment, depending upon timing. These impacts can be expected to last several days to a few weeks.

5.5.2 Impacts from Operation

Impacts or benefits from operations are associated with potential changes in the quality and nature of water in Budd Inlet and the current lake basin, and recurring maintenance dredging of areas in West Bay.

5.5.2.1 Budd Inlet

In terms of water quality, Ecology modeling has indicated that removal of the 5th Avenue Dam would result in improvements in DO concentrations in Budd Inlet, but that water quality standards would still not be met because external sources alone cause a violation of the standards (Ecology 2015b). Some improvement is predicted to occur through much of the lower inlet, primarily improving DO concentrations in bottom waters. The Ecology model (2015b) predicts that under the modeled conditions, DO concentrations could improve by approximately 1 mg/L during the critical late summer period in bottom waters in much of the lower Inlet. Even greater improvements are predicted for the East Bay area. However, the model predicts continued excursions below 5 mg/L in the bottom waters of East Bay (Figure 4.15). Differences between modeled conditions and recent field data were considered along with data trends (as summarized in Section 4). Water quality data indicate that DO changes could range from no improvement to something less than the improvement predicted by the model. However, as indicated in the Ecology reports, the predicted improvements in DO are not based solely on changes in nutrient dynamics but also on changes in flow and circulation patterns in the Inlet as a result of the dam removal. To take this into account, and in consideration of lower TOC concentrations measured in 2019, a DO improvement of half of what the model predicts is assumed for this analysis.

Table 5.2 provides a summary of the DO conditions that were predicted by Ecology's model as well as revised predictions for this water quality analysis based on the lower expected DO improvement assumed for this assessment. The cells selected for comparison represent a range of conditions in Budd Inlet. The cells selected for this comparison are shown on Figure 4.15. The concentration ranges are approximated from Figure 4.15. As shown, using this approach the key cell in East Bay would have DO concentrations of approximately 3.25 to 3.75 mg/L DO under the Estuary Alternative; although this represents an improvement in DO concentrations, this area would continue to experience water quality conditions that are unfavorable to cold water fish. These low DO concentrations naturally occur in tidal estuaries in Puget Sound and such levels are not expected to significantly impact fish (ESA 2021). In the key cell in West Bay, DO concentrations would range from approximately 5 to 5.75 mg/L and represent more favorable habitat conditions. In the cell in the Outer Inlet concentrations would range from approximately 4.75 to 5.5 mg/L DO, and not represent a notable change in water quality conditions when compared to existing conditions. Overall, DO concentrations could improve but not substantially change water quality conditions for cold water fish in the Inlet in relation to DO.

Table 5.2 Predicted Existing DO concentrations and Predicted Concentrations under the Estuary Alternative in the Bottom Waters of Key Cells in Budd Inlet (all concentrations in mg/L DO).

	Cell[a]	Ecology-Predicted Existing Concentration[b]	Ecology-Predicted Concentration under the Estuary Alternative[b]	Estimate of Predicted Improvement Based on Ecology's Model	Adjusted Estimate of Improvement[c]	Adjusted Prediction of Post Project Concentrations[c]
East Bay	BI-1	2.5–3	4–4.5	1.5	0.75	3.25–3.75
West Bay	BI-5	4.5–5	6	1–1.5	0.5–0.75	5–5.75
Outer Inlet	BA-2	4.5–5	5.5	0.5–1	0.25–0.50	4.75–5.5

a The cells are shown on Figure 4.15 and were selected to represent those cells that were predicted to exhibit the greatest improvement from dam removal.

b Predicted concentrations were visually estimated from Figure 4.15 for the critical time period as estimated from Ecology modeling results as reported in Ecology 2015b.

c Conservative estimates assume half of the improvement predicted by Ecology's model.

There would also continue to be a plentiful nutrient supply since the majority of the supply is from inflow from greater Puget Sound and the differences in the key marine nutrient (DIN) generated from the river versus lake is expected to increase. Therefore, Budd Inlet would continue to experience algae blooms of approximately the same extent and frequency as occur under existing conditions.

If the dam is removed, the nature of the sediments in the West Bay area would change; the sediments that accumulate in West Bay after dam removal would be similar to the sediments that currently exist in the lake basin (Herrera 2021). These sediments exert a lower sediment oxygen demand than existing Budd Inlet sediments (Herrera 2021). It is possible this would contribute to localized oxygen improvements in the bottom waters in depositional areas of West Bay but would not influence the majority of Budd Inlet. The improvement in West Bay from this sediment deposition would be offset somewhat by sedimentation of material derived from the marine waters of Budd Inlet.

There may be limited improvements in DO concentrations under the Estuary Alternative, but it is not expected to substantially change conditions for cold water fish in Budd Inlet in relation to DO. Based on this, the Estuary Alternative would have **minor to moderate benefits** on Budd Inlet water quality compared to existing conditions. No change is expected in frequency or extent of algae blooms.

The main impacts to Budd Inlet would be increased sedimentation; without the dam, sediment deposition has been estimated to be three to four times its current rate (Moffatt & Nichol 2021). This would result in an increase in the frequency of sediment dredging from West Bay. Infrequent but routine dredging of sediments from this area already occurs; therefore, this is not a new impact but an increase in the frequency of the impact. Since BMPs as described in Section 5.3.1 would be implemented to reduce offsite transport of sediments during dredging, the water quality impact from maintenance dredging would be localized (within the permit allowed mixing zone) increases in turbidity and suspended materials. The newly deposited sediment would be cleaner than what currently exists in West Bay; therefore, the dredging is not expected to result in release of dioxin and other contaminants as has been a concern for past sediment removal operations.

In terms of maintenance dredging, there is expected to be no change or minor changes in attainment of water quality standards or increase in extent or frequency of algae blooms as a result of increased dredging frequency. Based on this, the Estuary Alternative would result in **less-than-significant** impacts to Budd Inlet water quality from maintenance dredging when compared to existing conditions.

5.5.2.2 Lake Basin

Under the Estuary Alternative the existing lake basin would become part of the estuary, which by design would result in significant changes in the water quality of the lake basin to conditions typical of an estuary. The quality of the water in the lake basin would be an extension of what currently exists in West Bay, but with decreasing DO as the tidal water moves further into the inlet. (This is based on Ecology's modeling (Ecology 2014 and 2019b) and results from other estuaries and embayments in Puget Sound as modeled by Ecology and interpreted from Figure 4.12.) Therefore, the DO concentrations in the lake basin would be lower than West Bay and therefore, would be below the numeric water quality standard. It is important to note that the low DO concentrations predominantly reflect the natural condition of these narrow, shallow, tidal estuaries; and due to the influence of the Deschutes concentrations, would not be as low as experienced in neighboring inlets.

As would be expected in an estuary, the freshwater aquatic plant community that currently exists in the lake basin would be replaced by saltwater tolerant plant species and the habitat areas created as part of the project (ESA 2021).

Compared to existing conditions, where DO conditions are good throughout the lake basin, DO concentrations would be very low during certain periods under the Estuary Alternative and would not meet numeric standards. Again, these low DO concentrations naturally occur in tidal estuaries in Puget Sound. This will result in periods of degraded water quality conditions with respect to DO, but such changes are not expected to significantly impact fish (ESA 2021). Based on this, the Estuary Alternative would have **significant impacts** on water quality in the lake basin compared to existing conditions. Although these impacts are significant compared to existing conditions, they would reflect conditions that are similar to what is experienced in other inlets in South Puget Sound and reflect typical estuary conditions.

State water quality standards recognize that DO concentrations are naturally low in some areas, and when that is the case, the standard reverts to a narrative standard that limits the amount of additional decrease in DO that might be attributed to human activities. There are many factors that Ecology evaluates to determine whether the narrative standard relative to human caused variation is being met. This determination would be made by Ecology.

Algae blooms would continue to occur in the lake basin under this alternative. The algae blooms would be composed of different algal communities than currently exist in the basin. Possible increases in algae blooms that might be expected due to the quality of the incoming tidal waters will be offset by Deschutes River flows; thus, overall algae blooms may be similar to existing conditions in the basin.

Creation of habitat areas in the Middle and South Basins and formation of tideflats would impact hydrodynamics and depending upon the location of the islands with respect to river current and with respect to other islands and/or the shoreline it could create small areas of more stagnant waters that promote algae, thereby causing localized areas of poorer water quality. This is not expected to substantially change the overall condition of the basins.

The Estuary Alternative would provide a **substantial benefit** based on the reduction in aquatic plant communities when compared to existing conditions.

Table 5.3 provides a summary of key water quality impacts and benefits of long-term operations of the Estuary Alternative.

Table 5.3 General Comparison of Key Impacts and Benefits on Water Quality During Operation of the Estuary Alternative.

	DO Concentrations	Algae Blooms	Aquatic Plants
Budd Inlet	Increase: Limited improvement is expected	No change	No change
Lake Basin	Decrease: DO concentrations will reflect estuary conditions	No change	Decrease: aquatic plants would be largely absent

5.6 HYBRID ALTERNATIVE

5.6.1 Impacts from Construction

Construction impacts of the Hybrid Alternative on water quality would generally be as described for the Estuary Alternative in Section 5.5.1. associated with impacts from sediment dredging and construction activities associated with the constructed habitat and construction of the pedestrian bridge, boardwalk, and boat launch. However, this alternative would also include impacts associated with construction of a barrier wall and associated pedestrian concrete walkway on top of the wall that separates the estuary from a smaller reflecting pool.

5.6.1.1 Budd Inlet

Impacts associated with dam removal would be the same as described under the Estuary Alternative. Budd Inlet would experience a **significant impact** to water quality during and immediately following dam removal due to increased sediment that may be transported outside the established mixing zone, increased TOC load to Budd Inlet that contributes to oxygen depletion, and increased nutrient availability for algal uptake. These impacts would be expected to normalize after disturbed sediments from the lake basin are flushed out of the system, which may take several days to a few weeks.

5.6.1.2 Lake Basin

The impacts to the lake basin from construction are consistent with those described for the Estuary, but also include additional sediment and water quality disturbance associated with construction of the barrier wall. Dam removal would have the same temporary **significant impacts** to lake basin water quality as described for the Estuary Alternative. The change in hydrodynamics and flushing patterns would result in redistribution and transport of existing sediments, which would increase turbidity in the lake basin until equilibrium is restored. The Capitol Lake Basin would experience **significant impacts** to water quality during this transition period due to dramatic shifts in environmental conditions and a temporary increase in turbidity. This would result in loss of remaining aquatic plants and change in algal communities and possibly transition from a high DO to low DO environment, depending upon timing. These impacts can be expected to last several days to a few weeks.

Construction of the barrier represents a similar level of impact as associated with other construction activities described in Section 5.3.1 and would require similar permits and BMPs and would have **less-than-significant** impacts due to implementation of construction site BMPs.

Overall, there would be **significant impacts** to the lake basin during construction of the Hybrid Alternative due to redistribution and transport of sediments during the transition period.

5.6.2 Impacts from Operation

Impacts or benefits from operations are associated with potential changes in the quality and nature of water in the current lake basin, the quality of the water discharged to Budd Inlet, and routine dredging of the Inlet.

5.6.2.1 Budd Inlet

The benefits and impacts associated with the operation of the Hybrid Alternative in Budd Inlet would be similar to those described for the Estuary Alternative in Section 5.5.2. Sedimentation rates are predicted to be higher (Moffatt & Nichol 2021) but within the same relative range of increase as is predicted for the Estuary Alternative, and therefore dredging frequency is expected to be similar. Same as the Estuary Alternative, maintenance dredging is expected to result in less-than-significant impacts on Budd Inlet water quality compared to existing conditions.

DO concentrations would be similar to those described under the Estuary Alternative; there may be limited improvements, but it is not expected to substantially change the general habitat conditions for cold water fish in Budd Inlet in relation to DO. No change is expected in frequency or extent of algae blooms. Based on anticipated limited improvements in DO concentrations, the Hybrid Alternative would have **minor to moderate benefits** on Budd Inlet water quality when compared to existing conditions.

5.6.2.2 Lake Basin

The North Basin would have different operational impacts depending upon location with reference to the barrier; water quality conditions inside the barrier (eastern portion of the basin) would be very different from conditions in the open estuary (western portion of the basin). Therefore, in the following summary of impacts they are described separately for each of the new basins.

In the western portion, water quality conditions would be similar to those described in the Estuary Alternative for the lake basin. DO concentrations would be low when compared to existing conditions in the lake basin, although they may be somewhat higher than described for the Estuary Alternative due to the decreased water volume, and therefore increased influence of the river. The higher flushing rate could also correspond to decreased algae blooms relative to the Estuary Alternative but this is not expected to be significant; algae blooms would still occur similar to existing conditions. As noted under the Estuary Alternative, the low DO concentrations reflect the natural condition of these tidal estuaries. Periods of low DO concentrations would result in periods of degraded habitat conditions for cold water fish, but such changes are not expected to significantly impact fish (ESA 2021). Based on the anticipated changes in water quality in the western portion of the basin compared to existing conditions, the Hybrid Alternative would have **significant impacts** on water quality. (Although these impacts are significant when compared to existing conditions, they would reflect conditions that are similar to what is experienced in other inlets in South Puget Sound and reflect typical estuary conditions.) Numeric water quality standards for DO would not be met in the western portion of the basin under the Hybrid Alternative. There are many factors that Ecology evaluates to determine whether the narrative standard relative to human-caused variation is being met. This determination would be made by Ecology.

In the eastern portion (the saltwater reflecting pool), the water would be exchanged twice daily during high tides; and therefore, can be expected to be higher quality; cooler, with more DO, and less algae than the water in the western portion of the basin. Based on 1) DO concentrations in surface layers at BUD002 (the water quality monitoring station in West Bay), 2)only high tide waters would be flushed into the saltwater pool, and 3) water would be regularly exchanged, it is possible that DO concentrations would more frequently meet the numeric marine water quality standards. There would continue to be periods when DO concentrations do not meet the numeric standard and concentrations would still be lower than what currently exists in the lake basin. Based on the anticipated reduction in DO compared to existing conditions, the eastern portion of the basin would also experience **significant impacts** on water quality. The eastern portion of the basin would likely experience fewer or less extensive algae blooms than the western portion due to twice daily flushing of high tide water. No active management of the pool, other than daily flushing, is expected.

The Hybrid Alternative would provide a **substantial benefit** in the western and eastern portion of the existing lake basin based on the reduction in aquatic plant communities when compared to existing conditions. As would be expected in an estuary, the freshwater aquatic plant community that currently exists in the lake basin would be replaced by saltwater tolerant plant species and the habitat areas created as part of the project (ESA 2021).

Table 5.4 and Table 5.5 provide a summary of key water quality impacts and benefits of the Hybrid Alternative in the two different portions of the lake basin.

Table 5.4 General Comparison of Key Impacts and Benefits of the Hybrid Alternative on Water Quality During Operations in the Western Portion of the Lake Basin.

	DO Concentrations	Algae Blooms	Aquatic Plants
Budd Inlet	Increase: Limited improvement is expected	No change	No change
Lake Basin (West)	Decrease: DO concentrations will reflect estuary conditions that exist in lower reaches of inlets	No change	Decrease: Aquatic plants would be largely absent

Table 5.5 General Comparison of Key Impacts and Benefits of the Hybrid Alternative on Water Quality During Operations in the Eastern Portion of the Lake Basin.

	DO Concentrations	Algae Blooms	Aquatic Plants
Budd Inlet	Increase: Limited improvement is expected	No change	No change
Lake Basin (East)	Decrease: DO concentrations will reflect high tide estuary conditions	No change	Decrease: Aquatic plants would be largely absent

5.7 AVOIDANCE, MINIMIZATION, AND MITIGATION MEASURES

Enterprise Services would avoid and minimize potential impacts by complying with regulations, permits, plans, and authorizations. These anticipated measures, and other mitigation measures that could be recommended or required, are described below.

5.7.1 Measures Common to All Action Alternatives

Dredging and construction activities are associated with all action alternatives that have the potential to impact water quality. All activities would occur in accordance with the environmental permits that would be obtained prior to the work. BMPs for turbidity management and spill prevention would be implemented during construction and operational dredging activities to minimize and avoid impacts. The BMPs are non-discretionary actions that are needed to maintain water quality standards throughout the work. They often include the following measures:

- Timing of construction activities to avoid sensitive species
- Hydraulic dredging

- Closed bucket
- Limiting barge overflow
- Slowing dredge rate
- Seasonal/migratory windows
- Tidal dredging
- Use of silt curtains
- Other common erosion and sediment control techniques

A water quality monitoring and protection plan (WQMPP) would also be prepared, approved by the regulatory agencies, and implemented throughout construction. This plan is intended to measure the performance of the BMPs implemented to maintain water quality standards, identify potential exceedances, and outline contingency measures that would be implemented if water quality standards were exceeded. The plan will include real-time monitoring of turbidity within the established mixing zone of approximately 200 to 300 feet from the dredging and placement areas during construction and in maintenance dredging and dewatering areas. In addition, the WQMPP will include inspection of spill control equipment and actions required by the certification. Therefore, no specific water quality mitigation plans would be necessary for the project.

To reduce potential DO impacts to Budd Inlet during dredging, an additional mitigation strategy could be to modify dam operations to restrict lake outflow during dredging and increase lake outflow at night. This strategy would be most important to implement during the June 1 to August 15 period of allowable in-water work when river flows are low and bottom water DO concentrations are lowest in Budd Inlet. Dredging activities during the winter months (November 15 to February 15) when DO concentrations are higher would not need to be constrained.

Dam repair or removal is also a part of all action alternatives. To reduce potential DO impacts to Budd Inlet, an additional mitigation strategy could be to modify dam operations to restrict lake outflow during construction activities (daytime) and increase lake outflow at night. This strategy would be easiest and most important to implement during the summer months (June through August) when river flows are low and bottom water DO concentrations are lowest in Budd Inlet.

5.7.2 Measures Specific to Each Action Alternative

5.7.2.1 Managed Lake Alternative

There were no significant adverse impacts associated with the Managed Lake Alternative because it is essentially the existing condition. However, modeling has indicated that the 5th Avenue Dam is an important aspect of the DO problem in Budd Inlet due partially to the pulsed nature of the flow over the dam and its impact on circulation. This issue should be considered during design of the dam repairs to determine whether there are modifications that could be made to limit the pulsed nature of the discharge. It has also been suggested that when aquatic plants die in the fall the resultant increase in

TOC inflow to Budd Inlet contributes to DO problems in the Inlet. Late season removal of aquatic plant biomass should be considered as a means of reducing this impact.

5.7.2.2 Estuary and Hybrid Alternatives

No specific mitigation measures have been identified for these alternatives.

Significant long-term adverse impacts have been identified for the lake basin both the Estuary and Hybrid Alternatives because the freshwater lake basin would be converted from a well-oxygenated condition to one with very low oxygen conditions characteristic of Inner Budd Inlet. However, these conditions are common in the shallow parts of inlets and embayments around South Puget Sound, and no measures are recommended to minimize or mitigate these impacts on aquatic habitat or other beneficial uses.

5.7.3 Significant Unavoidable Adverse Impacts

In the few weeks after construction is complete and the existing lake basin is opened to tidal waters, there would be a transition period that would result in redistribution and transport of existing sediments. This is expected to increase turbidity in both the lake basin and Budd Inlet until equilibrium is restored.

Significant adverse impacts have been identified for both the Estuary and Hybrid Alternatives because the lake basin would be converted from a well oxygenated system to one with very low oxygen conditions. However, this is largely a reflection of the natural conditions that exist in the lower parts of inlets and embayments in South Puget Sound.

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Appendix A Water Resources Methodology for Capitol Lake — Deschutes Estuary

CAPITOL LAKE – DESCHUTES ESTUARY

Long-Term Management Project Environmental Impact Statement

Water Resources Methodology for Capitol Lake – Deschutes Estuary

Prepared for:

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July 1, 2019

This document presents the proposed methodology to assess discipline-specific impacts of the alternatives being considered for the Capitol Lake – Deschutes Estuary Long-Term Management Project. This memorandum has been reviewed by an independent third-party expert or experts and the methodology has been presented to, and discussed with, the resource agencies and local governments on the Technical Work Group. The methodology described has been prepared early in the Environmental Impact Statement (EIS) process, as alternatives are being optimized, and may reasonably evolve as conceptual design, modeling, and analysis of the alternatives progresses. The results of this discipline-specific analysis will be presented in a Discipline Report, which will be attached to and summarized in the Draft EIS. Public comment will be solicited on the Draft EIS, consistent with rules of the State Environmental Policy Act.

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List of Acronyms and Abbreviations

Acronyms/ Abbreviations	Definition
BOD_5	Total 5-day biochemical oxygen demand
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EIS	Environmental Impact Statement
Enterprise Services	Washington State Department of Enterprise Services
Herrera	Herrera Environmental Consultants, Inc.
QAPP	Quality Assurance Project Plan
TMDL	Total Maximum Daily Load
TN	Total nitrogen
TP	Total phosphorus
WAC	Washington Administrative Code

1.0 Introduction

The Capitol Lake – Deschutes Estuary includes the 260-acre Capitol Lake Basin, located on the Washington State Capitol Campus, in Olympia, Washington. The waterbody has long been a valued community amenity. Capitol Lake was formed in 1951 following construction of a dam and provided an important recreational resource. Historically, the Deschutes Estuary was used by local tribes for subsistence and ceremonial purposes. Today, the expansive waterbody is closed to active public use. It is plagued by environmental issues including the presence of invasive species, violations of water quality standards, and inadequate sediment management.

The Washington State Department of Enterprise Services (Enterprise Services) is responsible for the stewardship, preservation, operation, and maintenance of the Capitol Lake Basin. The 260-acre Capitol Lake Basin is maintained by Enterprise Services under long-term lease agreement from the Washington Department of Natural Resources.

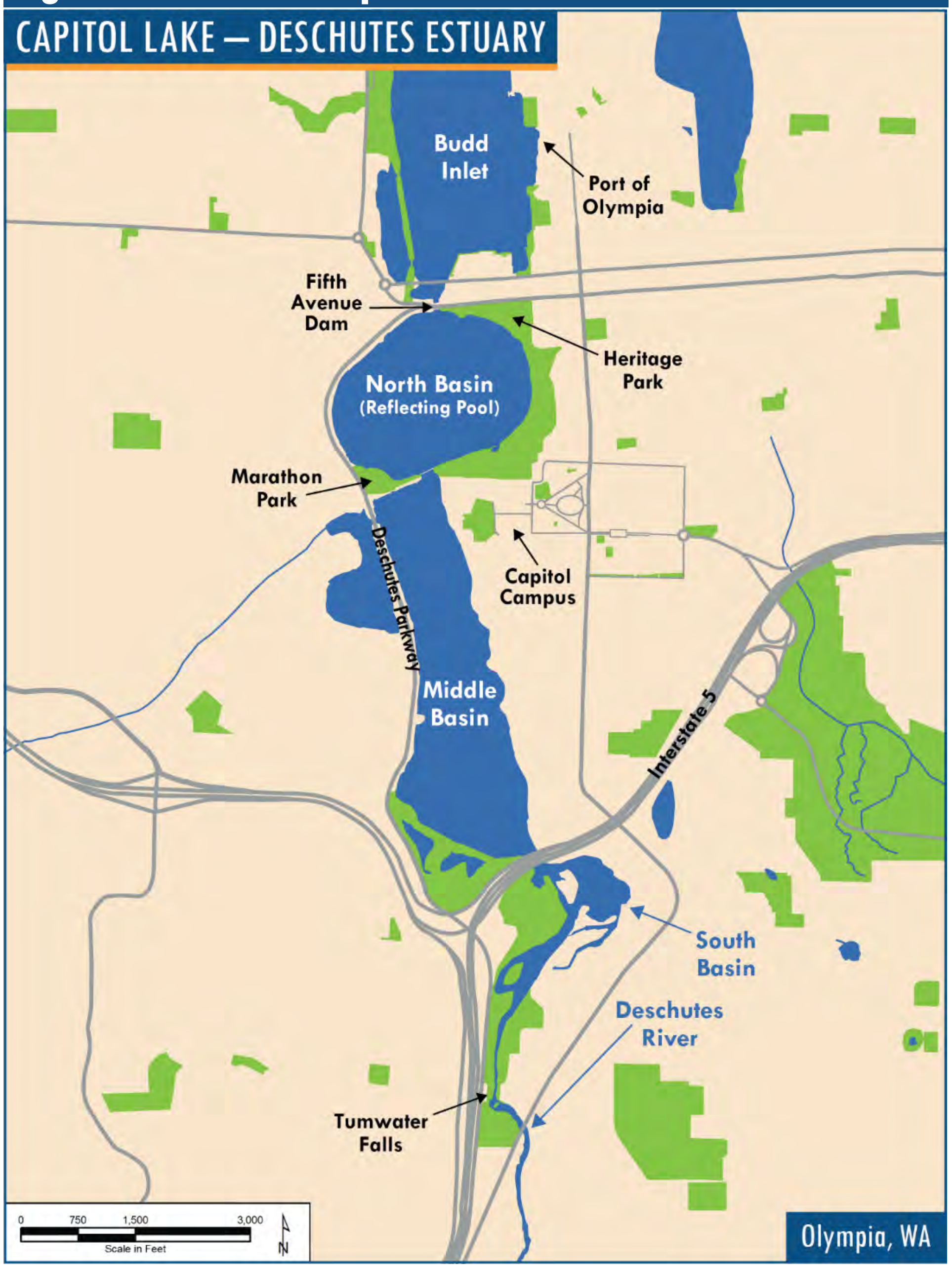
In 2016, as part of Phase 1 of long-term planning, a diverse group of stakeholders, in collaboration with the state, identified shared goals for long-term management and agreed an Environmental Impact Study (EIS) was needed to evaluate a range of alternatives and identify a preferred alternative. In 2018, the state began the EIS process. The EIS will evaluate four alternatives, including:

- **Managed Lake Alternative**: Similar to existing conditions with additional strategies to manage sediment accumulation and water quality. The Managed Lake Alternative would retain the 5th Avenue Dam and tide gate in its current configuration to maintain the reflecting pool and Capitol Lake Basin.
- **Estuary Alternative**: Full tidal hydrology would be restored throughout the basin. Sediment would be managed through initial dredging in Capitol Lake Basin and recurring maintenance dredging in Budd Inlet.
- **Hybrid Alternative**: Allows management of the Basin by establishing a tidal estuary in the western portion of the North Basin, and throughout the Middle and South Basins. A retaining wall would also be constructed resulting in a reflecting pool adjacent to Heritage Park in the North Basin.

- **No Action Alternative**: The No Action Alternative in intended to represent the most likely future for the project area if the project is not implemented.

These long-term management alternatives will be evaluated against the shared project goals of: improving water quality; managing sediment accumulation and future deposition; improving ecological functions; and enhancing community use of the resource. Refer to Figure 1.1 for the project area for long-term management. The Final EIS will identify a preferred environmentally and economically sustainable long-term management alternative for the Capitol Lake – Deschutes Estuary.

Figure 1.1 Area Map



The EIS process leverages momentum from the previous phase by continuing engagement with the existing Work Groups, which include the local governments, resource agencies, and tribe. It also provides for expanded engagement opportunities for the public, such as a community sounding board. **Additional information, including additional background context, description of project alternatives, and project goals, can be found at the project website: www.capitollakedeschutesestuaryeis.org.**

1.1 DISCIPLINE-SPECIFIC METHODOLOGY

This document has been prepared to describe the proposed approach to the water quality analysis to be conducted as part of the Capitol Lake – Deschutes Estuary Long-Term Management Project EIS. It has been prepared by Herrera Environmental Consultants, Inc. (Herrera), the water resources lead for the project, with input from Environmental Science Associates (ESA). The methodology proposed within this document has been developed following an initial review of existing background documents, available data, comments received during the scoping period, and coordination with the EIS Project Team. The purpose of this document is to solicit feedback on the water quality analysis to provide background for and increase understanding of the technical analyses before they begin and to improve the methodology through various levels of early review.

The sections below provide a summary of the process that will be used to investigate, evaluate, and describe the potential water quality effects that could occur during construction and operation of the long-term management alternatives. The long-term management alternatives that will be reviewed in the Draft EIS include Managed Lake, Estuary, Hybrid, and No Action Alternatives. The water quality analysis of these alternatives will (1) characterize existing conditions within the study area, (2) identify potential impacts and benefits of the alternatives, and (3) recommend mitigation measures that could be implemented to avoid or minimize potential adverse impacts.

2.0 What is the Study Area?

The study area is based on the area where water quality could be affected by the project, determined to include the Capitol Lake Basin (including Percival Cove) and Lower Budd Inlet. The southern boundary of the water resources analysis is generally defined as the base of Tumwater Falls, and the northern limits extend to the southern end of Priest Point Park (47 04'N) in Budd Inlet (Figure 1.1). Upstream water resources are not part of the study area for this EIS evaluation because they do not have the potential to be affected by construction or operation of a long-term management alternative. However, water quality and hydrologic data for the Capitol Lake – Deschutes Estuary will be compiled for estimating any long-term trends in watershed inputs as well as for identifying lake management techniques that might be used to support Managed Lake Alternative goals.

3.0 What Potential Water Quality Effects Will be Important to Address in the EIS?

The EIS will address potential water quality effects from construction and operation of each project alternative. Project alternatives may directly influence compliance with numerical water quality criteria for temperature, dissolved oxygen (DO), pH, turbidity, fecal coliform bacteria, *Escherichia coli* (*E. coli)* bacteria, and action thresholds for total phosphorus (TP). In addition to numerical criteria, project alternatives may directly influence compliance with narrative water quality standards for aesthetics, protection of beneficial uses, and anti-degradation. For example, algal productivity is an important issue that needs to be evaluated for its influence on several beneficial uses including recreation, aesthetics, and aquatic life. Therefore, the project alternatives will be evaluated against numerical and narrative water standards, consistent with project goals and use designations for the project area defined in the Washington Administrative Code (WAC).

Water quality affects aquatic habitat, including endangered species. Results from this evaluation will be used to characterize impacts to fish and wildlife, including threatened and endangered species. The methods used to characterize those impacts are discussed in a separate document: Fish and Wildlife Methodology.

4.0 What Existing Water Resources Data are Available?

There is an abundance of data for potential use in the water resources assessment. The key documents and databases that will be used are listed separately below for the watershed, Capitol Lake, and Budd Inlet. Appendix A presents a summary of water quality data available for each water body from the Environmental Information Management (EIM) system managed by the Washington State Department of Ecology (Ecology). Additional data not yet in EIM have been provided by Ecology to supplement the EIM data, and the data are also presented in Appendix A. Relevant data will be compiled in spreadsheets for analysis of existing water resources conditions.

4.1 WATERSHED DATA

The project watershed includes the Deschutes River watershed, Percival Creek watershed, and other areas draining to Capitol Lake from the nearshore basin. Documents and databases containing relevant water resource data for the project watershed will be reviewed for relevance to the current evaluation, and incorporated as appropriate. These data sources include the following:

- **USGS Stream Flow Monitoring:** One continuous flow monitoring station on the Deschutes River at the E Street Bridge (1946 to present). One continuous monitoring station (1987 to 1990) on Percival Creek near the mouth.
- **USGS Water Quality Monitoring:** Select water quality parameters (including temperature, turbidity, pH, and phosphate) from 1977 to 1980 for the Deschutes River at E Street Bridge.
- **Ecology Total Maximum Daily Load (TMDL) Monitoring:** Water quality monitoring of the Deschutes River for TMDL water quality model development and calibration/verification. Parameters include temperature, fecal coliform, DO, nutrients, and pH from July 2003 to March 2005.
- **Thurston County Stream Flow Monitoring:** Continuous streamflow gauging of Percival Creek near the mouth (1993 to 2015) and Black Lake Ditch (a tributary to Percival Creek) (2005 to present).

- **Thurston County Water Quality Monitoring:** Deschutes River (Tumwater Falls station since 1993); Percival Creek (one station since 1993); and Black Lake Ditch (one station since 2005). Water quality monitoring for temperature, pH, DO, conductivity, turbidity, TP, nitrate+nitrite nitrogen, and flow at all stations.
- **Thurston County Stormwater Monitoring:** Stormwater outfall sampling for outfalls discharging to the Deschutes River between Tumwater Falls and the southern end of Tumwater Falls Park. Parameters sampled include fecal coliform, turbidity, TP, nitrate+nitrite, and ammonia by Thurston County Environmental Health staff from December 1999 to February 2000.
- **Thurston County Groundwater Monitoring:** Groundwater elevation and water quality monitoring at various wells near Capitol Lake, monitoring results presented from 2008 to 2017.
- **NOAA Weather Station:** Olympia airport precipitation data.

4.2 CAPITOL LAKE DATA

Relevant water resources data for Capitol Lake include:

- **Thurston County Capitol Lake Monitoring:** Monthly summer (May to October) water quality monitoring from 1999 to 2014 at up to four stations for field profiles (pH, temperature, DO), Secchi, TP, total nitrogen (TN), nitrate, ammonia, chlorophyll *a*, fecal coliforms, and algae ID.
- **Thurston County Stormwater Monitoring:** Along with the stormwater sampling report listed above, Thurston County monitored two stations within Capitol Lake (one Middle and North Basin) for depth, pH, DO and conductivity in 1999.
- **USGS/NWIS 1974:** Capitol Lake monitoring in February, April, June, and August 1974 for 34 analytes, including pH, OC, chlorophyll *a*, calcium, temp, total suspended solids, total; dissolved solids, etc.
- **Entranco 1997 Capitol Lake Drawdown Monitoring:** Report completed to analyze the effects of drawdown of Capitol Lake by managing the dam. Consists of salinity, conductivity, temperature, and depth of Capitol Lake in the Middle and North Basins. Samples were collected before drawdown and 2 weeks after backfilling.
- **Entranco 1984:** Assessment of Capitol Lake to address issues with fish kill prevention (tide gate), sediment deposition, water quality issues, and swim beach restoration, including a water and phosphorus budget.
- **Entranco 1990:** Evaluation of the feasibility of creating wetlands in South and Middle Basin of Capitol Lake.

4.3 BUDD INLET DATA

Relevant water resources data for Budd Inlet include:

- **Ecology Ambient Monitoring Program 1973-Ongoing:** Inner and Outer Budd Inlet ambient water quality monitoring stations for profiles of temp, DO, pH, turbidity, pressure, conductivity, light transmittance, and near surface and near bottom samples for alkalinity, nitrate, nitrite, ammonium, orthophosphate, silicate, dissolved inorganic carbon, and chlorophyll *a*. Monitoring is conducted monthly every year at Outer Budd Inlet and every 5 years at Inner Budd Inlet.
- **LOTT 2000:** Scientific study of Budd Inlet to evaluate whether wastewater discharged into Budd Inlet was adversely impacting water quality. Historical data analysis, collection of temperature, DO, salinity, TN and phosphorus, chlorophyll *a*, fecal coliform, and the identification of phytoplankton and zooplankton. Modelling was also completed during this study to predict changes in seasonal inputs to Budd Inlet.
- **TMDL Technical Report 2012:** Modeling results will be reviewed as part of the evaluation of future conditions for the various alternatives.
- **Thurston County 1995:** Data collected from Budd Inlet and analyzed for various water quality parameters (turbidity, TP, nitrate, ammonia, coliform) from July 1992 to September 1994.

5.0 What Additional Water Resources Data Will be Collected for the Project?

5.1 LAKE WATER QUALITY MONITORING

While the assessment of the lake will rely heavily on existing data, some additional monitoring will occur. The primary purpose of this monitoring is to obtain current information on existing lake conditions. Water quality monitoring of Capitol Lake will be conducted from May through October 2019 to understand current water quality conditions. This time period was selected to be consistent with past monitoring of the lake and is consistent with monitoring approaches used on many lakes in Washington State. The purpose of collecting additional data is to compare current water quality conditions against historical conditions (2004 to 2014) to determine if current conditions are within the range of previous observations. Monitoring methods will follow those used by Thurston County Environmental Health for Capitol Lake, as specified in the Thurston County Surface Water Ambient Monitoring Program standard operating procedures (Appendix B) and as specified in an addendum to that Quality Assurance Project Plan (QAPP) that is included as Appendix C to this document.

As has been done by Thurston County in the past, the program will include monthly sampling from May through October at each of two mid-lake stations, historically sampled by Thurston County and located in the North and Middle Basins. Sampling will be conducted with the assistance of Washington State Department of Enterprise Services (Enterprise Services) staff, using a boat provided by Enterprise Services and dedicated to Capitol Lake. Proper equipment decontamination procedures will be used to prevent the spread of the New Zealand mudsnail in accordance with Washington Department of Fish and Wildlife protocols.

Physical and chemical variables measured will include temperature, pH, DO, specific conductivity, Secchi depth (water clarity), TP, soluble reactive phosphorus, TN, nitrate+nitrite nitrogen, ammonia nitrogen, total organic carbon, total suspended solids, total volatile suspended solids, DO, total 5-day biochemical oxygen demand (BOD_5) (filtered and unfiltered), chlorophyll *a*, fecal coliform bacteria, *E. coli* bacteria, and phytoplankton species presence and biovolume. A calibrated YSI multimeter will be used in the field to measure temperature, pH, DO, and specific conductivity at 1-meter depth intervals, and Secchi depth will be measured in the field with a standard 8-inch Secchi disk. Water samples will be collected to measure all other variables.

Water samples will be collected at two lake sites and three locations including; the surface (1-meter depth) of the North and Middle Basin stations, and the bottom (0.5 meters from the lake bottom) of the North Basin. Past Thurston County monitoring included collection of surface samples only. However, as part of this monitoring effort, a bottom water sample will be collected from the deepest part of the lake in the North Basin to evaluate vertical differences in all parameters except bacteria and phytoplankton enumeration. A total of six events will be monitored at the three locations for a total of 18 water samples, all of which will be collected with a Van Dorn sampler. Fecal coliform and *E. coli* bacteria samples will be collected at the two main lake sites as the other analytes (i.e., the North and Middle Basin sites) and additionally from a third site located near the eastern shore to represent nearshore conditions. Bacteria samples will be collected directly into sterile sample bottles by filling the bottle aseptically from just below the water surface. The samples will be analyzed by Ecology-accredited laboratories using U.S. Environmental Protection Agency-approved methods.

Total organic carbon, total suspended solids, total volatile suspended solids, and BOD_5 have not been routinely monitored in the past but will be included as part of this monitoring effort for analysis of suspended solids characteristics and DO depletion in Budd Inlet (see below).

5.2 LAKE SEDIMENT SAMPLING

Lake sediment proposed for dredging will be sampled to characterize physical and chemical parameters. The purpose of characterizing the lake sediment is to:(1) evaluate compliance with Washington State Sediment Management Standards and Model Toxics Control Act, (2) evaluate potential impacts on humans and aquatic biota from sediment removal and disposal activities, (3) develop mitigation measures for sediment removal and disposal activities, and (4) evaluate the resulting change in freshwater and marine sediment quality from the project alternatives. Sediment sampling will be conducted in accordance with a separate Sampling and Analysis Plan.

Some of the sediment core samples will be collected specifically to support development of a phosphorus budget and to evaluate potential impacts of sediment removal on lake phosphorus concentrations, under the Managed Lake Alternative. Subsamples of the core that represent the current sediment surface characteristics and sediment characteristics at various sediment depths representing the proposed dredging depth, as well as lower depths, to get closer to background conditions, will be analyzed for sediment phosphorus fractions using established methods (Pilgrim et al. 2007). Sediment core fractionation results will be used to estimate phosphorus contribution from lake sediments under existing conditions and to evaluate whether a change in sediment phosphorus loading might be expected under different dredging scenarios.

6.0 How Will Existing Conditions be Assessed?

Water quality data collected by Thurston County from 2004 through 2014 for Capitol Lake (eliminating the years between 2000 and 2004 when the brewery discharge was in operation) and collected by Ecology from 2004 through 2018 for lower Budd Inlet, will be compiled and evaluated to establish existing conditions of these project water resource elements. These compiled data sets will represent approximately 10 years of data for Capitol Lake and 15 years of data for Budd Inlet. These periods of time incorporate interannual variation and can be used to assess recent long-term trends. If no new trends are detected, it will be assumed that past conditions are reflective of existing conditions. If new, significant trends are detected, then this will be incorporated into the evaluation. While key data trends will be evaluated for the Deschutes River, Percival Creek, and other inputs to Capitol Lake, existing conditions will not be summarized for these water bodies because these upstream water resources will not be affected by the project. They would be considered consistent inputs to the project area. These water quality and hydrologic inputs from the Capitol Lake watershed will be compiled to develop a water and TP budget for Capitol Lake and for calculating loading estimates for other analytes. The water budget in combination with new lake bathymetry data (collected by others and not addressed in this document) will be used to evaluate existing lake retention time and flushing.

In general, existing water quality conditions will be assessed for Capitol Lake and Budd Inlet by comparison of historical water quality data to water quality criteria established by the Washington State Surface Water Quality Standards (WAC 173-201A). Additional thresholds may be developed for parameters of interest for which there are no numeric standards, such as nutrients and algae biomass (as chlorophyll *a*) that affect beneficial uses. Water quality statistics will be calculated for each parameter to include, but not be limited to, minimum, maximum, median, $25^{th}/75^{th}$ percentiles, percent detected, and percent exceeding water quality criteria for each year and for each month among all years. Data summaries may also be presented as seasonal summaries where warranted; for example, summertime loading estimates for phosphorus will likely be helpful. Summary statistics will be tabulated and presented in box and whisker plots for key parameters of interest.

Statistical methods for evaluating long-term trends and for determining if measured parameter values can be used to fill data gaps for parameters with a limited number of values will be selected based on data distribution.

Key water quality parameters of interest and associated criteria include:

- Temperature (WAC 173-201A criteria)
- Dissolved oxygen (WAC 173-201A criteria)
- pH (WAC 173-201A criteria)
- Turbidity (WAC 173-201A criteria)
- Secchi depth (Capitol Lake, trophic state criteria, and Budd Inlet [no criteria])
- Total suspended solids (criteria to be determined)
- Fecal coliform bacteria (WAC 173-201A criteria)
- *E. coli* bacteria (WAC 173-201A criteria)
- Chlorophyll *a* (Capitol Lake only, trophic state criteria)
- Total phosphorus (Capitol Lake only, trophic state criteria)
- Soluble reactive phosphorus (orthophosphate, no criteria)
- TN (sum of total Kjeldahl nitrogen and nitrate+nitrite nitrogen, no criteria)
- Nitrate+nitrite nitrogen (no criteria)
- Ammonia nitrogen (WAC 173-201A criteria)

Gaps in the data record for these parameters and assessment limitations will be identified. Concentrations of toxic substances (metals and organics) in the water column is a known data gap because they have not been routinely monitored in Capitol Lake or Budd Inlet. They are not routinely monitored because they are rarely detected in lakes or estuaries under normal conditions. Toxic substances will be addressed as part of the assessment of construction impacts related to sediment management activities that suspend toxic substances present in the sediments.

7.0 What Additional Data Analyses Will be Conducted for Developing the Adaptative Management Approach of the Managed Lake Alternative?

It is recognized that the Managed Lake Alternative (and at a smaller scale, the Hybrid Alternative) will need to be actively managed in order to achieve water quality standards and designated beneficial uses. The evaluation will consider common lake management objectives, upon which to develop an adaptive management plan, such as control of algae (e.g. blue-green algae and/or toxic algae blooms), bacteria, and aquatic plants. These objectives will be defined in coordination with Enterprise Services and with stakeholder input as part of the long-term planning and EIS processes.

Analysis of historical data will be used to identify whether there are trends in water quality associated with ongoing watershed management actions that should be considered in estimating watershed contributions to the lake to determine the extent to which water quality criteria can be met and beneficial uses supported under existing conditions. An analysis of phosphorus loadings was conducted during a previous restoration analysis of the lake (Entranco 1984). At that time, it was estimated that 70 percent of Capitol Lake phosphorus was contributed by the Deschutes River, while the remaining amount was contributed by Percival Creek (8 percent), Olympia Brewery discharges (14 percent), and miscellaneous sources including groundwater and internal loading (8 percent). Since that time many changes to the watershed have taken place; most significantly, the brewery has closed. An updated phosphorus budget will be developed to quantify phosphorus sources to the lake for evaluating potential effects of watershed management and sediment removal on phosphorus loadings, and to identify additional lake management actions that might be needed to meet lake management goals specified in WAC and further defined through this EIS process.

A water budget will be prepared for Capitol Lake using flow data for the Deschutes River and Percival Creek. Inflow data for the Deschutes River and Percival Creek will be separated into base flow and storm flow using a standard spreadsheet model for hydrograph separation. The water budget will be formulated on a monthly basis using up to 10 years of data from 2004 through 2014, which represents the period after the brewery discharge ended in 2003 and the most recent period that lake monitoring data are available. Inflow to the lake from storm drains in the nearshore basin will be estimated using the Simple Model (Schueler 1987) based on basin area, rainfall, and runoff coefficients for land cover types. (The Simple Model was selected because it is intended for use with small, urban catchments, consistent with the urban portion of the Capitol Lake drainage basin.) The basin consists of approximately 59 percent pervious surface, 34 percent untreated impervious surface, and 7 percent treated impervious surface (Olympia 2018). Rainfall data will be used to calculate direct precipitation input and pan evaporation data will be used to estimate lake evaporation loss. Groundwater inputs and outputs will be estimated from the residual in the volume balance of measured surface inputs and outputs. Base and storm flow inputs will be averaged for each water source by month over the 10-year study period. Lake bathymetry conducted by others will be used with lake elevation data to calculate lake storage volume.

Using the water budget described above as the water mass balance framework, a monthly phosphorus budget will be prepared for Capitol Lake by multiplying the average monthly water volumes by average monthly phosphorus concentrations. The phosphorus budget will only be prepared for the summer growing season from May through October because lake phosphorus data are not available for the remaining months and summer is the most critical period for evaluating water quality impacts. TP data sources will include:

- Inputs of direct precipitation to the lake surface using TP concentrations in rainfall samples collected by others in the region.
- Inputs of Deschutes River and Percival Creek using TP concentrations for storm and base flow events determined from the sample time and hydrograph separation or rainfall data.
- Inputs of stormwater from the nearshore basin using average TP concentrations in stormwater samples collected from the basin if available, or from the literature for representative land uses if local data are not available.
- Inputs of shallow groundwater using TP concentrations in nearby groundwater wells and baseflow stream/river TP concentrations.
- Inputs from TP release from lake sediments using sediment phosphorus fraction results of sediment core samples collected for the project.
- Inputs from aquatic plant decomposition will be estimated from published literature on phosphorus concentrations in the plants and gross estimates of plant volume. This input will be applied late in the season to reflect seasonal die-off.
- Outputs of TP by sedimentation within the lake using sedimentation rates calculated during development of the sediment budget and sediment phosphorus data collected as part of this work. (The sediment budget methodology and sediment transport modeling will be described in a separate study.)
- Outputs of the lake outlet using TP concentrations in lake surface water within the North Basin.
- Outputs of groundwater outflow using TP concentrations in lake water samples.
- Change in lake phosphorus storage using TP concentrations in the lake and changes in lake volume.

TP, total organic carbon, TN, dissolved inorganic nitrogen, and total suspended solids loading rates will be estimated for the Deschutes River and Percival Creek for summer (May through October) and winter (November through April) periods using average flow volumes and parameter concentrations measured during base and storm flow conditions for the 10-year study period. Average base and storm flow parameter concentrations will be calculated by flow weighting values if they correlate with flow. Lake outputs of these parameters, BOD_5, and chlorophyll will be estimated for the critical summer period using average lake concentrations and outflow volumes for the 10-year study period. Because total organic carbon, total suspended solids, and BOD_5 measurements have not been taken in the lake historically, they will be estimated (if possible) from historical concentrations of phosphorus, nitrogen, and chlorophyll observed in the lake based on parameter relationships measured in the summer of 2019. Differences in key lake inputs (i.e., Deschutes River and Percival Creek) and key outputs (loss over the dam) of carbon and nitrogen, along with outputs of BOD_5 and chlorophyll, will be used for evaluating the relative effects of alternatives on DO in Budd Inlet. Complete nutrient budgets for carbon and nitrogen will not be prepared because of inadequate data.

Total organic carbon inputs and outputs also will be estimated using monitoring data collected by Ecology and USGS and the loading estimates will be used to evaluate changes within the lake, and for comparing predicted oxygen depletion in Budd Inlet from lake outflow.

Total sediment inputs also will be estimated by a separate study using existing and collected data for development of the sediment rating curve and budget by various methods to include:

- Conversion of total suspended solids concentrations in samples collected from the surface of the Deschutes River to total sediment concentrations based on estimates of increasing sediment concentrations with river depth, and the relationship of total sediment loading rate with river flow rate
- Hydrotrend model of basin-wide sediment production based on river watershed characteristics and climate data
- Sediment deposition rate in the lake based on sediment core dating with lead-210 and analysis of sediment organic and inorganic fractions
- Sediment mass accumulation rate in the lake from increased sediment volume measured by two historical and one new bathymetric survey.

8.0 How Will Water Quality for the Project Alternatives be Assessed?

Impacts related to both long-term operation and construction will be evaluated, with a focus on comparatively evaluating the alternatives. In general, construction-related impacts will be based on impacts associated with dredging because that represents the major construction impact, however, impacts from other in-water construction will also be described. Future, long-term impacts and benefits of each of the four project alternatives will be evaluated based on the combination of historical trends and current conditions analysis. Qualitative categories such as "no substantial change," "minor improvement," or "major improvement" will be used to compare expected differences in key water quality variables and beneficial use impairments. These categories will be defined based on the success of meeting water quality criteria or lake-specific thresholds defined for other parameters. Using DO in Budd Inlet as an example, changes in DO would be considered an improvement if DO levels generally were expected to increase in the lower inlet. The change would be considered a major improvement if it is predicted that DO would change from frequently not meeting criteria to nearly always meeting criteria in the majority of the inlet. An example of a water quality impact summary matrix and type of color coding that would be used to depict the differences is presented in Figure 8.1. The details of this qualitative analysis would be further refined as part of the EIS process.

Figure 8.1 Water Quality Impact Summary Matrix— Representative Example

Capitol Lake – Deschutes Estuary Operation Water Quality Impact Summary									
	Temp	**DO**	**pH**	**Turbidity**	**Nutrients**	**Algae**	**Fecals**	**Metals**	**Organics**
Capitol Lake									
Existing									
No Action									
Lake									
Estuary									
Hybrid									
Budd Inlet									
Existing									
No Action									
Lake									
Estuary									
Hybrid									

Example Impact Summary Legend

- No Change
- Major Improvement
- Minor Improvement
- Major Deterioration
- Minor Deterioration

8.1 NO ACTION ALTERNATIVE

Historical data (2004 through 2012) will be evaluated in addition to the 2019 monitoring data described in this document to evaluate Capitol Lake water quality conditions for the No Action Alternative and to assess whether there have been any long-term trends in water quality that would result in changes beyond the existing condition. For example, if there are existing trends in phosphorus concentrations in the Deschutes River that can be assumed to reflect past watershed management activities, these trends will be used to predict future lake phosphorus concentrations and algae growth from future watershed management activities. Sediment budget results will be used to predict future water depths in the lake.

Capital Improvement Project lists from the City of Olympia, City of Tumwater, and Thurston County will be reviewed to evaluate whether planned watershed management efforts are likely to have a significant impact on the key water quality variables that are of interest to this project (i.e., summer period phosphorus, turbidity, DO, or flow conditions). It is assumed that these projects will occur under all alternatives and, therefore, any change in water quality from these efforts would apply across all alternatives.

Budd Inlet water quality conditions for the No Action Alternative will be assessed using results of the historical trend analysis and Ecology's TMDL Technical Report results (Ecology 2012).

8.2 MANAGED LAKE ALTERNATIVE

8.2.1 Identification of Operational Impacts

The Managed Lake Alternative will be designed to address water quality thresholds that will be defined for this project based on meeting beneficial use goals and assuming implementation of a long-term adaptive management plan. The water and phosphorus budgets for Capitol Lake will be used to identify feasible lake restoration methods for meeting beneficial use goals. For example, if there is a contact recreation goal, lake management techniques aimed at reducing algae or occurrence of toxic algae blooms and watershed control techniques for reducing bacteria will be considered. Changes in summer average concentrations of algae biomass (as chlorophyll *a)*, will be estimated from predicted changes in phosphorus concentrations as a result of estimated changes in phosphorus loadings based on historical relationships between these parameters for Capitol Lake.

Up to three lake management scenarios for the Managed Lake Alternative will be evaluated at a conceptual level to address feasibility and costs of various lake management techniques for improving water quality and meeting lake management goals. It is assumed that the scenarios will range from low to high degrees of management for sediment removal, water quality treatment, aquatic macrophyte control and invasive species control. The lake water quality evaluation will be primarily based on estimates of reduced phosphorus loadings and algae biomass and will consider the anticipated effectiveness and cost of management techniques, which may consider previously recommended active management approaches, as applicable.

Water quality impacts (both positive and negative) to Budd Inlet for the Managed Lake Alternative will be assessed for DO using Ecology's model output as reported in the TMDL Technical Report (Ecology 2012) and the estimated reduction in algae biomass and associated total organic carbon loadings discharged from Capitol Lake. Impacts on DO in Budd Inlet will also be assessed by examining relationships in summer DO concentrations with suspended solids, nutrient, BOD_5, and algae loadings from Capitol Lake over the 10-year study period with consideration of tidal mixing conditions and other factors. Impacts to other parameters (e.g., temperature, turbidity, pH, bacteria, and metals) will be qualitatively assessed based on the predicted changes to algae and DO.

8.2.2 Identification of Construction Impacts

Construction impacts of the Managed Lake Alternative would occur during dredging of lake sediments. The dredging approach and frequency, and handling and disposal of material will be defined as part of the EIS but have not yet been defined. Common water quality concerns during dredging include an increase in suspended solids, release of nutrients, and resuspension of potentially contaminated sediments. Water quality impacts of sediment dredging (and in-lake disposal if selected) will be assessed using current sediment quality data collected for this project combined with historical sediment quality and elutriate testing data for dredging investigations. Concentrations of toxic substances found in sediment elutriates will be related to those in the tested sediments for predicting potential exceedance of water quality criteria in Capitol Lake during future dredging and disposal actions based on the current sediment quality and quantity in the planned dredging areas. Potential impacts to Budd Inlet from suspended sediments will be assessed based on the distance from dredging/disposal locations to the dam and the anticipated sedimentation rates based on sediment grain size data collected for this project.

Dredged sediments within Capitol Lake also contain New Zealand mudsnails, which may require in situ chemical treatment prior to offsite disposal. Water quality impacts of in situ treatment (including impacts from tool and equipment cleaning) will be identified using literature for the selected chemical(s). These impacts would apply to all the Managed Lake, Estuary and Hybrid Alternatives.

8.3 ESTUARY ALTERNATIVE

8.3.1 Identification of Operational Impacts

The Estuary Alternative would create a river-estuary transitional zone where Capitol Lake currently exists between the mouth of the Deschutes River at the South Basin of the lake and Budd Inlet at the lake dam. Water quality effects of this alternative in Budd Inlet are described in the TMDL Technical Report (Ecology 2012), and those results will be used to describe impacts (both positive and negative) of the Estuary Alternative on temperature, DO, total organic carbon, nitrogen, and algae biomass (as chlorophyll *a*). Some modeling assumptions may vary between the proposed action and the model, a qualitative assessment of the impacts (both positive and negative) on predicted water quality will be made. In addition, impacts on DO in Budd Inlet will also be assessed from anticipated changes in loadings of oxygen-demanding substances (sediments, nutrients, and algae) to the inlet by removal of the dam. Water quality conditions in the transition zone and Percival Cove will be estimated to range from river/stream conditions during low tide to estuary conditions during high tide. Because the lower portion of Budd Inlet has variable water quality, the high tide estuary conditions will be based on modeling results as presented in the TMDL Technical Report (Ecology 2012)s from the southernmost portion of the inlet (near the Port of Olympia) rather than results from mid inlet since this will be a better representation of the water that will move into the transition zone/existing lake. Longer term impacts to lower Budd Inlet will be evaluated based on sediment transport modeling and potential turbidity increases and dredging needs. The methods for evaluating impacts from sediment transport will be described in a separate document.

8.3.2 Identification of Construction Impacts

Construction impacts of the Estuary Alternative will occur during sediment dredging/disposal and dam removal and during the years after dredging if modeling indicates that sediments will continue to move to the inlet over a multiple-year time scale. Water quality impacts from construction would primarily be related to increased suspended sediment concentrations and resuspension of potentially chemically impacted sediments during these activities. Sediment dredging/disposal would occur before dam removal; thus, immediate water quality impacts to Budd Inlet should be similar to those identified for the Managed Lake Alternative. Mitigation measures to prevent water quality impacts during dam removal will be identified to not exceed turbidity criteria at the compliance zone boundary in Budd Inlet. The compliance zone boundary will be predicted from those commonly applied by construction permits.

8.4 HYBRID ALTERNATIVE

8.4.1 Identification of Operational Impacts

The Hybrid Alternative will be similar to the Estuary Alternative except that a managed lake will be physically isolated from the estuary in the eastern portion of the North Basin of the existing lake by constructing a barrier across the basin, isolating a lake behind the wall. As this alternative includes both the lake and estuary areas, similar conditions will both apply to this alternative.

Impacts of the lake portion will depend on lake size, water source (groundwater, river water, and/or estuary water), flushing rate, phosphorus loading, and water resource management decisions. It is assumed that lake management goals for the lake portion will be the same as those developed for the Managed Lake Alternative to support beneficial uses. Phosphorus loading to the lake portion will be estimated using the methods and data described for the lake phosphorus budget with adjustments for the lake portion design elements, and assumptions about the water source used and flushing. Impacts of different lake water sources could be evaluated by predicting algae biomass in the lake portion based on observed relationships between chlorophyll *a* and phosphorus loading rates in lakes(Cooke et al. 2005). Cost-effective in-lake management techniques will be identified for meeting lake management goals and successfully creating a reflecting pool.

Impacts and benefits to Budd Inlet will be evaluated following the method used for the Estuary Alternative since the same estuarine processes will occur in a smaller transition zone between the Deschutes River and Budd Inlet. Impacts on DO in Budd Inlet from the lake portion will be estimated using results of Ecology's model as reported in the TMDL Technical Report (Ecology 2012) and accounting for changes in total organic carbon loading from the smaller lake portion.

8.4.2 Identification of Construction Impacts

Construction impacts will be evaluated for the Hybrid Alternative to include sediment dredging/disposal and dam removal, similar to the Estuary Alternative. Additional construction impacts will occur from construction of the barrier wall to separate the estuary and lake portions. Potential impacts to water quality will depend on construction methods and mitigation measures and will be evaluated based on the potential for increases in suspended solids and turbidity and resuspension of potentially chemically impacted sediments within Capitol Lake. Mitigation measures, such as constructing the wall before removing the dam and others, would be identified and evaluated for preventing downstream impacts to Budd Inlet during construction.

9.0 References

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Schueler, T. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. Metropolitan Washington Council of Government, Washington DC.

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Appendix A:
Available EIM Data and Additional Data Requested

Table A-1. Water Quality Data From EIM For Capitol Lake Deschutes Estuary EIS.

	Budd Inlet	Capitol Lake	Deschutes R at E St	Deschutes R Upstream	Percival Ck Downstm	Percival Ck Upstream	Black Lake Ditch	Nearshore Basin	
								Stormwater	Groundwater
Number of Stations	0	21	6	21	8	6	5	2	244
Number of Studies	0	3	10	5	1	1	5	1	21
Record Begin Year		1974	1941	1941	2003	2003	2003	2013	2003
Record End Year		2013	2017	2016	2013	2013	2009	2013	2018
Number of Values									
Conventionals									
Alkalinity, Total as CaCO3		22	68	178				3	1
Biochemical Oxygen Demand					2				
Chemical Oxygen Demand			3						
Chloride				3					
Conductivity		526	358	646	1			4	3
Dissolved Organic Carbon		99	84	64	20			3	5
Dissolved Oxygen		1516	879	1105	92		34	4	6
Dissolved Oxygen % Saturation		95	465	174					
Flow			486	402	18	12	3	3	1
Hardness, Total as CaCO3			161	144					
pH		573	878	1407	101	2	36	4	13
Silicon			16						
Specific Conductivity (at 25 deg C)		2	512	493	20	11			6
Stream/River Discharge					14	11	3		
Temperature, water		1474	889	1207	62	13	14	4	11
Total Suspended Solids		32	499	267	14			3	5
Total Organic Carbon								1	
Turbidity			475	331					
Water Transparency		7							
Well Water Level									114
Nutrients									
Chlorophyll		22							
Ammonia		98	514	458	45		14		4
Nitrate			165	147					
Nitrate-Nitrite as N			554						
Nitrite		5	237	191					
Nitrite-Nitrate		98	311	233	46		14		4
Nitrogen				1					
Ortho-Phosphate		100	514	405	46		14		4
Phosphorus		98	391	372			13		4
Total Kjeldahl Nitrogen				43					
Total Organic Carbon		90	80	64	20				
Total Persulfate Nitrogen		120	364	149	65		21		4
Total Phosphorus			139	33					
Bacteria									
E. coli			7	2	2				
Enterococci			12						
Fecal Coliform		68	532	398	126	6	41		
Metals									
Antimony									1
Arsenic			60					3	106
Barium									25
Cadmium			60					6	102
Chromium			60						
Copper			61	6				6	8
Lead			60					6	233
Manganese									1
Mercury			30						92
Nickel			60					6	8
Selenium									25
Silver			60						25
Tin									1
Zinc			61	6				6	8
PCBs									
PCB-aroclors									34
Petroleum Hydrocarbons									
Gasoline Range Organics									368
Gasoline									133
Diesel Range Organics									402
Diesel Fuel									27
#2 Diesel									7
Heavy Fuel Oil									94
Lube Oil									201
Motor Oil									86
Oil and Grease									33
Extractable Petroleum Hydrocarbons									4
Volatile Petroleum Hydrocarbons									4

Table A-1. Water Quality Data From EIM For Capitol Lake Deschutes Estuary EIS.

	Budd Inlet	Capitol Lake	Deschutes R at E St	Deschutes R Upstream	Percival Ck Downstm	Percival Ck Upstream	Black Lake Ditch	Nearshore Basin	
								Stormwater	Groundwater
Other Organic Chemicals									
1,1,1,2-Tetrachloroethane									63
1,1,1-Trichloroethane									77
1,1,2,2-Tetrachloroethane									63
1,1,2-Trichloroethane									76
1,1-Dichloroethane									77
1,1-Dichloroethene									138
1,1-Dichloropropene									76
1,2,3-Trichlorobenzene									61
1,2,3-Trichloropropane									63
1,2,4-Trichlorobenzene									64
1,2,4-Trimethylbenzene									67
1,2-acenaphthylenedione								3	1
1,2-Dibromo-3-Chloropropane									63
1,2-Dichlorobenzene									77
1,2-Dichloroethane									99
1,2-Dichloroethene									26
1,2-Dichloropropane									76
1,2-Diphenylhydrazine									1
1,3,5-Trichlorobenzene									2
1,3,5-Trimethylbenzene									63
1,3-Dichlorobenzene									77
1,3-Dichloropropane									60
1,3-Dichloropropene									3
1,4-Dichlorobenzene									77
1-Methylnaphthalene								3	50
2,2-Dichloropropane									76
2,4,5-Trichlorophenol									1
2,4,6-Trichlorophenol									1
2,4-Dichlorophenol									1
2,4-Dimethylphenol									1
2,4-Dinitrophenol									1
2,4-Dinitrotoluene									1
2,6-Dinitrotoluene									1
2-Chlorophenol									1
2-Chlorotoluene									76
2-Hexanone									37
2-Methylnaphthalene								3	50
2-Nitroaniline									1
2-Nitrophenol									1
3,3'-Dichlorobenzidine									1
4,6-Dinitro-2-Methylphenol									1
4-Chloro-3-Methylphenol									1
4-Chlorophenyl-Phenylether									1
4-Chlorotoluene									76
4-Nitroaniline									1
4-Nitrophenol									1
4-Nonylphenol									1
5,12-Naphthacenequinone								3	1
7,12-Benz[a]anthracenquinone								3	1
9,10-Anthracenedione								3	1
9-Fluorenone								3	1
Aceanthrenequinone								3	1
Acenaphthene									36
Acenaphthylene									36
Acetone									37
Anthracene								3	36
Benz[a]anthracene								3	57
Benzanthrone								3	1
Benzene									505
Benzene, methyl(1-methylethyl)-									19
Benzo(a)pyrene								3	57
Benzo(b)fluoranthene								3	52
Benzo(ghi)perylene								3	36
Benzo(k)fluoranthene								3	52
Benzo[a]fluorenone								3	1
Benzo[cd]pyrenone								3	1
Benzofluoranthenes, Total (b+k+j)									5
Benzoic Acid									1
Benzyl Alcohol									1
Bis(2-chloro-1-methylethyl) ether									1
Bis(2-Chloroethoxy)Methane									1
Bis(2-Chloroethyl)Ether									1

Table A-1. Water Quality Data From EIM For Capitol Lake Deschutes Estuary EIS.

	Budd Inlet	Capitol Lake	Deschutes R at E St	Deschutes R Upstream	Percival Ck Downstm	Percival Ck Upstream	Black Lake Ditch	Nearshore Basin	
								Stormwater	Groundwater
Bisphenol A									1
Bromobenzene									63
Bromochloromethane									29
Bromoform									63
Bromomethane									63
Butyl benzyl phthalate									1
Caffeine									1
Carbazole								3	2
Carbon Tetrachloride									76
Captan								3	
CFC-11									63
CFC-12									60
Chlorobenzene									63
Chlorodibromomethane									63
Chloroethane									77
Chloroform									76
Chloromethane									76
Cholesterol									1
Chromium									101
Chromium, Hexavalent									2
Chrysene								3	57
Cis-1,2-Dichloroethene									139
Cis-1,3-Dichloropropene									76
Coprosterol									1
Cumene									63
Cyanide									8
Cyclohexane									2
cyclopenta(def)phenanthrenone								3	1
Di(2-ethylhexyl) phthalate									1
Dibenzo(a,h)anthracene								3	57
Dibenzofuran								3	2
Dibromomethane									63
Dibutyl phthalate									1
Dichlorobromomethane									63
Dichlorodifluoroethylene									3
Diethyl phthalate									1
Dimethyl phthalate									1
Di-n-octyl phthalate									1
Ethylbenzene									497
Ethylene dibromide									113
Fluoranthene								3	36
Fluorene								3	36
Fluoride									7
Hexachlorobenzene									1
Hexachlorobutadiene									64
Hexachlorocyclopentadiene									1
Hexachloroethane									1
Hexane									5
Indeno(1,2,3-cd)pyrene								3	57
Isophorone									1
m, p-Xylene									52
Methyl ethyl ketone									37
Methyl isobutyl ketone									37
Methyl t-butyl ether									100
Methylene Chloride									64
m-Nitroaniline									1
Naphthalene								3	130
n-Butylbenzene									50
Nitrobenzene									1
N-Nitrosodi-n-propylamine									1
N-Nitrosodiphenylamine									1
n-Propylbenzene									63
o-Cresol									1
o-Xylene									52
Paraffin oils									68
PBDE-003									1
PCN-002								3	2
p-Cresol									1
Pentachlorophenol									1
Phenanthrene								3	36
Phenol									1
p-Isopropyltoluene									44
Pyrene								3	36

Table A-1. Water Quality Data From EIM For Capitol Lake Deschutes Estuary EIS.

	Budd Inlet	Capitol Lake	Deschutes R at E St	Deschutes R Upstream	Percival Ck Downstm	Percival Ck Upstream	Black Lake Ditch	Nearshore Basin	
								Stormwater	Groundwater
Retene								3	2
Sec-Butylbenzene									63
Styrene									63
Tert-Butylbenzene									67
Tetrachloroethene								3	139
Toluene									497
Total Xylenes									423
Trans-1,2-Dichloroethene									139
Trans-1,3-Dichloropropene									76
Trichloroethene									139
Triclosan									1
Triethyl citrate									1
Vertical Hydraulic Gradient									9
Vinyl Chloride									139
Xylene									22

Capitol Lake Deschutes Estuary EIS Water Resource Data Requests by Herrera

CITY OF OLYMPIA

1. Reports and data in spreadsheets for water elevation and water quality parameter values in the West Bay Lagoon.
2. Stormwater flow and water quality monitoring data in spreadsheets for drainages in the Capitol Lake watershed.
3. Groundwater elevation and water quality parameter values in spreadsheets for wells located in the vicinity of Capitol Lake.
4. Spreadsheet or GIS shape file of all water monitoring locations.

THURSTON COUNTY ENVIRONMENTAL HEALTH

1. Water quality monitoring plans for the Thurston County Surface Water Ambient Monitoring Program prepared since or supplement to the Standard Operating Procedures revised in February 2009.
2. Capitol Lake water quality monitoring data in spreadsheets for all lake monitoring stations, all years, and all parameters including field parameter profiles, nutrients, chlorophyll, fecal coliform bacteria, phytoplankton, cyanotoxins, and trace metals/organics.
3. Percival Creek flow (continuous and discrete) and water quality data in spreadsheets for all stations, all years, and all parameters.
4. Deschutes River flow (continuous and discrete) and water quality data in spreadsheets for all stations, all years, and all parameters.
5. Stormwater flow and water quality monitoring data in spreadsheets for drainages in the Capitol Lake watershed.
6. Groundwater reports and elevation and water quality parameter values in spreadsheets for wells located in the vicinity of Capitol Lake.
7. Precipitation data in spreadsheets for the rain gauge nearest Capitol Lake
8. Spreadsheet or GIS shape file of all water gauging and monitoring locations.
9. Spreadsheet or GIS shape file of all known storm drain outfalls in Capitol Lake.
10. GIS shapefile of all drainage basins in the Capitol Lake watershed.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

1. Water quality data collected by Ecology and not available from EIM for Capitol Lake, Deschutes River, Percival Creek, stormwater in the vicinity of Capitol Lake, and groundwater in the vicinity of Capitol Lake.
2. Tables and figures of water quality modeling output data for the Deschutes River, Percival Creek, Capitol Lake, and Budd Inlet.

DEPARTMENT OF ENTERPRISE SERVICES

1. Water surface elevation and outflow/inflow data in spreadsheets for Capitol Lake at the dam.

Appendix B:
Thurston County Surface Water Ambient Monitoring Program; Standard Operating Procedures and Analysis Methods for Water Quality Monitoring

These standard operating procedures and analysis methods have been adopted by the Capitol Lake -- Deschutes Estuary EIS Project Team for water quality sampling in Capitol Lake. This document guided the sampling conducted by Thurston County in Capitol Lake historically and is intended to ensure that quality data is collected.

Thurston County
Surface Water Ambient Monitoring Program

Standard Operating Procedures and Analysis Methods
For Water Quality Monitoring

Revised February 2009

Thurston County Public Health and Social Services Department
Environmental Health Division

Project Manager: Sue Davis
(360) 754-4111 ext 7316

****Contact Update: Jane Mountjoy-Venning**
360-867-2643 **Updated 10/11/17**

QAPP Submitted for:

Protecting Puget Sound Watersheds, Water Quality and Aquatic Resources from the Impacts of Growth EPA Grant Project # WS-96073601-0 (Project Name)	
Thurston County Dept. of Water and Waste Management (Agency responsible for Grant)	
July 1, 2008 (Date)	
Thurston Co. Grant Project Manager	Barb Wood
Signature / Date	Barb Wood 2/20/09
Thurston Co. Water Quality Project Manager	Sue Davis
Signature / Date	Sue Davis 2/19/09
EPA Project Officer, EPA Region 10	Tony Fournier [signature] 3/11/09
Signature / Date	[signature] for GGG 3/5/09 *see attached email 3/3/09 w/comments.
EPA QA Manager, EPA Region 10	Gina Grepo-Grove
Signature / Date	
EPA Project Monitor, EPA Region 10	Krista Mendelman
Signature / Date	Krista Mendelman 3/10/09

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Project Organization

The Thurston County surface water ambient monitoring program is coordinated through the Thurston County Department of Water and Waste Management, Storm and Surface Water Utility. The water quality monitoring element of the ambient monitoring program is conducted by staff in the Public Health and Social Services Department, Environmental Health Division. The individuals involved in the water quality monitoring are as follows:

Sue Davis, Project Manager and Field Collection
Cathy Hansen, Data Management and Reporting
Linda Hofstad, Data Management and Reporting
Heather Saunders, Field Collection
Mike Clark, Thurston County Environmental Health Laboratory Manager
Steven Lazoff, Aquatic Research, Inc., Laboratory Manager

Project Background

The Thurston County ambient surface water quality monitoring program is part of the overall, on-going Thurston County monitoring program, which includes surface water quality monitoring, stream discharge gauging, lake level monitoring, and precipitation gauging. Most rivers, streams, and public-access lakes in the county are being monitored. The monitoring network is supported by Thurston County and the Cities of Lacey, Olympia, and Tumwater. The program compliments the marine and fresh water quality monitoring conducted by Washington Departments of Health and Ecology and the US Geological Survey stream discharge measurement program.

The data generated by this project are used by the local jurisdictions' storm and surface water utilities and by the public, professional consultants, tribes, and other environmental agencies such as Washington Department of Ecology and US Environmental Protection Agency.

Project Description and Design

Project Objectives

The objectives of this long-term water quality monitoring program are the following:

- Provide a long-term, consistent water quality baseline of data for streams and lakes;
- Provide data that is used to track water quality and quantity trends over time and identify problems areas where corrective actions should be taken.
- Enable broad analysis of the data with the capacity for comparison between areas;
- Ensure that monitoring equipment is available for routine monitoring and emergency response;
- Provide easy access to information/data by jurisdictions, agencies, and citizens;

- Compliment state Departments of Health and Ecology marine and freshwater monitoring programs.

Project Tasks and Timetable

Table 1. Tasks and Timetable

Activity	Frequency	Completion Date
Field data collection and sampling	Monthly	On-going
QA/QC	Monthly	On-going
Data management	Monthly	On-going
Data posting to County website	Annually	January 31
Report preparation	Every 2 years	June 30

For EPA project # WS-96073601-0, the project began July 1, 2008.

Sampling Locations and Selection Rationale

All monitored rivers and streams have sampling stations near their mouths to evaluate the impacts of activities in the watershed on the receiving water. A few of the rivers and streams have additional up-stream stations to segment sections based upon major land-uses or to isolate known problem areas.

Most lakes in the monitoring program have one sampling station located over the deepest part of the lake. Those lakes that have multiple basins have a monitoring station in two basins. The lakes that are included in the 2009 monitoring program include Long (2 sites), Pattison (2 sites), St Clair (2 sites), Capitol (2 sites), Hicks, Deep, Ward, Black, and Summit.

The number and locations of monitoring stations are periodically adjusted as the program is adapted to new information or changing priorities. Table 2 on the following page lists the streams and rivers in the 2008/2009 water year monitoring program is included below. A map showing the sampling locations for all of the water bodies is included in Appendix B.

Table 2. Stream Sampling Sites

2008/09 Ambient WQ Monitoring Sites					
Monitoring Sites	Location	Site ID	Stream Ambient	TCEH Macros	NH_3
NISQUALLY					
McAllister	Southbound I-5 on-ramp	NISMC0000	X		
Eaton	at Yelm Hwy	NISEA0000	X		
Yelm @ 103rd	at 103rd and Creek St.	NISYL0030	X		
Yelm mouth	off Mud Run Rd	NISYL0000	X new		
Thompson	At Centralia Power Park	NISTH0000	X new		
HENDERSON					
Woodard	4116 Libby	HENWO0000	X	X	
Tanglewilde	Tanglewilde Outfall	HENWL0800	X		X
Woodland	at Pleasant Glade Rd	HENWL0000	X		
BUDD/DESCHUTES					
Black Lk Ditch	at RW Johnson	BUDBD0000	X		
Chambers	off end of 58th	DESCH0300	X	X	
Deschutes @ Tumwater	at Tumwater Falls Park under bridge	DESDE0000	x		
Deschutes @ Waldrick	off bridge at Waldrick Rd.	DESDE0025	X		
Deschutes @ Vail Lp	under bridge at Vail Lp. Rd.	DESDE0045	X		
Percival	at Footbridge	BUDPE0000	X	X	
Spurgeon	at Boe residence off Rich Road	DESSP0500	X		
Reichel	at Vail Loop Rd	DESRE1100	X		
Indian	at Quince Ave	BUDIN0010	X		
Mission	at East Bay Dr	BUDMI0000	X		
Ellis	at East Bay Dr	BUDEL0000	X		
Moxlie	at Marine Dr	BUDMO0000	X		X
Schneider B	at West Bay Dr	BUDSC0000	X		
ELD					
Green Cove	mouth off Cooper Pt Rd	ELDGC0000	X	X	
McLane	mouth at Delphi Rd bridge	ELDMC0000	X	X	
Perry	off Perry Creek Rd	ELDPE0000	X	X	
TOTTEN					
Kennedy	at Mouth	TOTKE0000	X	X	
Schneider T	Pneumonia Gulch off 101	TOTSC0000	X	X	
Schneider Head	upstream of Steamboat Interchange	TOTSC0040	X		
CHEHALIS					
Beaver	at Littlerock Rd	BLABE0700	X		
Black @ Moon	at Moon Rd	BLABL0010	X		
Black @ 128th	at 128th in Littlerock	BLABL0050	X		
Chehalis	At Independence Rd	CHECH0010	X		
Prairie	Off Old Highway 9	CHEPR0510	X		
Salmon	at Littlerock Rd by Quarry	BLASA1020	X		
Scatter @ James	at James	CHESC0100	X		
Scatter @ Gibson	at Gibson Rd	BLASA1020	X		
Blooms Ditch	off 110th	BLABM0910	X		
Skook	at Highway 507	SKOSK0000	X		

Sampling Frequency and Rationale

The streams and rivers are **sampled monthly** throughout the year. The monthly ambient monitoring program has been in place since December 2003. The major water quality impacts of concern in this region occur during the wet season and are associated with contaminants washing off the land into the streams during storm events. The typical water quality concerns associated with dry season/low flow conditions are high water temperature, low dissolved oxygen, and elevated concentrations of specific contaminants associated with continuous (not storm related) pollution sources. To acquire a sufficient amount of data which reflects both wet and dry season influences, samples are collected monthly.

The emphasis for lake sampling is during the warm weather growing season because it is the period when symptoms of nutrient enrichment are manifested and beneficial uses may be impaired. Lake sampling is conducted **six times per year, monthly from May through October**.

Sampling Parameters

Parameters measured at **stream and river** stations include:

- temperature
- pH
- dissolved oxygen
- specific conductance
- stream discharge
- staff gage level (if present)
- total phosphorus
- nitrate-nitrite
- ammonia
- turbidity
- fecal coliform bacteria
- field observations - including any changes from previous sampling events, water appearance, etc.

Parameters measured at **lake** stations include:

- temperature
- pH
- dissolved oxygen
- specific conductance
- secchi disk visibility
- total phosphorus - at surface and bottom depths
- total nitrogen - at surface and bottom depths
- chlorophyll *a* (phaeophyton *a* adjusted) - epilimnion composite
- algae identification - epilimnion composite
- field observations - including water color and appearance, changes from previous sampling, macrophyte growth, etc.

Measurement Quality Objectives and Quality Control Requirements

Laboratory Quality Control

Quality assurance objectives for measurement data are usually expressed in terms of accuracy, precision, completeness, representativeness, and comparability. The laboratory submits quality control and quality assurance results and calculations to the project manager with the analytical reports. A sample QA/QC reports from Aquatic Research, Inc. is included in Appendix C.

Definitions of these characteristics are as follows:

Accuracy: A sample spike is prepared by adding a known amount of a pure compound to the environmental sample (before extraction for extractable), and the compound is the same or similar (as in isotopically labeled compound) as that being tested for in the environmental sample. These spikes simulate the background and interference found in the actual sample. The percent recovery of the spike is taken as a measure of accuracy and is calculated as follows:

$$\%R = \frac{100\,(O-X)}{T}$$

where: %R = Percent recovery; O = Measured value of analyte concentration after addition of spike; X = Measured value of analyte concentration in the sample before the spike is added; and T = Value of spike.

Tolerance limits for acceptable percent recovery established by the lab in accordance with contract laboratory procedures (CLP) guidelines will be followed for this program. Sample spike recoveries that fall outside the tolerance limits shall be assessed and the problem identified and corrected by the lab.

Surrogate spikes are also a measure of accuracy. When surrogate recoveries are outside the control limits, the corrective action procedures specified in the methods must be followed by the laboratory.

Laboratory blanks are analyzed by the lab to ensure samples are not contaminated during the analytical process of the lab. If there is contamination in the blank, the lab should be contacted immediately and requested to check their QA data. Samples should be re-analyzed if holding times have not been exceeded. If an environmental sample result is greater than ten times the concentration in the blank, then the data is acceptable but always qualified. If the sample result is less than ten times the concentration in the blank, the data must be discarded. If holding times have expired and the data is essential, then re-sample.

Precision: Precision is the degree to which a set of results are repeatable using the same methods and performed under the same conditions. To examine precision the lab performs duplicate analyses. Two aliquots of the same sample are made in the laboratory and each aliquot is treated exactly the same throughout the analytical method. The percent difference between the values of the duplicates, as calculated below, is taken as a measure of the precision of the analytical method.

$$\%D = 2\,\underline{(D1 - D2)} \times 100$$

$$(D1 + D2)$$

where: %D = Percent difference; D1 = First sample value; and D2 = Second sample value (duplicate)

The tolerance limit for percent difference between laboratory duplicates will be +/- 25%. If the precision values are outside the limits, the laboratory will recheck the calculations and/or identify the problem. Reanalysis may be required. Sample results associated with the out-of-control precision results may be qualified at the time of validation.

Completeness: Completeness is a measure of analytical effort and will be measured as:

$$\%C = V/T \times 100$$

where: C = Completeness of analytical effort, in percent; V = Number of sample analyses that have been validated (validation is the process of review and approval of sample data); and T = Total number of samples that have been submitted for validation.

The target for completeness by the analytical laboratory is 95 percent.

Table 3 shows the acceptance levels for data generated from this program.

Table 3. Quality Assurance/Quality Control Criteria for Laboratory Analysis

PARAMETER	PRECISION (RPD)	ACCURACY (%)	COMPLETENESS (%)
nutrients	25	>80% <120%	95%
chlorophyll a	25	--	95%

RPD = Relative Percent Difference from duplicate analysis; Control limit is 25 RPD if result is > 5 times the detection limit, and is ± the detection limit if the result is ≤ 5 times detection limit.

The target for completeness of the overall project data is 83%, or 10 of 12 sampling events for streams and 5 of 6 sampling events for lakes.

Representativeness: Representativeness is the degree to which data accurately and precisely represent the true value of a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is maximized by following standard procedures for sampling and analysis.

Replicate samples are taken every ten samples (10%) for all sampled parameters. The replicates are taken side-by-side to reduce field variability. In the lab, blanks, spikes, and splits are used to evaluate the accuracy and precision of the analysis. Field replicates are used to evaluate overall variability. There are no control limits established for field replicates. Data from field replicates are averaged and entered as one number in the database system.

Comparability: Comparability is maximized through the use of standard analytical methods with demonstrable equivalency in terms of method performance criteria and equivalent reported units. Use of standard methods applies to both the laboratory analysis and field procedures.

Field Instrument Quality Control

Table 4 provides instrument specifications for the field instruments used in the ambient monitoring program.

Table 4 - Instrument Specifications

Parameter	Instrument	Range	Accuracy	Resolution
pH	YSI Multi-Parameter Instrument (650 MDS display - 6920 Sonde Unit)	0-14 units	+/-0.2 units	0.01 units
Temperature	YSI Multi-Parameter Instrument (650 MDS display - 6920 Sonde Unit)	-5 to 45 °C	+/- 0.15 °C	0.01 °C
Conductivity	YSI Multi-Parameter Instrument (650 MDS display - 6920 Sonde Unit)	0 to 100 mS/cm	+/- 5% of reading +0.001mS/cm	0.001 mS/cm - 0.1 mS/cm (range dependent)
Dissolved Oxygen	YSI Multi-Parameter Instrument (650 MDS display - 6920 Sonde Unit)	0 to 50 mg/L	Within 0 to 20 mg/L, +/- 2% of the reading or 0.2 mg/l, whichever is greater	0.01 mg/L
Turbidity	YSI Multi-Parameter Instrument (650 MDS display - 6920 Sonde Unit)	0 to 1000 NTU	+/- 5% of the reading or 2 NTU, (whichever is greater) relative to calibration stds	0.1 NTU
Discharge	Swoffer Model 2100 current meter	0.1 to 25 ft/ sec	± 1%	

All field instruments are pre- and post-calibrated. The results of the calibrations and any deviation from the expected values are recorded. Significant deviations result in a variety of actions, including: using new standards for calibration, changing membranes, cleaning probes, replacing probes. The action(s) taken are recorded, along with the results of the actions. Table 5 shows the tolerances for drift in the field instruments between the pre-and post-calibrations. Drift beyond those levels will result in the data being flagged or discarded. For temperature, the instruments will be checked, annually, using a certified thermometer under ice bath and room temperature conditions. If the instrument is greater than ± 0.5 degrees C, the instrument will be sent to the manufacturer for re-calibration.

Table 5. Field Instrument Drift Tolerance Limits

Parameter	Post-Calibration Drift Tolerance Limit
pH	$\pm$0.2 units
dissolved oxygen	$\pm$0.5 mg/l
specific conductance	$\pm$10%
turbidity	$\pm$10%

Data Quality Control

When, during post-calibration procedures, a field parameter falls outside of the acceptable range, the field data for that sampling date is either flagged or discarded.

Lab data is reviewed against criteria in Table 3 upon receipt. It is also reviewed to identify any data that appears to be an outlier. If any problems are found, project staff contact the lab to discuss the data. Based on the findings, a decision is made to either accept, flag (qualify), or discard the data.

Instrument Calibration and Frequency

Calibration Procedures for YSI Model 6920 sonde with 650 MDS display

The instrument is calibrated prior to sampling each day. The instrument is post-calibrated following a day of sampling to ensure that the instrument performed within the acceptable range of accuracy and precision. The manufacturer's calibration procedures are followed for each parameter in accordance with the instrument manual provided. Calibration for dissolved oxygen is an air calibration. Conductivity is calibrated using a single calibration standard solution. pH and turbidity probes are calibrated using a two point calibration method with certified calibration standards. The two pH calibration standards used for stream sampling are 4 and 7, and for lakes they are 7 and 10. The turbidity calibration standards used are 0 and 100 NTU. Between the calibration of each probe, the instrument is rinsed three times with deionized water and once with the next parameter's standard solution.

As with the other instruments, all calibration information is recorded in a calibration logbook. If, during post-calibration procedures, a parameter falls outside of the acceptable range, staff troubleshoot the problem and take action in accordance with the equipment manual. Actions taken may include cleaning probes, soaking probes in specific solutions, changing a membrane, replacing a probe, or sending to the instrument for service to the manufacturer.

The equipment is routinely cleaned and maintained in accordance with the manufacturer's recommendations contained in the equipment manual.

Calibration Procedures for Swoffer Model 2100 Current Meter

1. Switch to CALIBRATE and read the calibration number. If the displayed number is lower, check the battery. A weak battery will allow the calibration number to "drift" downward and cause erroneous readings. Always keep a fully charged 9 volt battery in the spare compartment.

   Changes in the calibration number are proportional to the measurement error on a percentage basis. If the calibration number is 186 and the meter reads 184 then the velocity error due to calibration error will be about 1%. Record the calibration number in the logbook.

   Swoffer Meter #1 Calibration number is 175.
   Swoffer Meter #2 Calibration number is 186.
   Swoffer Meter #3 Calibration number is 184.

2. Check the propeller for damage, such as cracks or rough edges, which would change the calibration. Rough edges can be repaired with fine sandpaper. Cracks and other major damage require the replacement of the propeller.

3. Spin-test the instrument by laying the wading rod on a table or floor with the propeller perpendicular to the floor. Set the knob to "count". Blow on the propeller, and hit the reset button at the moment you stop blowing on the propeller. The propeller should free-spin to a count of at least 400 or greater. If it does not, the instrument should be cleaned or parts replaced as necessary to obtain that level of free-spin before use.

Sampling Methods

A. Field Instruments

Field parameters (temperature, pH, dissolved oxygen, and turbidity) are measured using a Yellow Springs Instrument (YSI) multi-parameter field instrument, Model 6920 and display unit 650 MDS. For streams, the instrument is placed in the flow with the probes facing upstream. For lakes, field parameters are measured by lower the instrument into the lake by one or two meter increments from the surface to the bottom of the lake, as determined by the depth sensor on the instrument.

The nutrient samples for lakes at the bottom are collected using a Kemmerer sampler. Chlorophyll *a* samples are taken as composite samples from the epilimnion (warm surface layer) or the photic zone (the surface area where sunlight can penetrate) using the Kemmerer sampler. Secchi disk visibility (or water clarity) is measured using a standard black and white quadrant disk. A Swoffer Model 2100 current meter is used to measure stream discharge using the wading technique.

B. Field Procedures

A field log is used to record field measurements and observations, including samples collected, date, time, station, weather, field personnel, field instruments used, and any notes regarding deviation from standard procedures. The following is a step-by-step procedure for taking measurements and samples in the field.

1. Streams

Field Measurements and Observations

- record date, time, weather conditions, field crew, field instruments used, field measurements, visual observations, samples taken, and any changes in procedures at each sampling station. Data will be recorded in a water-proof field book.
- allow instrument to stabilize
- record measurements in field book
- measure stream discharge using the primarily the six-tenth wading method described by US Geological Survey (USGS Water Supply Paper 2175, 1982), or the two-point method where depth is greater than 2.5 feet.

Sample Collection

- Stream samples, where possible, will be collected mid-channel and mid-depth. Usually collection is accomplished by wading. At non-wadable sites, samples will be taken mid-stream off a bridge with a custom sampling device.

- Mark sample bottles with the **station identification, date, time, parameters to be analyzed for, field personnel, source of water, and budget charged**. For fecal coliform bacteria samples, fill out the laboratory form with the above information and wrap the form around the sample bottle.

- Store samples on ice in a cooler until returned to the office. Store all bottles in a refrigerator until shipped (in a cooler on ice) or analyzed. Deliver bacteria samples to the Thurston County Health Lab upon returning from the field.

    Fecal Coliform Bacteria Samples

    Use pre-cleaned and sterilized bottles prepared by the Thurston County Environmental Health Lab. When sampling for bacteria, avoid touch the inside or mouth of the bottle. If there is any question about the sterility of a bottle, use another bottle. This parameter is time sensitive and should be analyzed no more than 24 hours after collection.

    To sample:
    - open the bottle with care (do not touch the mouth or inside of the bottle);
    - do **not** rinse the bottle as the bottle contains a preservative;
    - sample from mid-stream and mid-depth if possible, avoiding the surface micro-layer;
    - face up-stream when collecting the sample to ensure collecting water unimpacted by the presence of the field personnel;
    - fill the bottle to the neck, leaving some air space;
    - cap the bottle and attach the completed lab slip;
    - transport in cooler on ice and deliver to the EH lab same day.

Nutrients

Collect samples in pre-cleaned polyethylene bottles supplied by the laboratory. Nutrient samples may include ammonia, nitrate + nitrite, total nitrogen, soluble reactive phosphorus, and total phosphorus.

To sample:

- rinse the bottle(s) two times with the sample water;
- sample from mid-stream and mid-depth when possible;
- face up-stream when collecting the sample to ensure collecting water unimpacted by the presence of the field personnel;
- fill the bottle to the neck, leaving some air space;
- transport on ice, store refrigerated until shipped, ship on ice in a cooler to the analyzing lab.

2. Lakes

Lake stations will be sampled monthly from May through October. The stations are generally located over the deepest basin in the lake. Field parameters are measured at one-meter depth increments (or 2-meter depth increments for lakes over ten meters deep) to identify stratification. The temperature and dissolved oxygen profiles are used to determine appropriate sampling depths for chlorophyll *a* and algae samples and to determine the depth for bottom sample collection.

Field Measurements and Observations

At the established lake station, first check the depth reading before placing the instrument in the water and zero if necessary. Place the YSI instrument in the water so all the probes are completely covered. Wait for all of the parameters to stabilize before recording. Record depth, temperature, pH, conductivity, and dissolved oxygen in the field book. Also record: date, time, field personnel, equipment used, lake color, weather (including wind conditions). Then lower the instrument one meter at a time using the depth reading on the instrument, and record the field parameters at each depth increment (take measurements every two meters in lakes where depth exceeds ten meters).

Secchi Disk Measurement

- lower disk into the water to the point where it cannot be seen;
- pull it back up to where it is just visible;
- record the depth (in meters to the nearest hundredth) in the field book.

Sample Collection

Chlorophyll a (and Phaeophyton a) and Algae Identification Samples

Samples will be collected using a Kemmerer water sampler and composited from two or three discreet samples to obtain a one-liter composite sample for chlorophyll and a 250-ml sample for algae.

To sample:

- determine sampling depths necessary for the composite sample (Use the temperature profile data to determine extent of the epilimnion in the summer. The epilimnion is the warm upper layer of water having a fairly uniform temperature. If sampling in the winter when most local lakes are not stratified, use 1.5 times the secchi disk depth as the surface layer to sample);
- record the composite sampling depths in the field book;
- lower the Kemmerer column sampler to the determined depth;
- rinse the bottle with water in the epilimnion (surface is OK);
- fill the sample bottle from the Kemmerer sampler with the appropriate volume of water to have an equal volumes from each depth, i.e. fill bottle one-third volume from each depth if three depths will be sampled to comprise the composite.
- repeat steps above the appropriate number of times to fill the composite samples;
- add the 1 mg/L $MgCO_3$ preservative to the chlorophyll samples and shake;
- transport in cooler on ice, store refrigerated until shipped or analyzed
- preserve the algae identification samples with 4 drops of the preservative Lugols solution

Nutrients

Samples are taken at approximately 0.5 meters below the surface and 0.5 meters above the lake bottom with a Kemmerer sampler. Procedure is as follows:

- label the sample bottles. The sample identification is "station identification" followed by an "A" for surface sample or a "B" for bottom sample;
- determine the lake depth with the YSI instrument;
- for the near-surface sample, rinse the bottle with lake surface water two times;
- collect the near-surface sample by submerging the bottle mouth down in the water, when at 1.5 feet depth tilt the bottle side-wise and move forward in a scooping motion until filled. Empty enough liquid to bring the water level to the shoulder of the bottle.
- For the near-bottom sample, lower the Kemmerer to the appropriate depth, using caution to avoid hitting the bottom and disturbing the bottom sediment;
- rinse the sample bottle twice with the sample water from the Kemmerer;
- discard the bottom sample if suspended sediment is present; sample again as necessary;
- record the sampling depths in the field book;
- transport in cooler on ice, store refrigerated, Shipped in a cooler on ice to the analyzing lab via Greyhound bus

Sample Handling and Custody Procedures

Samples to be analyzed at the Thurston County Environmental Health lab are delivered directly to the lab by field staff on the same day as collection. Attached to every sample is a sample slip completed by the field staff. Samples are analyzed within 30 hours of collection.

Samples to be analyzed by Aquatic Research, Inc. are stored in the Environmental Health sample refrigerator immediately upon returning from the field. The morning after completion of the sampling event, a chain of custody form is completed and enclosed in a cooler with the samples and blue ice. The cooler is shipped via Greyhound bus to the Aquatic Research lab in Seattle. The samples arrive in Seattle and are picked up by lab staff on the same day as shipped.

Analytical Methods

Pre-cleaned water sampling bottles are supplied by the analyzing laboratory with the exception of algae identification bottles which are prepared by Environmental Health ambient program staff.

Analyzing entities used for this project have the appropriate certification from Washington Department of Ecology or Washington Department of Health for the parameters tested. The Quality Assurance Plan for the Thurston County Environmental Health Laboratory is in Appendix A. The analytical methods are listed in the table below.

Table 6. Analysis of Surface Water Samples

Chemical Analysis	Reporting Units	Recommended Holding Times	Analytical Method	Detection Limit
Ammonia-Nitrogen (NH_3)	mg/L as N (ppm)	7 days	EPA350.1	0.010 mg/l
Chlorophyll *a* (with Phaeophyton *a*)	ug/l	30 days	SM18 10200H.1 & 2	0.1 ug/l
Fecal Coliform (FC) most probable number membrane filter	cfu/100 mL	30 hours	APHA-9221C APHA-9222D	1 cfu/100ml
Nitrate + Nitrite (NO_3+NO_2)	mg/L as N	48 hours OR 28 days if preserved	EPA353.2	0.010 mg/l
Total Nitrogen (TN)	mg/L as N	28 days	SM 20 4500N-C	0.100 mg/l
Total Phosphorous (TP)	mg/L as P	28 days	SM18 4500PF	0.002 mg/l

Nutrient samples analyzed by Aquatic Research for this project are analyzed within 5 days of collection and are not acid preserved. The rationale for this is as follows: 1) This ambient monitoring program requires low level detection limits due to the nature of the waters being sampled. Acid preserving would require samples to be neutralized before analysis and then diluted, which would raise the detection limits above the desired limits. 2) For the nutrient parameters being analyzed, there is expected to be very little measurable loss or conversion between time of collection and time of analysis when analyzed within 5 days of collection .

Data Analysis and Reporting

At the end of each water year (September 30), the data is compiled and compared against the data objectives. Laboratory reports, QA worksheets, chain-of-custody records, and field notes are retained in the ambient monitoring program records. Upon completion of the data analysis, the project will be evaluated against the stated project goals and objectives.

Specific QA information that is evaluated is as follows:

- changes in the monitoring / QA project plan
- results of performance and/or systems audits
- significant QA problems and recommended solutions
- data quality assessment in terms of precision, accuracy, representativeness, completeness, comparability, and detection limits
- data qualifiers and rejections
- examination of whether the QA objectives were met, and the resulting impact on decision-making limitations on use of the measurement data

Data generated from this project are annually posted to the County website for accessibility by the public. Every two-year water resources monitoring report is prepared, and the document is posted to the website. In addition to being a compilation of two-years of data, the data is compared to the state water quality standards established in Chapter 173-201A WAC and shown in Table 7 below. Streams with several years of data are graphed to examine trends.

Water Quality Standards

The Washington State water quality standards for all surface water bodies are established in Chapter 173-201A of the Washington Administrative Code (WAC) which was amended July 1, 2003. Water quality standards for surface waters were established consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife. The standards for the parameters that are monitored by Thurston County are shown in Table 6. Refer to WAC 173-201A for a complete description of the water quality standards.

Table 7. Water Quality Standards for Surface Waters

Water Contact Recreation Criteria				
Parameter	Extraordinary Primary Contact Recreation (includes lakes)	Primary Contact Recreation	Secondary Contact Recreation	
Fecal Coliform (colonies/100 mL) Freshwater – geometric mean and not more than 10% of the samples >XXX	50; 100	100; 200	200; 400	
Freshwater Aquatic Life Uses Criteria				
	Char	Salmon & Trout Spawning, **Core** Rearing, and Migration	Salmon & Trout Spawning, **Non-core** Rearing, and Migration	Salmon & Trout Rearing and Migration **Only**
Dissolved Oxygen (mg/l) Lowest 1-Day Minimum	9.5	9.5	8.0	6.5
Temperature (degrees C) Highest 7-DAD* Maximum	12°C (53.6°F)	16°C (60.8°F)	17.5°C (63.5°F)	17.5°C (63.5°F)

pH Within range shown with human-caused variation within the range of less than XX units.	6.5 – 8.5; 0.2	6.5 – 8.5; 0.2	6.5 – 8.5; 0.5	6.5 – 8.5; 0.5
Turbidity (NTUs) Not exceed X over background when background is 50 NTU or less; or a XX% increase in turbidity when background is > 50 NTU.	5; 10%	5; 10%	5; 10%	10; 20%

*7 day average of the daily maximum temperatures

The "General Water Quality" condition stated in the descriptive summary for each stream and lake in the water resources report is made on the basis of the guidelines below.

Stream Water Quality Categories

"Excellent" - No water quality standard violations, and very low fecal coliform and nutrient concentrations.

"Good" - Usually meets water quality standards; OR violates only one part of the two part fecal coliform standard; OR the violation is most likely the result of natural conditions rather than pollution.

"Fair" - Frequently fails one or more water quality standards and other parameters such as nutrients indicate water quality is being impacted by pollution.

"Poor" - Routinely fails water quality standards by a large margin; other parameters such as nutrients are at elevated concentrations.

Lake Water Quality Categories

"Excellent" - Very low nutrient and chlorophyll *a* concentrations, and very high water clarity; Classified as Oligotrophic; Uses not impaired.

"Good" - Low to moderate nutrient and chlorophyll *a* concentrations, and moderate to high water clarity; Classified as Mesotrophic; Uses not impaired.

"Fair" - Moderate to high nutrient and chlorophyll *a* concentrations, and low to moderate water clarity; Classified as Eutrophic; Uses sometimes impaired.

"Poor" - High nutrient and chlorophyll *a* concentrations, and low water clarity; Classified as Eutrophic; Uses impaired during most of the summer season by excess algae and/or aquatic macrophyte (plant) growth.

Data Management Procedures

The lab data for fecal coliform bacteria results is received as hard copies of individual sample sheets. The lab data from Aquatic Research Inc is received as hard copies of lab reports for each sampling event. The field data is kept in field notebooks. These records are stored in ambient monitoring program files by water year.

The field and lab data is entered into the Thurston County's surface water Access database, from which it is easily accessible and can be transferred electronically upon request. The data entry is check by the data entry staff and ten percent of the data entry is reviewed for errors by a second project staff. At the end of each water-year after the data management activities are complete, the data is posted on the County ambient monitoring website for easy public access.

Audits and Reports

The Thurston County Environmental Health laboratory is certified by Ecology to perform the fecal coliform bacteria analyses and participate in audits by Ecology. These performance and system audits have verified the adequacy of the laboratory standard operating procedures, which include preventive maintenance and data reduction procedures.

The Thurston County Environmental Health Department laboratory schedule for auditing methodology and quality control is every two years by Department of Ecology. All quality control reports as required for certification are maintained on-site in the lab. The responsible person is Thurston County microbiologist, Mike Clark, at (360) 786-5465. The Ecology staff who conducts the audits is Aimee Bennett from the Laboratory Accreditation Program.

Aquatic Research, Inc is certified by Ecology to perform the nutrient and chlorophyll analysis. The responsible person is Steve Lazoff, at (206) 632-2715. The Ecology staff who conducts the audits is Aimee Bennett from the Laboratory Accreditation Program. A copy of the Scope of Accreditation can be found in Appendix D.

Data Validation and Verification

Field and laboratory data will be verified and validated throughout the project and at the completion of the data collection period. The staff will verify in the field the measurement collected and upon completion of the instrument post-calibration process. The lab staff will verify all lab-generated data following standard protocol.

The project manager will validate the data according the data objective in this QA Project Plan.

APPENDIX A

THURSTON COUNTY

ENVIRONMENTAL HEALTH

QUALITY ASSURANCE PLAN

FOR

SURFACE WATER ANALYSIS

INTRODUCTION

To assure that routinely generated analytical data in the Thurston County Environmental Health Laboratory is scientifically valid and defensible, a regime of quality assurance procedures are in place. The following is a description of these procedures. Where appropriate reference is made to Standard Method for the Examination of Water and Wastewater, 16th Edition.

I. Sampling Procedures:

Upon receipt of a sample in our laboratory the date and time of receipt as well as the initials of the person receiving the sample is written on the accompanying sample information form. The sample is then either immediately placed in the laboratory refrigerator to await analysis or analysis is begun at once. Every attempt is made to begin analysis the same day that a sample is taken and in all cases within 24 hours.

To begin analysis, each sample is unwrapped and placed on it's accompanying form. The form is then examined for information completeness and accuracy and a decision is made whether to subject the sample to membrane filtration (MF) or multiple tube fermentation (MTF). Generally, sewage effluent and very turbid surface water samples are subjected to the MTF technique; all other samples are run MF. Each sample bottle and it's accompanying form are given a number and the 'date of analysis" is stamped on the form. The bottle and form are then separated and analysis is begun. The information on each form is computerized and printed out on a laboratory log sheet (See Dilution Log Book). Each test's data is then entered in the appropriate space on the log sheets next to the respective sample information.

After analysis, each sample bottle is autoclaved, emptied, washed, and sterilized according to Standard Methods Section 9040.

II. Measurements and Calibrations:

All instruments, reagents, and media are monitored regularly to assure their accuracy and performance. The following table summarizes the type of measurements or calibrations and their frequency:

INSTRUMENT OR MEDIA	TYPE OF MEASUREMENTS OR CALIBRATIONS	FREQUENCY
Autoclave	Sterilizing of spore strips. Maximum reg. thermometer timer accuracy	Monthly Quarterly Quarterly
Automatic Pipettor	Accuracy at 10ml.	Quarterly
pH Meter	To pH 4 and 7	Weekly
Conductivity Meter	To 10 Micromhos	Monthly
Thermometers	To incubator temperature with NBS thermometer	Annual
Balance	1mg. to 100gm	Quarterly
MF Funnels	To 100ml, 50ml, 20ml, 10ml	Annual
Air Incubator	To 35 $\pm$ .5 C	Twice Daily
Water Bath Incubator	To 44.5 $\pm$ .2 C	Twice Daily
Refrigerator	TO $\leq$ 5 C	Daily

Pure Water System	Conductivity Plate Count pH Chlorine Residual	Monthly
	Biological Suitability	Annual
	Trace Metals Analysis	Annual
Oven	Thermometer - 175 C Timer: 2 Hours	Annual Annual
UV Sterilizer	Effectiveness on Control Cultures as measured by plate count.	Biannual
Media	pH Control Cultures	Each Batch
Sample Bottles	Sterility	Each Batch
Buffer	pH Sterility	Each Batch

III. Data Reduction, Validation, and Reporting:

Data Reduction: MF fecal coliform analyses are performed on a variety of sample volumes in an attempt to produce a culture plate with twenty (20) to sixty (60) CFU's. Once the appropriate plate is counted, the colony number is converted to colony forming unites per 100ml. using the following formula.

$$\# \text{ colonies per 100ml} = \frac{\text{colonies counted X 100}}{\text{ML sample filtered}}$$

MTF serial dilutions are reported directly as fecal coliforms per 100ml. No data conversion is necessary.

Data Validation: Water bacteriological report forms are filled out and the data is rechecked against the log book data.

Reporting: All analytical data is reported directly to the individual who submitted the sample. A copy is kept on file by Thurston County Environmental Health. All data is also kept on computer disk.

IV. External Quality Control Checks:

Annual EPA proficiency samples are analyzed for total and fecal coliform bacteria by Membrane Filtration and Multiple Tube Fermentation.

V. Preventive Maintenance Procedures and Schedules:

Autoclave: Under contract with MDT Corporation - inspected and serviced four times per year:

MDT Corporation
177 E. Henrietta Road
Rochester, NY 14623

Mettier Balance: Serviced and calibrated annually by:

Quality Control Services
516 SE Morrison, Suite 213
Portland, Oregon 97214

Pure Water System: Maintained and serviced biannually by:

Continental Water Systems NW
PO Box 1084
Kent, Washington 98035

Other laboratory equipment is cleaned and serviced as necessary by laboratory personnel.

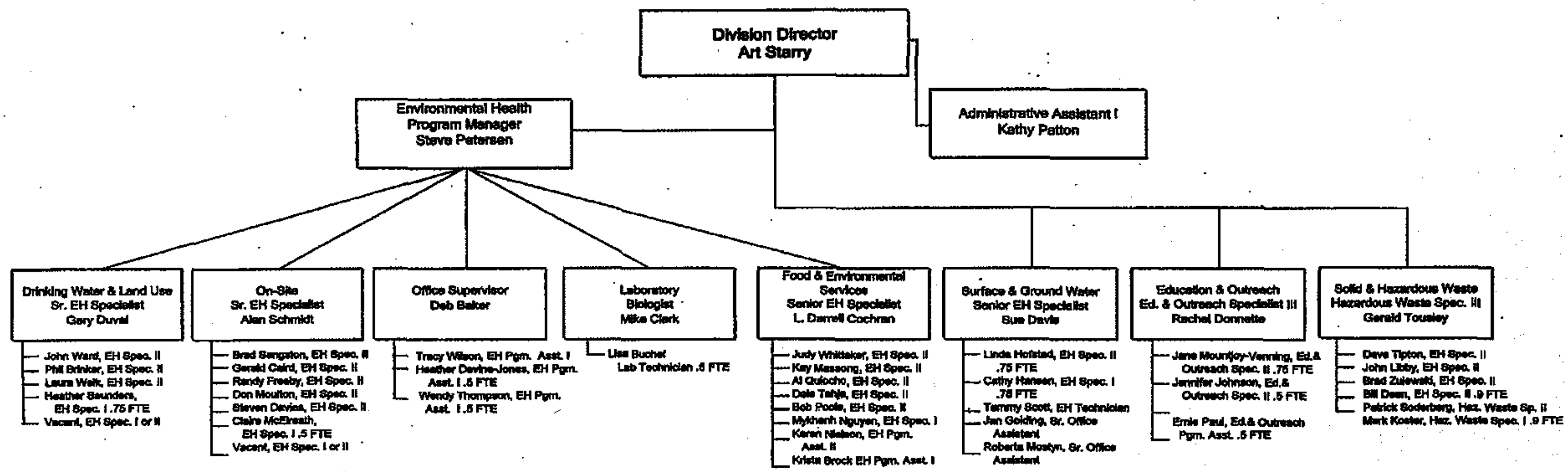
VI. Data Quality Control:

Ten percent (10%) of all growth positive countable MF plates are subcultured to verify up to ten colonies per plate and up to ten colony forming units per plate subcultured to EC broth. If there is a disparity between initial counts and verified counts, the final count is amended accordingly.

"Begin Run" and "End Run" controls are performed on each Membrane Filtration Series. If controls show any growth, the data from that MF series is deemed invalid and requests for new samples are made.

With MTF cultures (A-1 Broth), growth and gas positive tubes do not require further verification.

Environmental Health Division
Organization Chart



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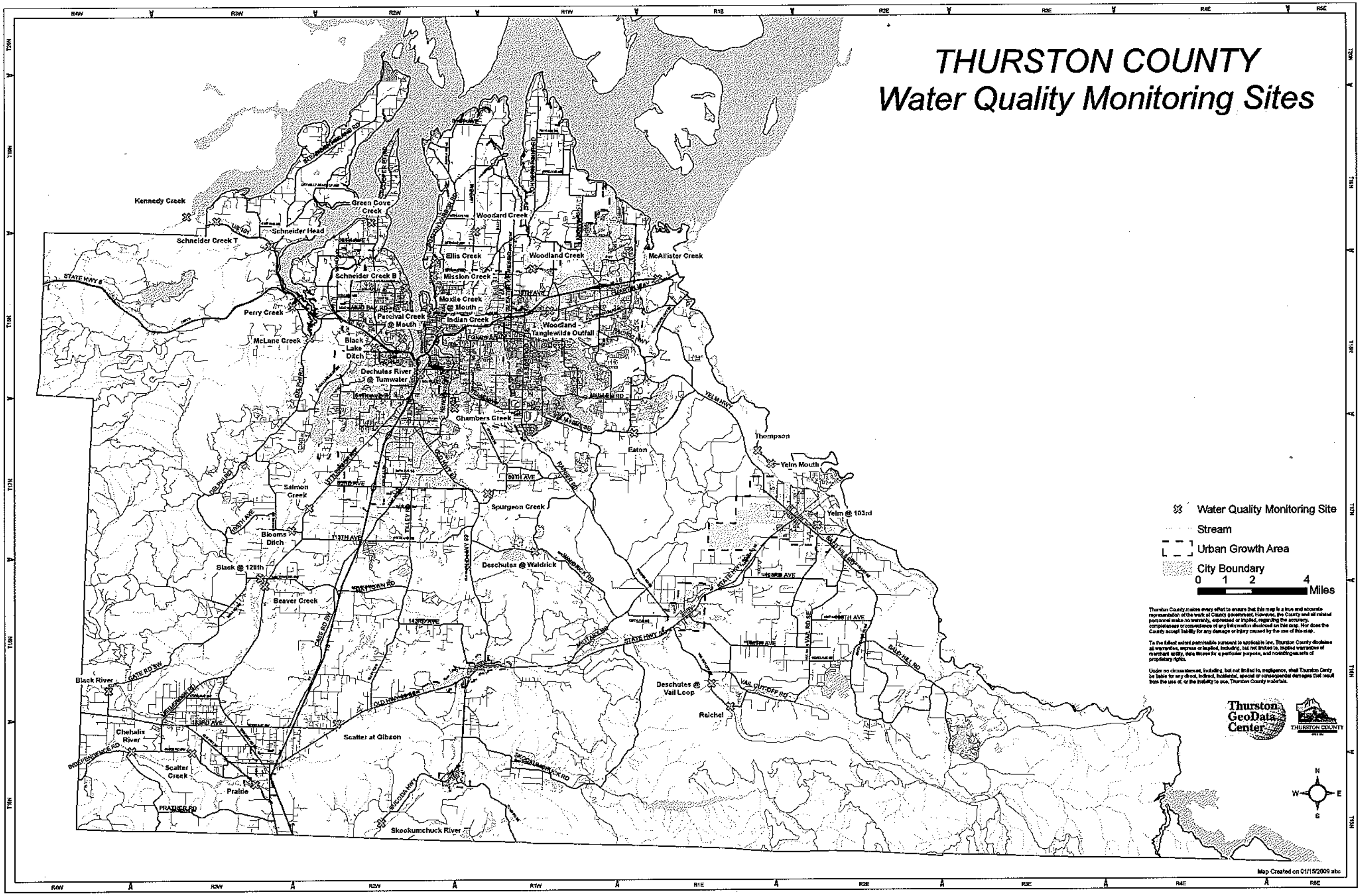
APPENDIX B


THURSTON COUNTY
Water Quality Monitoring Sites
Water Quality Monitoring Site
Stream
Urban Growth Area
City Boundary
0 1 2 4
Miles
Thurston GeoData Center
THURSTON COUNTY
Map Created on 01/15/2009 abc
Kennedy Creek
Schneider Creek T
Schneider Head
Green Cove Creek
Schneider Creek B
Perry Creek
McLane Creek
Black Lake Ditch
Percival Creek @ Mouth
Deschutes River @ Tumwater
Woodard Creek
Ellis Creek
Mission Creek
Moxlie Creek @ Mouth
Indian Creek
Woodland Creek
Woodland Tanglewilde Outfall
McAllister Creek
Chambers Creek
Eaton
Thompson
Yelm Mouth
Yelm @ 103rd
Salmon Creek
Spurgeon Creek
Blooms Ditch
Black @ 128th
Deschutes @ Waldrick
Beaver Creek
Black River
Chehalis River
Scatter Creek
Prairie
Scatter at Gibson
Skookumchuck River
Deschutes @ Vail Loop
Reichel

APPENDIX C

AQUATIC RESEARCH INCORPORATED
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER:	TCH031-74		PAGE 3
REPORT DATE:	05/30/08		
DATE SAMPLED:	05/19-21/08	DATE RECEIVED:	05/22/08

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM THURSTON COUNTY HEALTH / LAKES PROGRAM

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/l)	TOTAL-N (mg/l)	AMMONIA (mg/l)	NO3+NO2 (mg/l)
METHOD	SM18 4500PF	SM20 4500N-C	EPA 350.1	EPA 353.2
DATE ANALYZED	05/28/08	05/27/08	05/23/08	05/23/08
DETECTION LIMIT	0.002	0.100	0.010	0.010
DUPLICATE				
SAMPLE ID	CA2	CA2	BATCH	BATCH
ORIGINAL	0.022	0.558	0.020	0.330
DUPLICATE	0.022	0.558	0.021	0.331
RPD	0.55%	0.05%	6.32%	0.36%
SPIKE SAMPLE				
SAMPLE ID	CA2	CA2	BATCH	BATCH
ORIGINAL	0.022	0.558	0.020	0.330
SPIKED SAMPLE	0.078	1.63	0.208	0.531
SPIKE ADDED	0.050	1.00	0.200	0.200
% RECOVERY	112.67%	107.05%	94.15%	100.36%
QC CHECK				
FOUND	0.091	0.435	0.304	0.416
TRUE	0.090	0.435	0.324	0.408
% RECOVERY	100.88%	100.02%	93.75%	101.91%
BLANK	<0.002	<0.100	<0.010	<0.010

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

APPENDIX D

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Post Office Box 488 • Manchester, Washington 98353-0488 • (360) 895-6144

August 5, 2008

Mr. Steven Lazoff
Aquatic Research, Inc.
3927 Aurora Ave N
Seattle, WA 98103

Dear Mr Lazoff:

Thank you for submitting the information we requested in support of your accreditation for metals by ICP-MS. Here is a revised Scope of Accreditation showing full accreditation for all of the metals for which we have received satisfactory proficiency testing (PT) sample results. Accreditation will granted for silver and vanadium upon receipt of the necessary PT sample results.

If you have any questions concerning the accreditation of your lab, please contact me at (360) 895-6148, fax (360) 895-6180, or by e-mail at slom461@ecy.wa.gov.

Sincerely,

Stewart M. Lombard
Lab Accreditation Unit Supervisor

SML:sml
Enclosures

Scope of Accreditation

Aquatic Research, Inc.

Seattle, WA

is accredited by the State of Washington Department of Ecology to perform analyses for the parameters listed below using the analytical methods indicated. This Scope of Accreditation may apply to any of the following matrix types: non-potable water, drinking water, solid and chemical materials, and air and emissions. Accreditation for all parameters is final unless indicated otherwise in a note. Accreditation is for the latest version of a method unless otherwise specified in a note. EPA refers to the U.S. Environmental Protection Agency. SM refers to American Public Health Association's publication, Standard Methods for the Examination of Water and Wastewater, 18th, 19th or 20th Edition, unless otherwise noted. ASTM stands for the American Society for Testing and Materials. PSEP stands for Puget Sound Estuary Program. Other references are detailed in the notes section.

Matrix Type/Parameter Name	Reference	Method Number	Notes
Drinking Water			
Alkalinity, Total	SM	2320 B(4a)	
Color	SM	2120 B	
Cyanide, Total	SM	4500-CN E	
Fluoride	SM	4500-F C	
Hardness, Total (as CaCO3)	SM	2340 C	
Nitrate	SM	4500-NO3 F	
Nitrate + Nitrite	EPA	353.2	
Nitrite	SM	4500-NO3 F	
Orthophosphate	EPA	365.1	
Orthophosphate	SM	4500-P F	
Solids, Total Dissolved	SM	2540 C	
Specific Conductance	SM	2510 B	
Sulfate	SM	4500-SO4 E	
Sulfate	ASTM	D516-02	
Total Organic Carbon	SM	5310 B	
Turbidity	EPA	180.1	1
Aluminum	EPA	200.8	
Aluminum	SM 18/19	3113 B	
Aluminum	EPA	200.7	

Matrix Type/Parameter Name	Reference	Method Number	Notes
Antimony	EPA	200.8	
Antimony	SM 18/19	3113 B	
Arsenic	SM 18/19	3113 B	1
Arsenic	EPA	200.8	
Barium	EPA	200.7	
Barium	EPA	200.8	
Beryllium	EPA	200.8	
Beryllium	SM 18/19	3113 B	
Cadmium	EPA	200.8	
Cadmium	EPA	200.7	
Calcium	EPA	200.7	1
Chromium	EPA	200.7	
Chromium	EPA	200.8	
Copper	EPA	200.8	
Copper	EPA	200.7	
Copper	SM 18/19	3113 B	
Iron	EPA	200.7	
Iron	EPA	200.8	
Lead	EPA	200.8	
Lead	SM 18/19	3113 B	
Magnesium	EPA	200.7	
Manganese	EPA	200.8	
Manganese	EPA	200.7	
Mercury	EPA	245.1	
Mercury	EPA	200.8	
Nickel	EPA	200.7	
Nickel	EPA	200.8	
Selenium	EPA	200.8	
Selenium	SM 18/19	3113 B	
Silver	EPA	200.7	

THE SEAL OF THE STATE OF WASHINGTON 1889

Matrix Type/Parameter Name	Reference	Method Number	Notes
Sodium	EPA	200.7	
Thallium	EPA	200.8	
Zinc	EPA	200.8	
Zinc	EPA	200.7	
Chlorinated Pesticides	EPA	508.1	1
PCBs	EPA	508.1	1
Organic Compounds	EPA	525.2	1
Purgeable Organic Compounds	EPA	524.2	
Trihalomethanes	EPA	524.2	
Vinyl Chloride	EPA	524.2	1
Non-potable Water			
Acidity	SM	2310 B(4b)	
Alkalinity, Total	SM	2320 B(4b)	
Ammonia	EPA	350.1	
Ammonia	SM 18	4500-NH3 H	
Anionic Surfactants	SM	5540 C	
Biochemical Oxygen Demand, BOD/CBOD	SM	5210 B	
Chemical Oxygen Demand (COD)	SM	5220 D	
Chloride	SM	4500-Cl- C	
Color	SM	2120 B	
Cyanide, Total	SM	4500-CN E	
Fluoride	SM	4500-F C	
Hardness, Total (as CaCO3)	SM	2340 C	
Hexane Extractable Material	EPA	1664	
Nitrate	EPA	353.2	
Nitrate	SM	4500-NO3 F	
Nitrate + Nitrite	EPA	353.2	
Nitrogen, Total	SM 20	4500-N C	
Nitrogen, Total Kjeldahl	SM	4500-Norg C	
Nitrogen, Total Kjeldahl	EPA	351.1	

Matrix Type/Parameter Name	Reference	Method Number	Notes
Orthophosphate	SM	4500-P F	
Orthophosphate	EPA	365.1	
Phosphorus, Total	EPA	365.1	
Phosphorus, Total Persulfate	SM	4500-P F	
Solids, Total Dissolved	SM	2540 C	
Solids, Total Suspended	SM	2540 D	
Solids, Total Volatile	SM	2540 E	
Specific Conductance	SM	2510 B	
Sulfate	SM	4500-SO4 E	
Sulfate	ASTM	D516-02	
Sulfide	SM	4500-S2 D	
Sulfide	SM	4500-S2 F	
Total Organic Carbon	SM	5310 B	
Turbidity	SM	2130 B	
Aluminum	SM 18/19	3113 B	
Aluminum	EPA	200.7	
Aluminum	EPA	200.8	
Antimony	SM 18/19	3113 B	
Antimony	EPA	200.8	
Arsenic	EPA	200.8	
Arsenic	SM 18/19	3113 B	1
Barium	EPA	200.8	
Barium	EPA	200.7	
Beryllium	EPA	200.8	
Beryllium	SM 18/19	3113 B	
Boron	EPA	200.8	
Cadmium	EPA	200.7	
Cadmium	EPA	200.8	
Cadmium	SM 18/19	3113 B	
Calcium	EPA	200.7	

Matrix Type/Parameter Name	Reference	Method Number	Notes
Chromium	EPA	200.8	
Chromium	EPA	200.7	
Chromium	SM 18/19	3113 B	1
Copper	EPA	200.8	
Copper	SM 18/19	3113 B	
Copper	EPA	200.7	
Hardness, Total (as CaCO3)	EPA	200.7	1
Iron	EPA	200.7	
Iron	EPA	200.8	
Lead	EPA	200.7	1
Lead	SM 18/19	3113 B	
Lead	EPA	200.8	
Magnesium	EPA	200.7	
Manganese	EPA	200.7	
Manganese	EPA	200.8	
Mercury	EPA	1631	
Mercury	EPA	200.8	
Molybdenum	SM	3113 B	1
Molybdenum	EPA	200.8	
Nickel	EPA	200.7	
Nickel	EPA	200.8	
Potassium	EPA	200.7	1
Selenium	SM 18/19	3113 B	
Selenium	EPA	200.8	
Silica	EPA	200.7	
Silver	SM 18/18	3113 B	1
Silver	EPA	200.7	
Sodium	EPA	200.7	
Thallium	EPA	200.8	
Vanadium	EPA	200.7	1

Matrix Type/Parameter Name	Reference	Method Number	Notes
Zinc	EPA	200.7	
Zinc	EPA	200.8	
BNA Extr (Semivolatile) Organics	EPA	8270	
Volatile Organic Compounds	EPA	8260	
Fecal Coliform - count	SM	9222 D	2
Total & Fecal Coli - count	SM	9221 B1,2,C&E1	
Solid and Chemical Materials			
Aluminum	EPA	6010	1
Barium	EPA	6010	1
Beryllium	EPA	6010	1
Cadmium	EPA	6010	1
Calcium	EPA	6010	1
Chromium	EPA	6010	1
Cobalt	EPA	6010	1
Copper	EPA	6010	1
Iron	EPA	6010	1
Lead	EPA	6010	1
Manganese	EPA	6010	1
Molybdenum	EPA	6010	1
Nickel	EPA	6010	1
Silver	EPA	6010	1
Sodium	EPA	6010	1
Strontium	EPA	6010	1
Titanium	EPA	6010	1
Vanadium	EPA	6010	1
Zinc	EPA	6010	1
Glycols	EPA	8015	
Total Pet Hydrocarbons - Diesel	WDOE	NWTPH-Dx	1
BNA Extr (Semivolatile) Organics	EPA	8270	1

Matrix Type/Parameter Name	Reference	Method Number	Notes

Accredited Parameter Note Detail

(1) Provisional pending acceptable proficiency testing (PT) results (WAC 173-50-110). (2) Provisional pending receipt of eveidence that requirements in the microbiology audit report have been met.

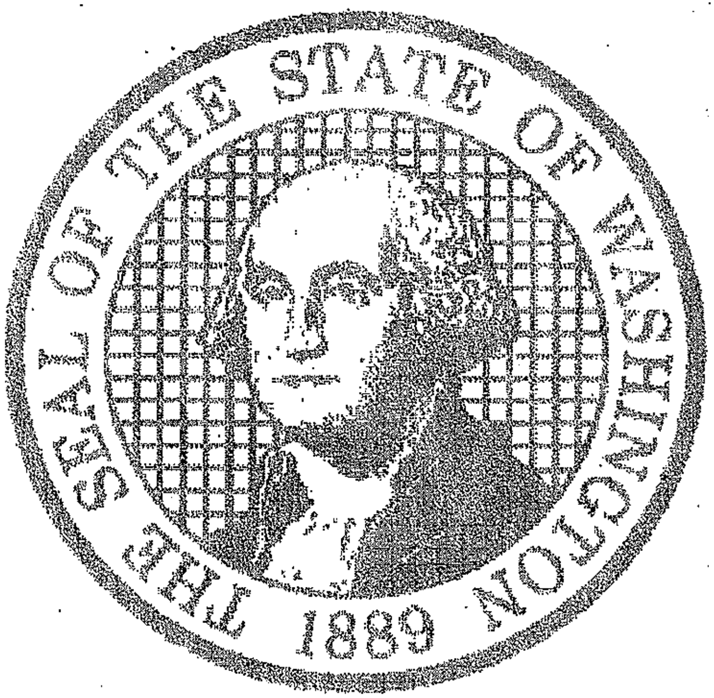
SM Lombard

Authentication Signature

August 5, 2008

Date

Stewart M. Lombard, Lab Accreditation Unit Supervisor



Appendix C:
QAPP Addendum to Support 2019 Capitol Lake Monitoring Program

QAPP Addendum to Support 2019 Capitol Lake Monitoring Program

The following includes data quality objectives for analytes not included in the adopted Thurston County Surface Water Ambient Monitoring Program Standard Operating Procedures and Analysis Methods (Appendix B). The analytes described in this Quality Assurance Project Plan (QAPP), which will supplement the Thurston County plan adopted for this project, include total organic carbon, total suspended solids, total volatile suspended solids and filtered and unfiltered BOD5. The QAPP also addresses methods for collecting phytoplankton species and biovolume data which are described in Attachment C.1.

SAMPLE HANDLING AND CUSTODY PROCEDURES

Additional analyte samples will be collected at sampling locations, and following sampling procedures outlined in Thurston County QAPP (Thurston County, 2009). All samples will be delivered on ice directly to the lab by field staff the same day as collection, apart from phytoplankton which will be preserved and mailed to the Aquatic Analysts. Sample chain of custody forms will be completed and enclosed in phytoplankton shipment.

Samples are to be analyzed at three separate laboratories, Table C1 indicates which analytes will be measured at each laboratory. Laboratories include:

- IEH Laboratory: Seattle, WA
- LabCor: Seattle, WA
- Aquatic Analysts: Friday Harbor, WA

Laboratory analytical procedures will follow USEPA approved methods (APHA 1998; USEPA 1983, 2015b). These methods provide detection limits that are below the state and federal regulatory criteria or guidelines, and they will enable direct comparison of analytical results with these criteria.

The laboratories identified for this project are certified by the Washington State Department of Ecology (Ecology) for each of the analytical parameters. IEH participates in audits and inter-laboratory studies by Ecology and USEPA. These performance and system audits have verified the adequacy of the laboratory standard operating procedures, which include preventative maintenance and data reduction procedures.

The laboratories will report the analytical results within 30 days of receipt of the samples. If necessary, the laboratory will provide draft results within hours of receipt of the samples. Sample and quality control data will be reported in a standard format. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Laboratory data quality objectives are listed below in Table C.1. Samples analyzed for phytoplankton species and biovolume data will following procedures included in Attachment C.1.

Table C.1

Analyte	Method	Holding Time	Method Reporting Limit	Control Sample Recovery (%)	Matrix Spike Recovery (%)	Duplicate Relative Percent Difference	Lab
TSS	SM 2540D	7 days	0.5 mg/L	80–120%	NA	≤20%	IEH
TVSS	SM 2540E	48 hrs	0.5 mg/L	80–120%	NA	≤20%	IEH
Total Organic Carbon	SM 5310B	7 days	0.25 mg/L	80–120%	NA	≤20%	IEH
BOD5	SM 5210B	48 hrs	4 mg/L	80–120%	NA	≤20%	IEH
Total Phosphorus	SM 4500PF	28 days	0.002 mg/L	80–120%	75–125%	≤20%	IEH
Soluble Reactive Phosphorus	SM 4500PF	48 hrs	0.001 mg/L	80–120%	75–125%	≤20%	IEH
Total Persulfate Nitrogen	SM 4500NC	28 days	0.05 mg/L	80–120%	75–125%	≤20%	IEH
Ammonia Nitrogen	SM 4500NH3H	7 days	0.01 mg/L	80–120%	75–125%	≤20%	IEH
Nitrate+Nitrite Nitrogen	SM 4500NO3F	48 hrs	0.01 mg/L	80–120%	75–125%	≤20%	IEH
Chlorophyll *a*	SM 10200H	28 days	0.1 µg/L	NA	NA	≤20%	IEH
Fecal Coliform/ *E. coli*	SM 9222 D	30 hrs	1 CFU/ 100 mL	NA	NA	≤ 35%	LabCor
Phytoplankton Cell/Biovolume	Microscope	6 mo	cells/mL	NA	NA	≤ 30%	AA

Abbreviations:

AA	Aquatic Analysts
BOD5	5-day biochemical oxygen demand
CFU	Colony-forming unit
hrs	Hours
IEH	IEH Laboratory
µg/L	Micrograms per liter
mg/L	Milligrams per liter
mL	Milliliters
mo	Months
NA	Not applicable
TSS	Total suspended solids
TVSS	Total volatile suspended solids

Attachment C.1

Aquatic Analysts

Algae Analytical and Quality Assurance Procedures

September 3, 2018

These quality assurance procedures have been adopted by the Capitol Lake – Deschutes Estuary Long-Term Management Project Environmental Impact Statement Project Team for collecting phytoplankton species and biovolume data. These procedures will supplement the Thurston County Surface Water Ambient Monitoring Program Standard Operating Procedures and Analysis Methods, which has been adopted for water quality sampling in Capitol Lake.

Sample Handling

Sample Collection and Preservation

Phytoplankton are collected by filling bottles with natural water samples. Samples are collected at either discrete depths, or integrated through the photic zone of lakes. A volume of 125 mL is sufficient for most samples.

These samples are preserved with 1% Lugol's solution immediately after collection. Refrigeration is not necessary, and holding times are a year or more.

Sample Tracking

All samples received in the laboratory are immediately logged into a Sample Receipt Log. All samples are stored in a dedicated area until they are processed. After samples are processed and analyzed and data reports have been submitted to clients, samples are placed in storage for at least one year.

Sample Preparation

Permanent microscope slides are prepared from each sample by filtering an appropriate aliquot of the sample through a 0.45 micrometer membrane filter (APHA Standard Methods, 1992, 10200.D.2; McNabb, 1960). A section is cut out and placed on a glass slide with immersion oil added to make the filter transparent, followed by placing a cover slip on top, with nail polish applied to the periphery for permanency. A benefit to this method is that samples can be archived indefinitely; we have nearly 35,000 slides archived.

Microscopic Analyses

Algae Identifications

Aquatic Analysts has an extensive library of algae literature, including journal reprints, standard reference books, and internet reference sites. We also maintain files, notes, and photographs of algae we've encountered during the past 35 years of identifying algae. Most algae are identified by cross-referencing several taxonomic sources.

Enumeration

Algal units (defined as discrete particles - either cells, colonies, or filaments) are counted along a measured transect of the microscope slide with a Zeiss standard microscope (1000X, phase contrast). Only those algae that were believed to be alive at the time of collection (intact chloroplast) are counted. A minimum of 100 algal units are counted. (Standard Methods, 1992, 10200.F.2.c.).

Biovolume Estimates

Average biovolume estimates of each species are obtained from calculations of microscopic measurements of each alga. The number of cells per colony is recorded during sample analysis to arrive at biovolume per unit-alga. Average biovolumes for algae are stored in a computer, and measurements are verified for each sample analyzed.

Data Analyses and Reports

Sample Reports

Results of sample and data analyses are provided to the client in electronic format. Deliverables include individual sample reports, data summaries, database file, and combined species lists.

Individual sample reports include sample identification, a trophic state index, total sample density, total sample biovolume, and a list of algae species with their absolute and relative densities and biovolumes. All data are reported in Excel format.

Data summaries include sample identification, total density, total biovolume, the trophic state index, and the top 5 most common algae species (codes) and their relative densities. The summary format allows for easy calculations and graphs of algae sample data.

Database files include information for each species from each sample within a sample set. Information includes sample ID, species names and codes, densities and biovolumes, taxonomic group, and any notes on each sample.

Combined species lists of all species within related groups of samples allow greater sensitivity in comparing different lakes, sites, dates, or depth. Algae species are compiled according to their relative densities.

Trophic State Index

A Trophic State Index based upon phytoplankton biovolume has been developed from a data set of several hundred lakes located throughout the Pacific Northwest (Sweet, 1986, Report to EPA). The index was derived in a similar fashion as Carlson (1977) derived indices for Secchi depth, chlorophyll concentration, and total phosphorus concentration. The biovolume index ranges from 1 for ultraoligotrophic lakes to 100 for hypereutrophic lakes. Values agree well with Carlson's indices.

The index is defined as:

TSI (biovolume) = (Log-base 2 (B+1)) * 5

Where B is the phytoplankton biovolume in cubic micrometers per milliliter divided by 1000.

TSI values below 20 are generally considered to be ultraoligotrophic, values from 20 to 35 are oligotrophic, 35 to 50 mesotrophic, 50 to 65 eutrophic, and above 65 is hypereutrophic.

Quality Assurance

Microscope Calibration

Aquatic Analysts use a Zeiss Standard phase-contrast microscope primarily with a 1000X magnification for identification and enumeration of algal samples. The diameter of the field of view at 1000X magnification is 0.182 mm. The effective area of a filter is 201 millimeters square.

Algae are enumerated along a measured transect, measured accurately to 0.1 mm with a stage micrometer. The algal densities are calculated from the area observed (transect length times diameter of field of view), the effective filter area, and the volume of sample filtered.

The microscope was calibrated using a standard concentration of latex spheres provided by EPA (Cincinnati, OH). The concentration of these spheres was 12,075 per milliliter. Duplicate preparations of the standard spheres were analyzed; the average result was 11,700 spheres per milliliter (96.9 percent). The computer program used to calculate algae densities compensates for this 3.1% error.

Replicates

Replicate algae samples are analyzed at the client's request. We encourage blind replicates for approximately 10% of all samples collected. Replicates are assessed for algae abundance (relative mean difference of densities) and species composition (similarity indices, species lists).

Independent Analyses

Aquatic Analysts has participated in the analyses of split algae samples on several occasions, with general agreement between samples in terms of algae density and algae species compositions. On occasion, we also contract independent algae analysts for second opinions on some difficult to identify algae species.

Internal Data Verification

A custom computer program handles all calculations and data analyses. Final sample reports are compared with laboratory bench sheets before releasing data.

Data summaries, tables of similarity indices, abundance graphs, and combined species lists are searched for inconsistencies, outliers, and interrupted patterns that may indicate possible errors.

Archives

Aquatic Analysts maintains an herbarium of all microscope slides analyzed (over 35,000 to date). These may be reviewed if questions arise after data are reported. In addition, all computer data (sample tracking data, raw count data, final reported data, data analyses, narrative reports) are archived on CD’s in permanent storage.

ADDENDUM TO APPENDIX A OF THE WATER RESOURCES DISCIPLINE REPORT

Water Resources Methodology for Capitol Lake – Deschutes Estuary, Section 7.0

Additions to Section 7.0 of the Water Resources Methodology report were made during the development of the water and phosphorus budgets. These changes to the methods were based on data availability and are all described in detail below for each budget.

Water Budget:

- Hydrograph separation was not needed because the concentration of TP was not correlated with the flow rate in the Deschutes River.
- Since Percival Creek flows were measured monthly, continuous water level gage data from an upstream site on Black Lake Ditch (water level gauge 44a), were used to model Percival Creek flows. This resulted in a continuous time series to more accurately represent the input to Capitol Lake.
- The area surrounding Capitol Lake has a high density of artesian wells that contribute to the total inflow to the lake. Following the hydrologic budget presented in Entranco (1984), ground water input was estimated as 10 wells each at 30 gpm. The magnitude of these flow rates was validated based on measurements taken by the EIS Project Team at two nearby wells in 2020 that were estimated to discharge at rates of 10 and 35 gpm.
- Monthly storage volumes for Capitol Lake were estimated with the use of a lake storage curve (NHC 2016) and lake level data from 2016-2019. Average lake level for each day was calculated using available data. The data were used to create a best fit 2^{nd} order polynomial, to estimate the lake level over time. This model was then combined with the storage curve to estimate the monthly storage volume for Capitol Lake.
- Evaporation was calculated using the Penman formula as a function of temperature, dewpoint, latitude, and elevation.
- Output over the dam was calculated as the residual from the water budget. Other sources and sinks were considered more accurate than any data or methods that could be used to determine dam outflow.

Phosphorus Budget:

- Average Deschutes River TP concentrations for the entire year were used each month to avoid concentration variability that would significantly alter TP loads.
- TP concentrations in rainfall (24 ug/L) were based on Ecology (2013).
- Groundwater concentrations were set at 435 µg/L based on the average concentrations at two nearby wells in 2020. This was much higher than the 76 µg/L used in Entranco (1984)
- Outlet concentration for the tide gate were assumed to be equal to the observed concentration in the surface water in the North Basin.
- Internal loading was not directly estimated since bottom DO data did not show signs of anoxia. Net internal loading is considered to be included in the calculated residual.

- When the residual (output-input) was negative, this was attributed to sedimentation. When the residual was positive, the unquantified sources were due to macrophyte decay, waterfowl excretion, and/or sediment release. Sedimentation is likely a constant ratio to the Deschutes River input, but the sign of the residual depends on the magnitude of the unquantified inputs.

Appendix B 2019 Water Quality Data for Capitol Lake and the Deschutes

APPENDIX B OVERVIEW

Appendix B summarizes the water quality monitoring data collected in 2019 by Herrera Environmental Consultants to augment the historical dataset and characterize the current conditions of both Capitol Lake and the Deschutes River. Samples were collected from May – October to be consistent with Thurston County-collected data. Capitol Lake was sampled near the surface and bottom at the same two stations Thurston County used in the past in the Middle and North Basin. An additional site located close to the eastern shore of the North Basin was monitored for FC and *E. coli* bacteria only. The Deschutes River was sampled near Tumwater Falls.

Table B-1. 2019 Capitol Lake Database																		
Date	5/28/2019			6/26/2019			7/24/2019			8/22/2019			9/24/2019			10/22/2019		
Location	MB	NB1	NB2	MB	NB1	NB2	MB	NB1	NB2	MB	NB1	NB2	MB	NB1	NB2	MB	NB1	NB2
FC (CFU/100 mL)	16	540	115	10	2	-	2	2	-	2	4	78	64	7	9	171	35	44
Ec (CFU/100 mL)	11	335	68	10	2	-	2	2	-	2	4	66	54	7	4	171	35	44
S-Temp (C)	16.8	17.8	-	18.8	20.2	-	19	20.9	-	18.5	20.3	-	15.4	16.5	-	11.9	11.7	-
B-Temp (C)	16.5	16.3	-	17.2	17.5	-	-	18.6	-	18	19.5	-	14.3	15.8	-	11	10.9	-
S-DO (mg/L)	9.75	12.04	-	14.25	13.28	-	9.01	11.34	-	9.56	11.44	-	9.74	13.54	-	10.69	10.39	-
B-DO (mg/L)	10.92	7.39	-	12.41	12.81	-	-	7.01	-	9.12	4.28	-	10.06	10.77	-	10.07	10.46	-
S-Cond (uS/cm)	136.5	526	-	139.8	149.8	-	146.7	143	-	149.4	435.2	-	147.5	470.7	-	98.2	188.7	-
B-Cond (uS/cm)	137.7	850	-	142.8	143.8	-	-	160	-	150.1	570	-	147.4	383.1	-	100.5	285.1	-
S-pH	7.74	8.67	-	8.93	9.44	-	7.64	9.34	-	7.8	9.16	-	7.69	8.89	-	7.31	7.2	-
B-pH	8.01	7.6	-	8.62	8.88	-	-	8.35	-	7.92	8.07	-	7.71	8.82	-	7.07	7.21	-
S- TP (mg/L)	0.036	0.035	-	0.07	0.061	-	0.445	0.071	-	0.106	0.084	-	0.608	0.117	-	0.038	0.046	-
B-TP (mg/L)	-	0.039	-	-	0.062	-	-	0.047	-	-	0.072	-	-	0.061	-	-	0.048	-
S-SRP (mg/L)	0.014	0.002	-	0.043	0.014	-	0.269	0.036	-	0.061	0.029	-	0.284	0.048	-	0.018	0.015	-
B-SRP (mg/L)	-	0.003	-	-	0.021	-	-	0.009	-	-	0.028	-	-	0.012	-	-	0.019	-
S-Ammonia (mg/L)	0.075	0.019	-	0.08	0.22	-	0.139	0.01	-	0.055	0.01	-	0.069	0.021	-	0.034	0.05	-
B-Ammonia (mg/L)	-	0.032	-	-	0.045	-	-	0.01	-	-	0.022	-	-	0.022	-	-	0.046	-
S-N+N (mg/L)	0.418	0.243	-	0.273	0.01	-	0.264	0.03	-	0.298	0.05	-	0.445	0.072	-	0.794	0.801	-
B-N+N (mg/L)	-	0.296	-	-	0.014	-	-	0.043	-	-	0.074	-	-	0.094	-	-	0.766	-
S-TN (mg/L)	0.501	0.501	-	0.514	0.349	-	0.604	0.298	-	0.699	0.289	-	0.586	0.43	-	0.998	1.08	-
B-TN (mg/L)	-	0.449	-	-	0.455	-	-	0.365	-	-	0.308	-	-	0.427	-	-	1.08	-
S-Chlor (ug/L)	6.7	17	-	3.5	9.9	-	4.2	8	-	4.3	9.9	-	2.7	36	-	1.6	4	-
B-Chlor (ug/L)	-	17	-	-	12	-	-	7.7	-	-		-	-		-	-	3.7	-
S-Phaeo (ug/L)	2.3	4.3	-	1.6	2.1	-	1	0.9	-	1.7	3.4	-	2.2	5.9	-	1.6	3.3	-
B-Phaeo (ug/L)	-	4.2	-	-	1	-	-	3.3	-	-		-	-		-	-	3.4	-
S-TSS (mg/L)	4	3.5	-	1.3	2.3	-	1.3	2.3	-	1.6	2.5	-	0.67	3.7	-	2	1.5	-
B-TSS (mg/L)	-	3.4	-	-	4.3	-	-	2.7	-	-	0.75	-	-	3.3	-	-	2.5	-
S-VSS (mg/L)	2	1.8	-	0.67	2	-	1	1.3	-	0.8	1.8	-	0.67	2.3	-	1.5	1	-
B-VSS (mg/L)	-	1.4	-	-	3.7	-	-	1.3	-	-	0.75	-	-	2.3	-	-	0.5	-
S-TOC (mg/L)	1.35	1.65	-	1.36	1.74	-	1.58	1.62	-	1.26	1.63	-	2	1.97	-	5.76	6.66	-
B-TOC (mg/L)	-	1.59	-	-	1.57	-	-	1.65	-	-	1.59	-	-	5.3	-	-	5.91	-
S-DOC (mg/L)	1.16	1.64	-	1.31	1.7	-	1.41	1.57	-	1.11	1.59	-	1.75	1.73	-	5.24	6.41	-
B-DOC (mg/L)	-	1.52	-	-	1.54	-	-	1.65	-	-	1.55	-	-	1.77	-	-	4.58	-
S-BOD5 (mg/L)	2	2.46	-	2.36	2.9	-	2	2	-	2	2	-	2	2.14	-	2	2	-
B-BOD5 (mg/L)	-	2	-	-	2.46	-	-	2	-	-	2	-	-	2	-	-	2	-
Secchi (m)	2.2	1.37	-	-	-	-	1.8	2.01	-	2.2	2.07	-	2.01	1.16	-	1.4	1.37	-

Red letters indicate values below the detection limit

S = Surface; B = Bottom

Table B-2. 2019 Dechutes River Database Measured at Tumwater Falls Park				
Date	7/16/2019	8/21/2019	9/17/2019	10/15/2019
Total Phosphorus (mg/L)	0.034	0.029	0.042	0.025
SRP (mg/L)	0.019	0.014	0.016	0.018
Total Nitrogen (mg/L)	0.843	0.714	0.866	0.711
TSS (mg/L)	2	0.5	3.7	0.6
VSS (mg/L)	1	0.5	2	0.5
TOC (mg/L)	0.981	0.838	1.42	4.08
BOD5 (mg/L)	2	2	2	2
Dissolved BOD5 (mg/L)	2	2	2	2

Red letters indicate values below the detection limit

Appendix C 2019 Data Lab Reports and QA

APPENDIX C OVERVIEW

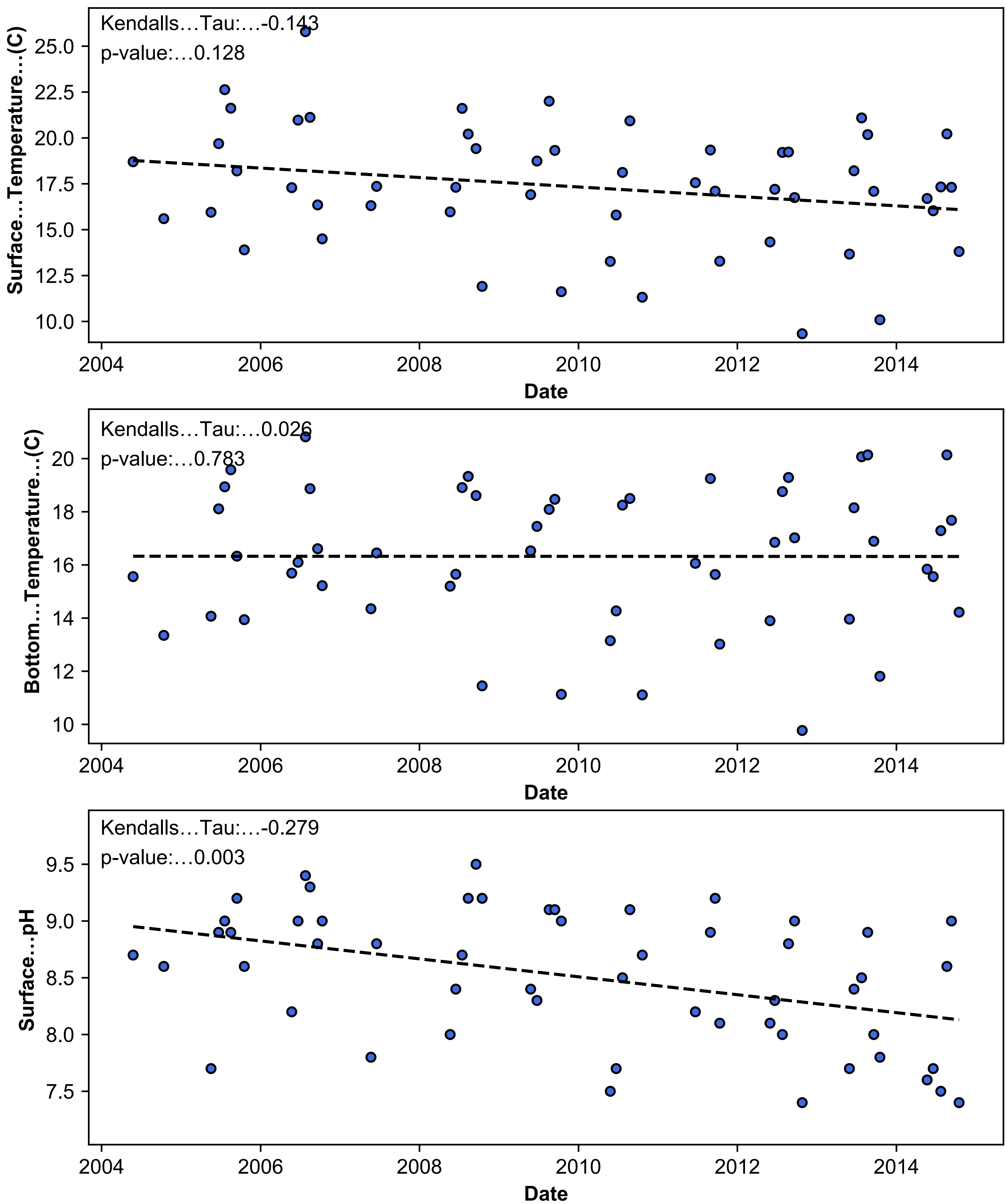
Appendix C summarizes the phytoplankton data collected in 2019 as part of the water quality monitoring effort to characterize the current state of Capitol Lake. Samples were collected on a monthly basin at the surface from May through October in the North Basin at NB-1 and in the Middle Basin at MB (Figure 3.1; WRDR). The tables presented here summarize the data by phytoplankton species group for each sampling event based on total count and biovolume.

Middle Basin - Surface														
	5/28/2019		6/26/2019		7/25/2019		8/22/2019		9/24/2019		10/22/2019		Average	
Group	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume
Diatom (%)	95	94	52	86	56	84	68	78	79	80	98	98	75	87
Cryptophyte (%)	1	0	41	10	27	8	16	14	13	14	1	0	17	8
Dinoflagellate (%)	2	5	2	2	0	0	0	0	0	0	0	0	1	1
Chrysophyte (%)	0	0	4	0	4	1	2	0	1	0	0	0	2	0
Bluegreen (%)	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Green (%)	1	0	0	0	13	8	13	8	7	5	1	2	6	4

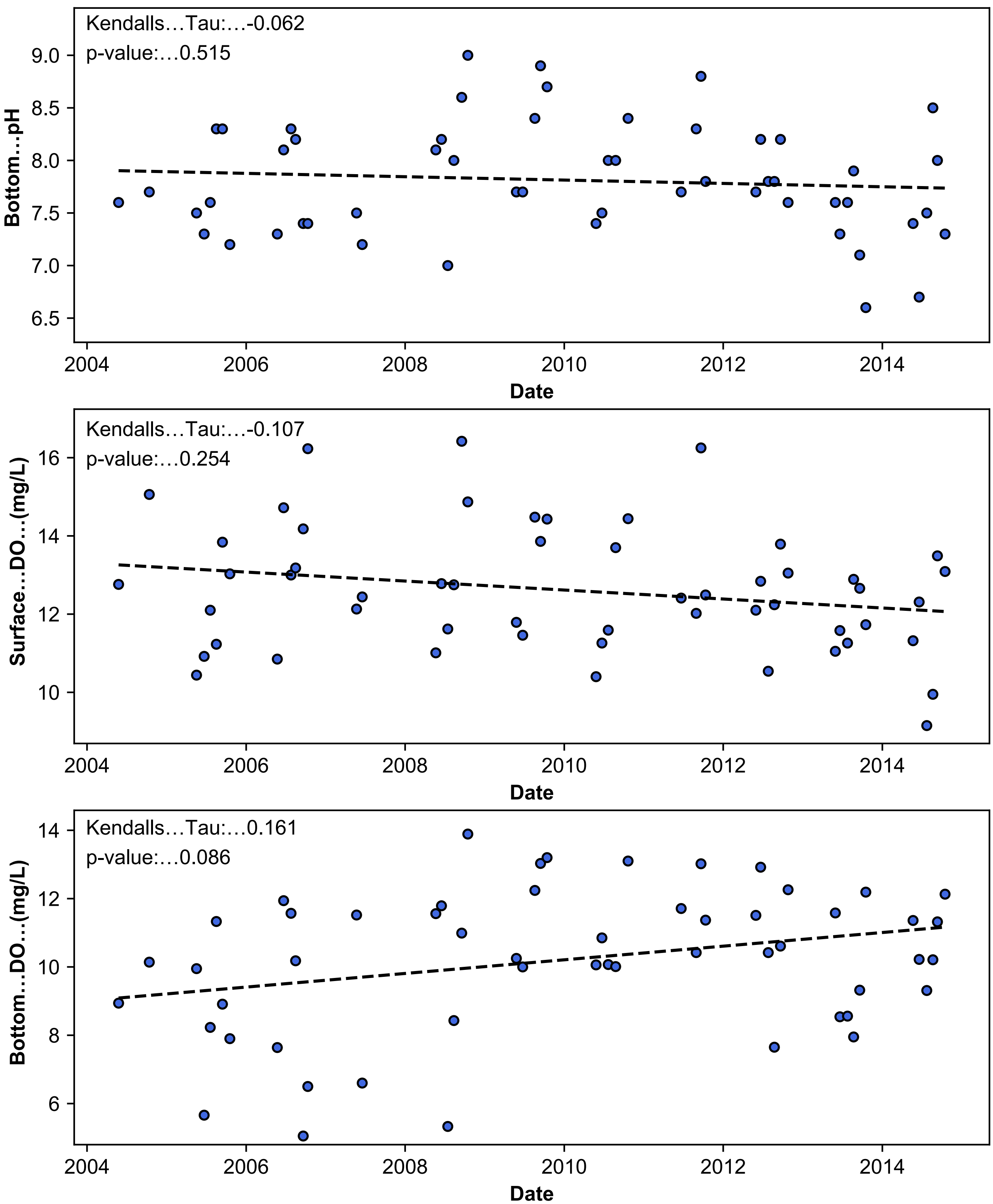
North Basin - Surface														
	5/28/2019		6/26/2019		7/25/2019		8/22/2019		9/24/2019		10/22/2019		Average	
Group	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume
Diatom (%)	94	96	90	87	75	81	91	84	99	98	84	75	89	87
Cryptophyte (%)	3	0	9	11	22	12	5	2	1	1	13	19	9	8
Dinoflagellate (%)	1	2	0	0	0	0	0	2	0	0	0	0	0	1
Chrysophyte (%)	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Bluegreen (%)	0	0	0	0	1	6	1	9	0	0	1	4	0	3
Green (%)	1	1	1	2	1	0	2	3	0	0	2	2	1	1

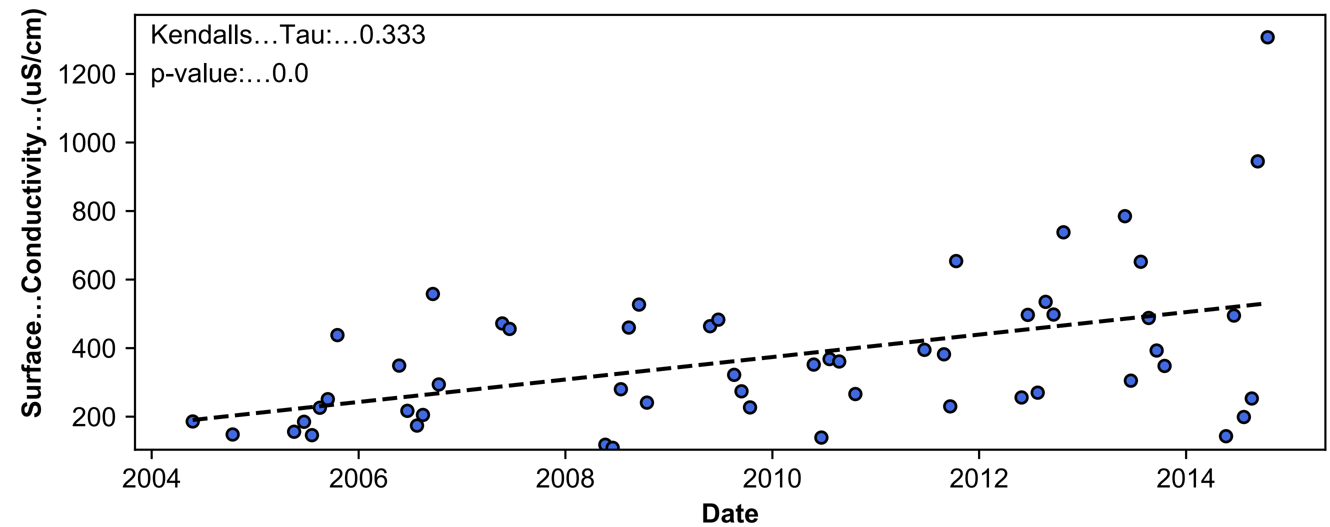
Appendix D Kendall's Tau Correlation Analysis Plots

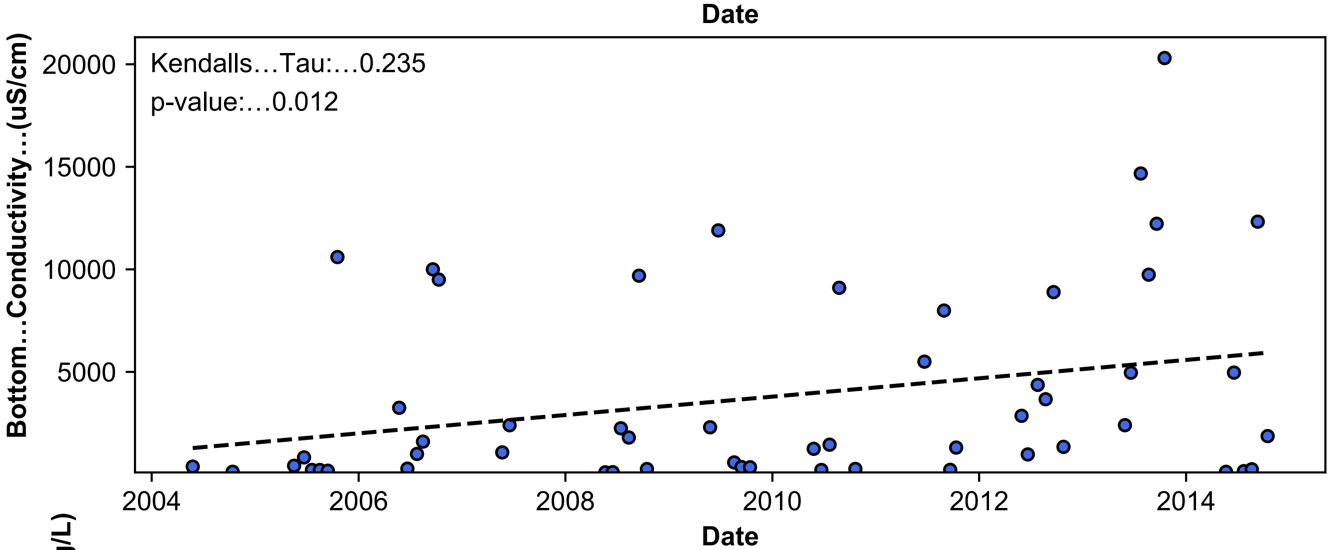
Appendix D displays all the graphs associated with the Kendall's Tau trend analyses results in Tables 4.1 and 4.2 of the Water Resources Discipline Report for Capitol Lake and the Deschutes River, respectively. The data presented in the graphs was collected from 2004-2015 at Tumwater Falls and NB-1 (Figure 3.1; WRDR) which represents Deschutes River and Capitol Lake, respectively. Temporal trends were evaluated using Kendall's Tau rank correlation coefficients (Kendall 1938) and the associated p-value. Kendall's Tau was the selected method as it is not strongly impacted by small sample sizes or irregular values (Helsel and Hirsch 1992). For trends to be considered significant, the associated p-values must be less than 0.05. The trends are determined to be positive or negative from the calculated Tau for the related time series. The Tau value indicates the sign of the trend and can be either positive (increasing) or negative (decreasing). For water quality variables a positive or negative trend can signify improving or worsening conditions depending upon the variable. Note, the best fit line shown on the figures is calculated separately from the Kendall's Tau and is only displayed to better visualize the temporal trend.

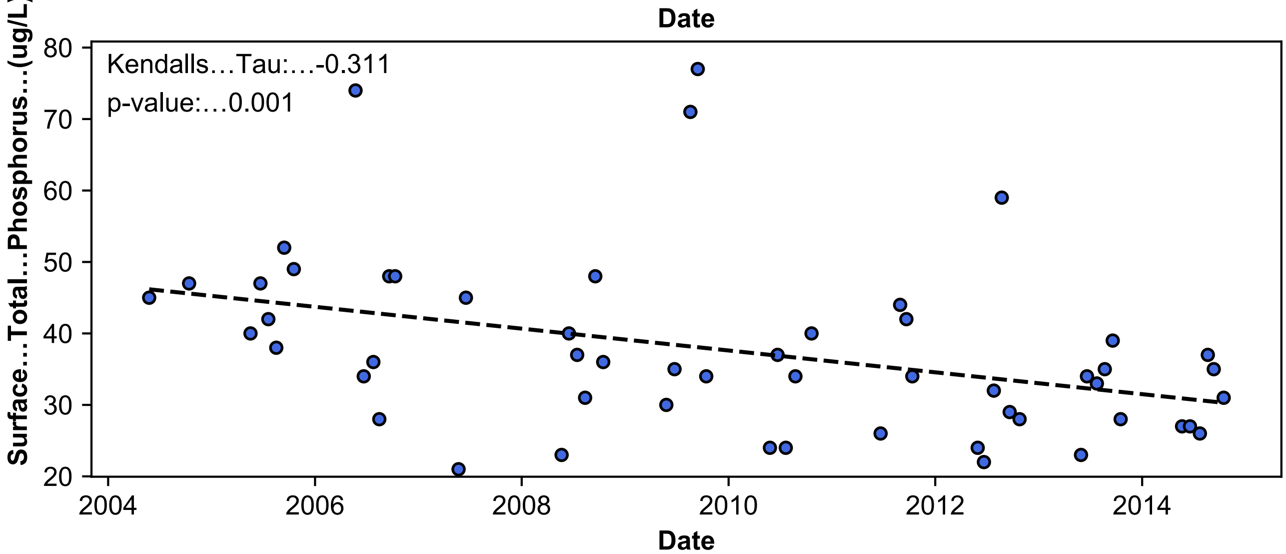


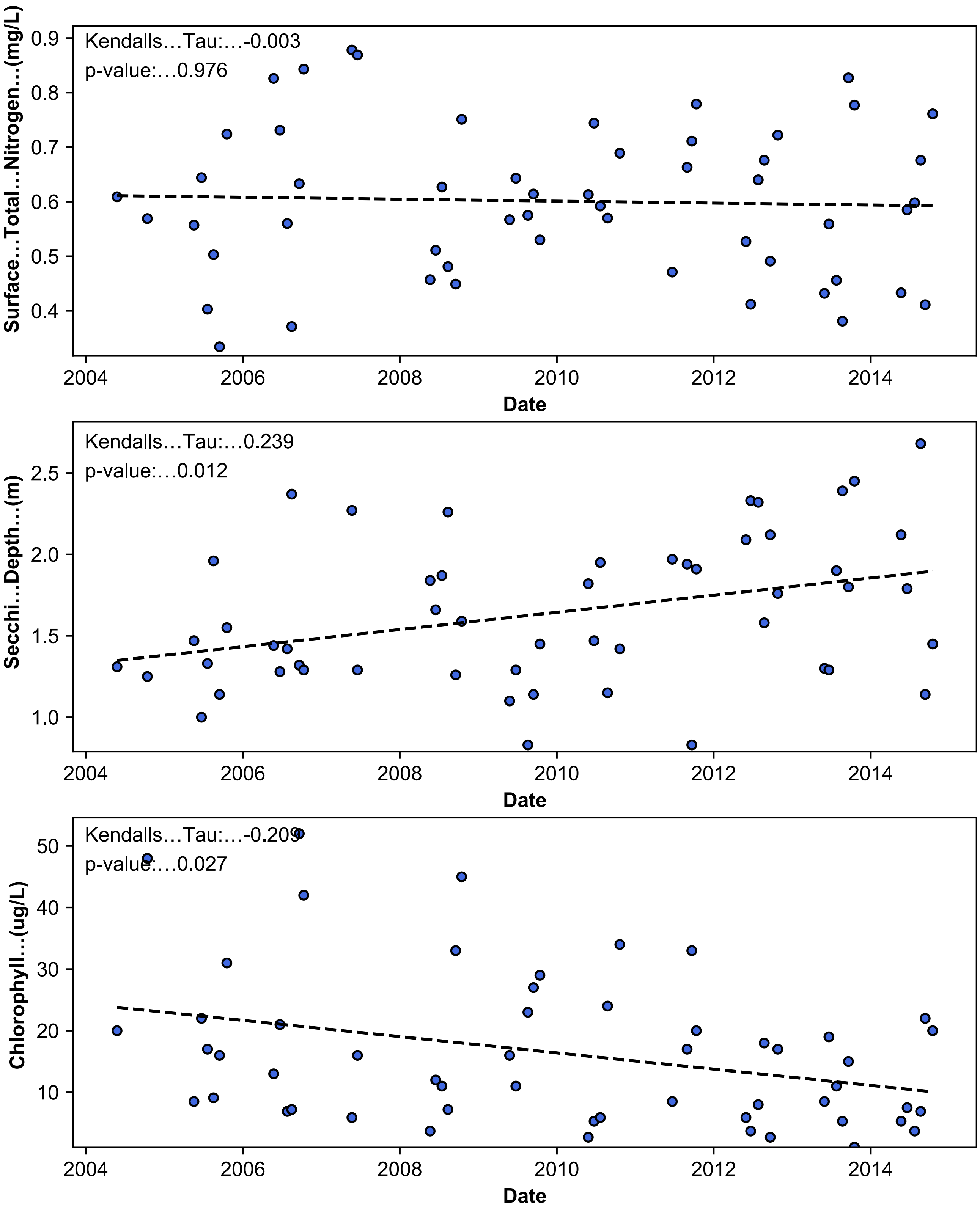
Kendalls…Tau:…-0.143
p-value:…0.128
Surface…Temperature…(C)
25.0
22.5
20.0
17.5
15.0
12.5
10.0
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.026
p-value:…0.783
Bottom…Temperature…(C)
20
18
16
14
12
10
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.279
p-value:…0.003
Surface…pH
9.5
9.0
8.5
8.0
7.5
2004
2006
2008
2010
2012
2014
Date

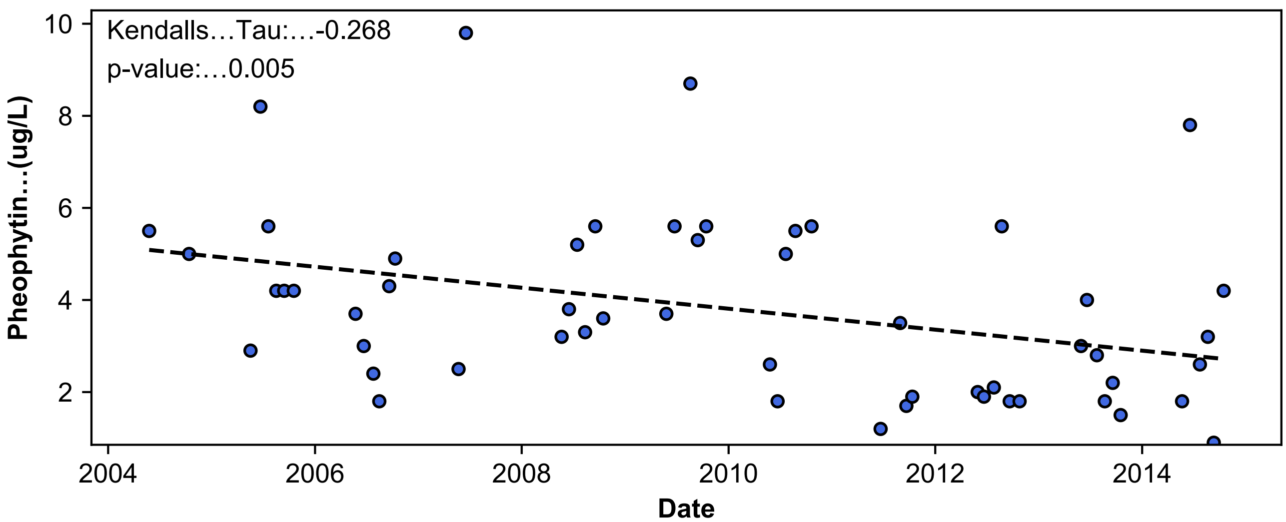

Kendalls…Tau:…-0.062
p-value:…0.515
Bottom…pH
9.0
8.5
8.0
7.5
7.0
6.5
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.107
p-value:…0.254
Surface…DO…(mg/L)
16
14
12
10
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.161
p-value:…0.086
Bottom…DO…(mg/L)
14
12
10
8
6
2004
2006
2008
2010
2012
2014
Date

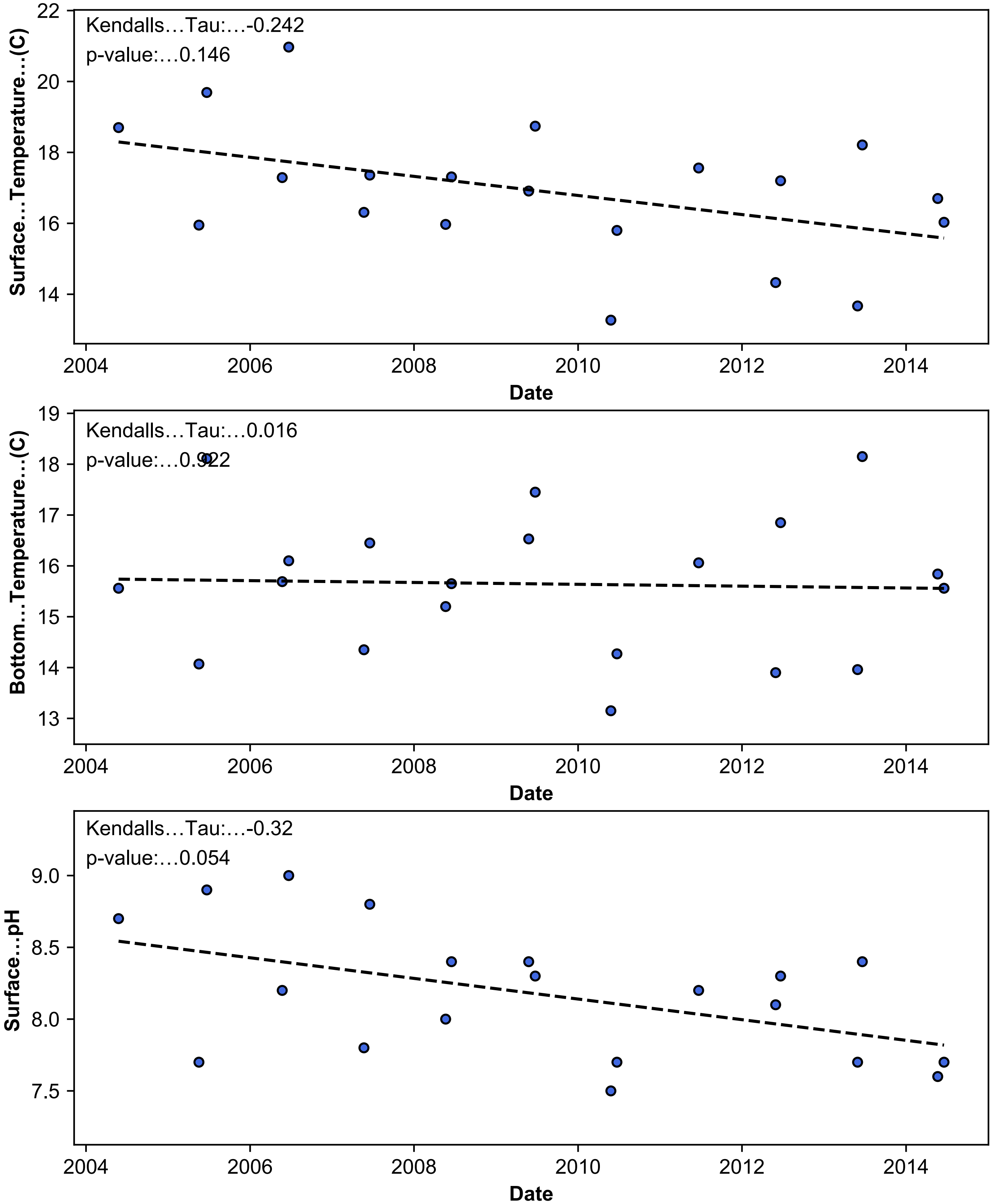

Kendalls…Tau:…0.333
p-value:…0.0
Surface…Conductivity…(uS/cm)
1200
1000
800
600
400
200
2004
2006
2008
2010
2012
2014
Date

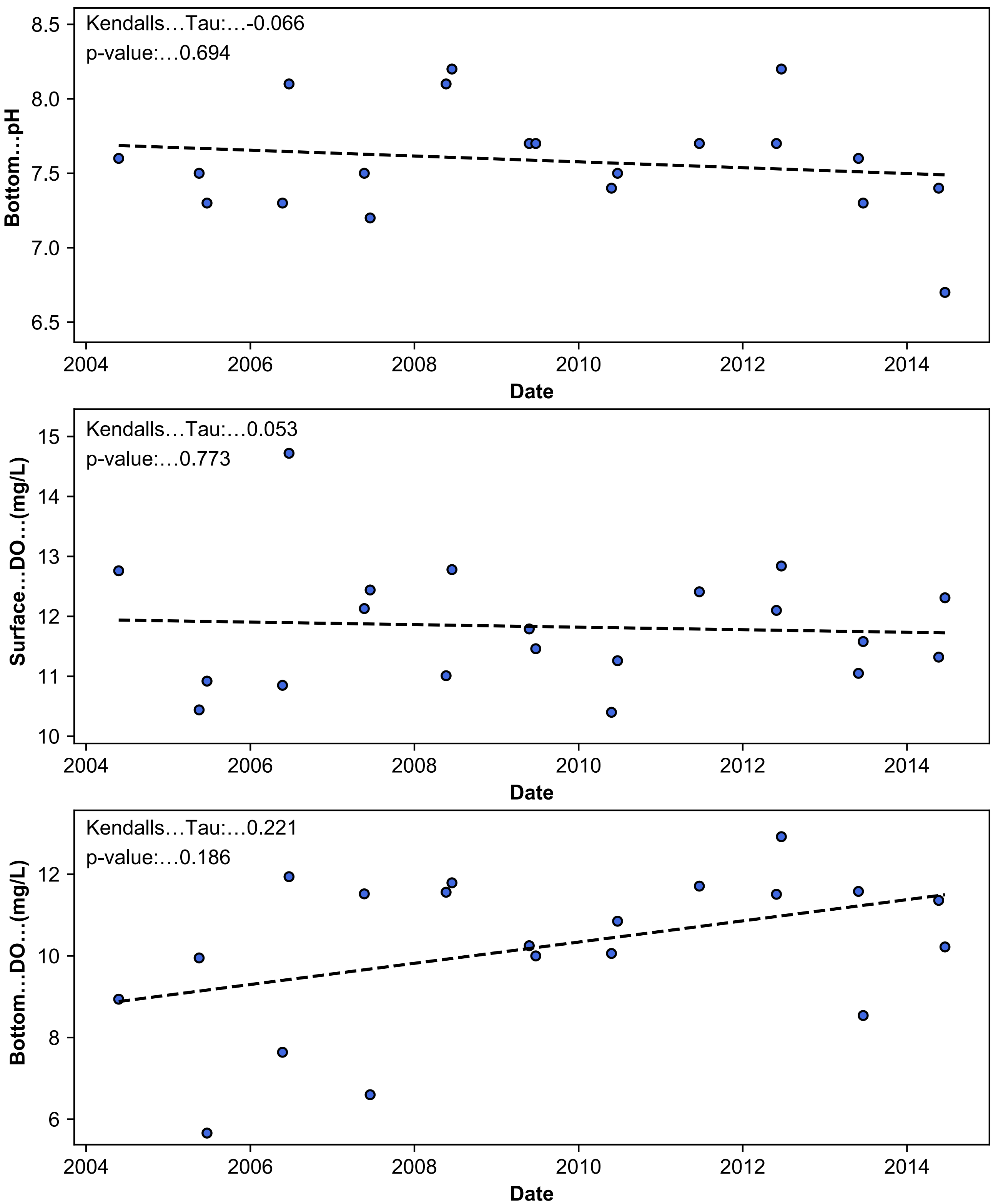

Kendalls…Tau:…0.235
p-value:…0.012
Bottom…Conductivity…(uS/cm)
20000
15000
10000
5000
2004
2006
2008
2010
2012
2014
Date

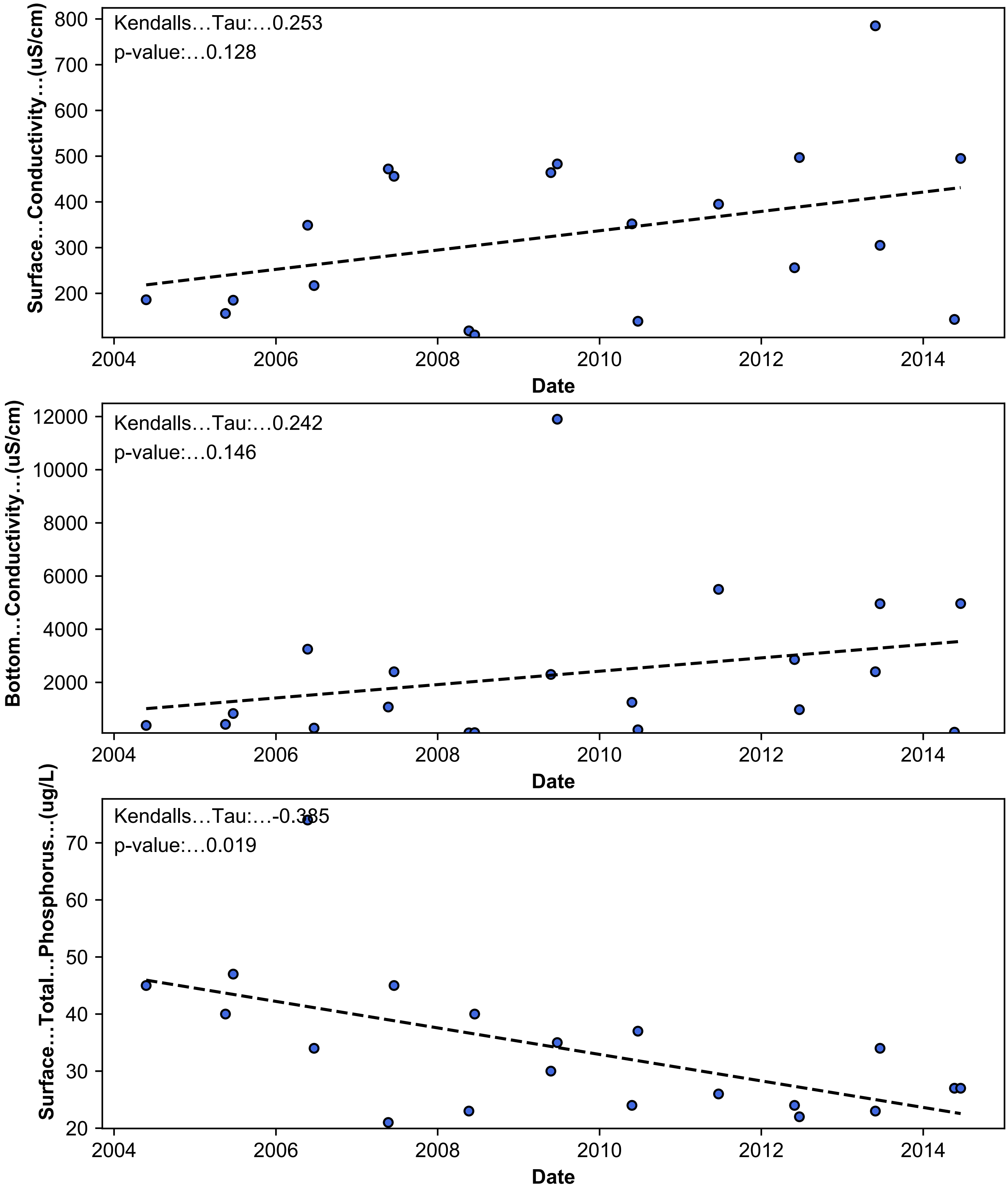

Kendalls…Tau:…-0.311
p-value:…0.001
Surface…Total…Phosphorus…(ug/L)
80
70
60
50
40
30
20
2004
2006
2008
2010
2012
2014
Date

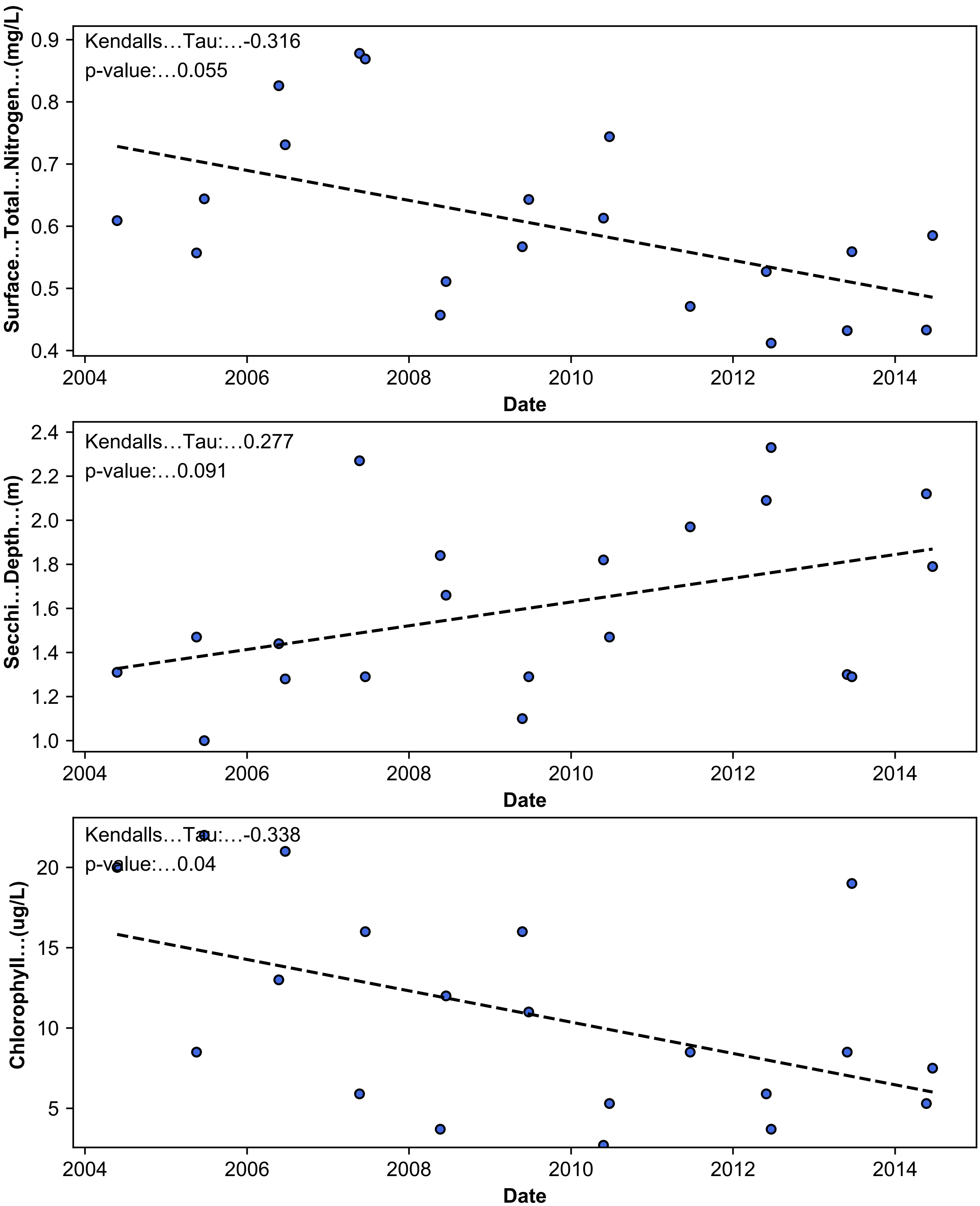

Kendalls…Tau:…-0.003
p-value:…0.976
Surface…Total…Nitrogen…(mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
Date
Kendalls…Tau:…0.239
p-value:…0.012
Secchi…Depth…(m)
2.5
2.0
1.5
1.0
Date
Kendalls…Tau:…-0.209
p-value:…0.027
Chlorophyll…(ug/L)
50
40
30
20
10
2004
2006
2008
2010
2012
2014
Date


Kendalls…Tau:…-0.268
p-value:…0.005
Pheophytin…(ug/L)
10
8
6
4
2
2004
2006
2008
2010
2012
2014
Date

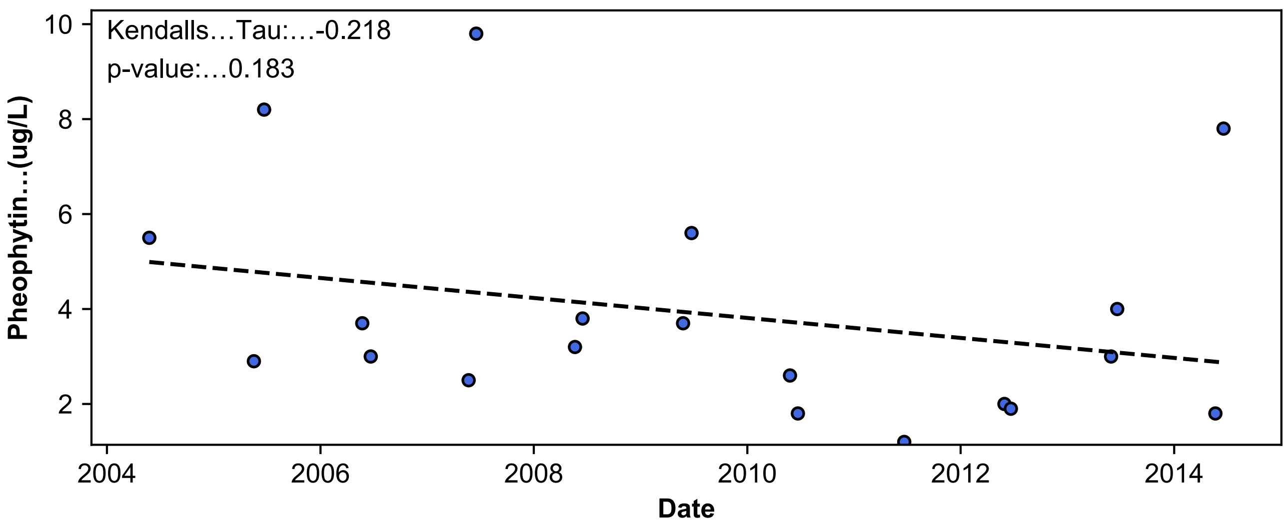

Kendalls…Tau:…-0.242
p-value:…0.146
Surface…Temperature…(C)
Date
Kendalls…Tau:…0.016
p-value:…0.922
Bottom…Temperature…(C)
Date
Kendalls…Tau:…-0.32
p-value:…0.054
Surface…pH
Date

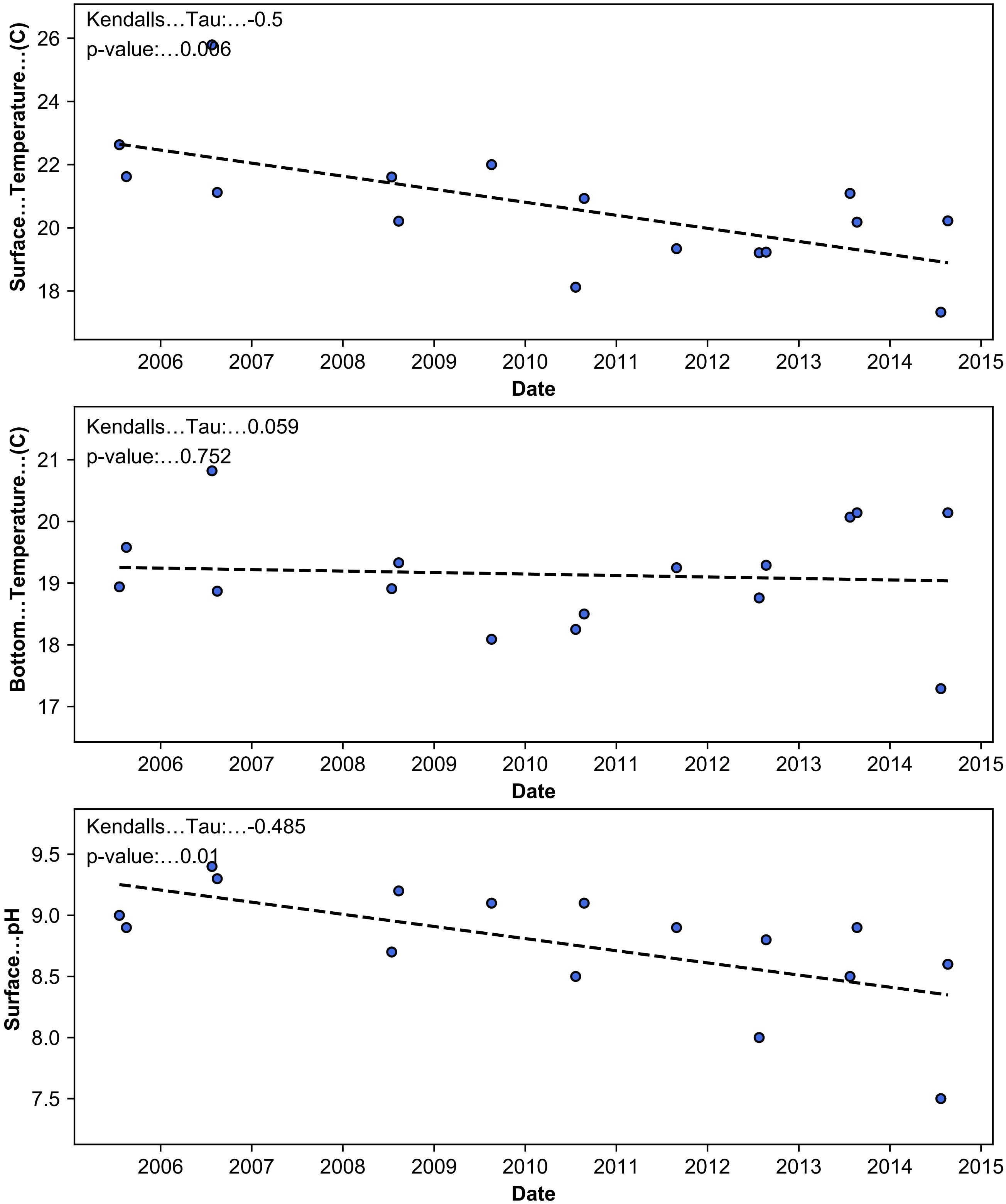

Kendalls…Tau:…-0.066
p-value:…0.694
Bottom…pH
8.5
8.0
7.5
7.0
6.5
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.053
p-value:…0.773
Surface…DO…(mg/L)
15
14
13
12
11
10
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.221
p-value:…0.186
Bottom…DO…(mg/L)
12
10
8
6
2004
2006
2008
2010
2012
2014
Date


Kendalls…Tau:…0.253
p-value:…0.128
Surface…Conductivity…(uS/cm)
800
700
600
500
400
300
200
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.242
p-value:…0.146
Bottom…Conductivity…(uS/cm)
12000
10000
8000
6000
4000
2000
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.385
p-value:…0.019
Surface…Total…Phosphorus…(ug/L)
70
60
50
40
30
20
2004
2006
2008
2010
2012
2014
Date

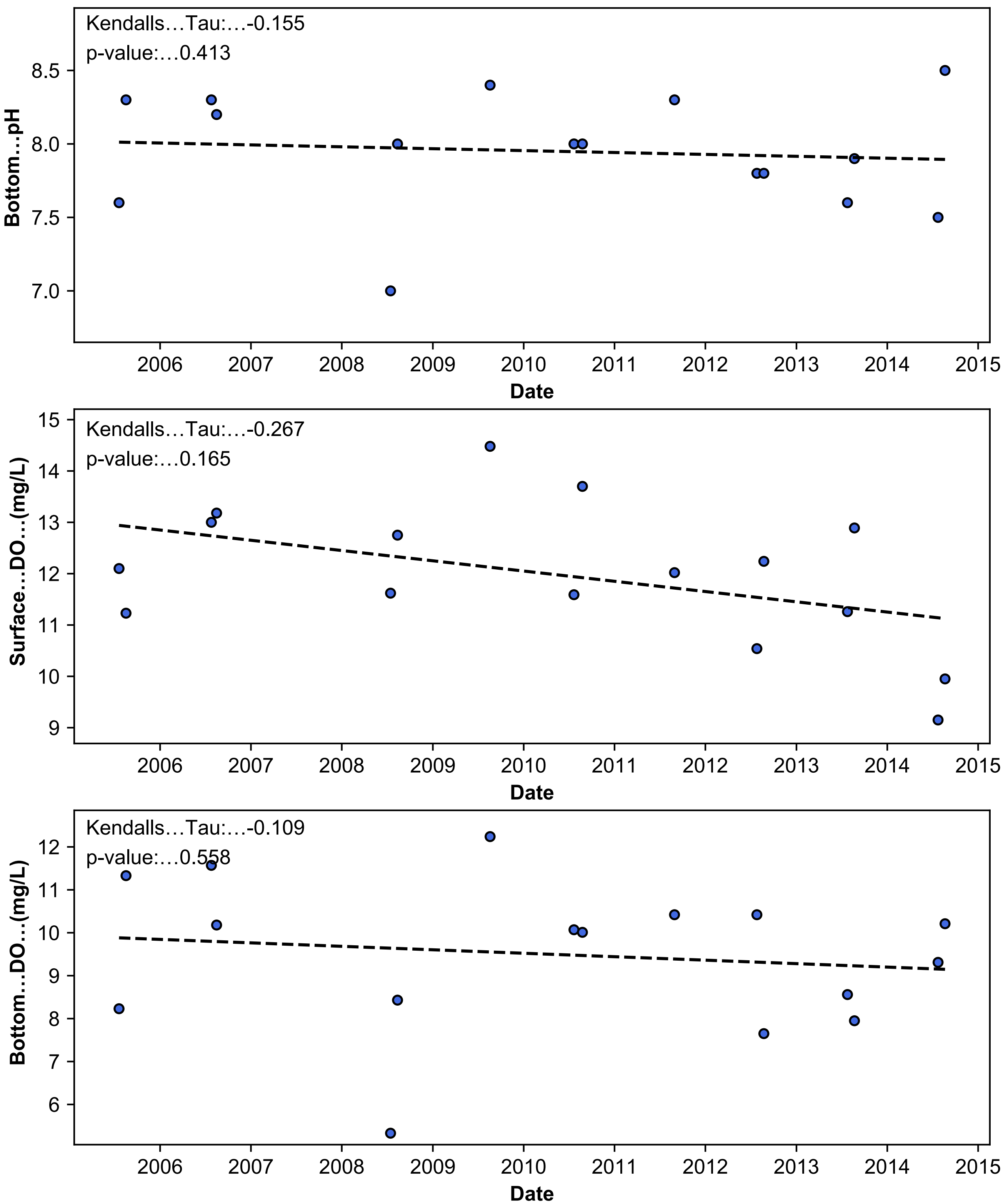


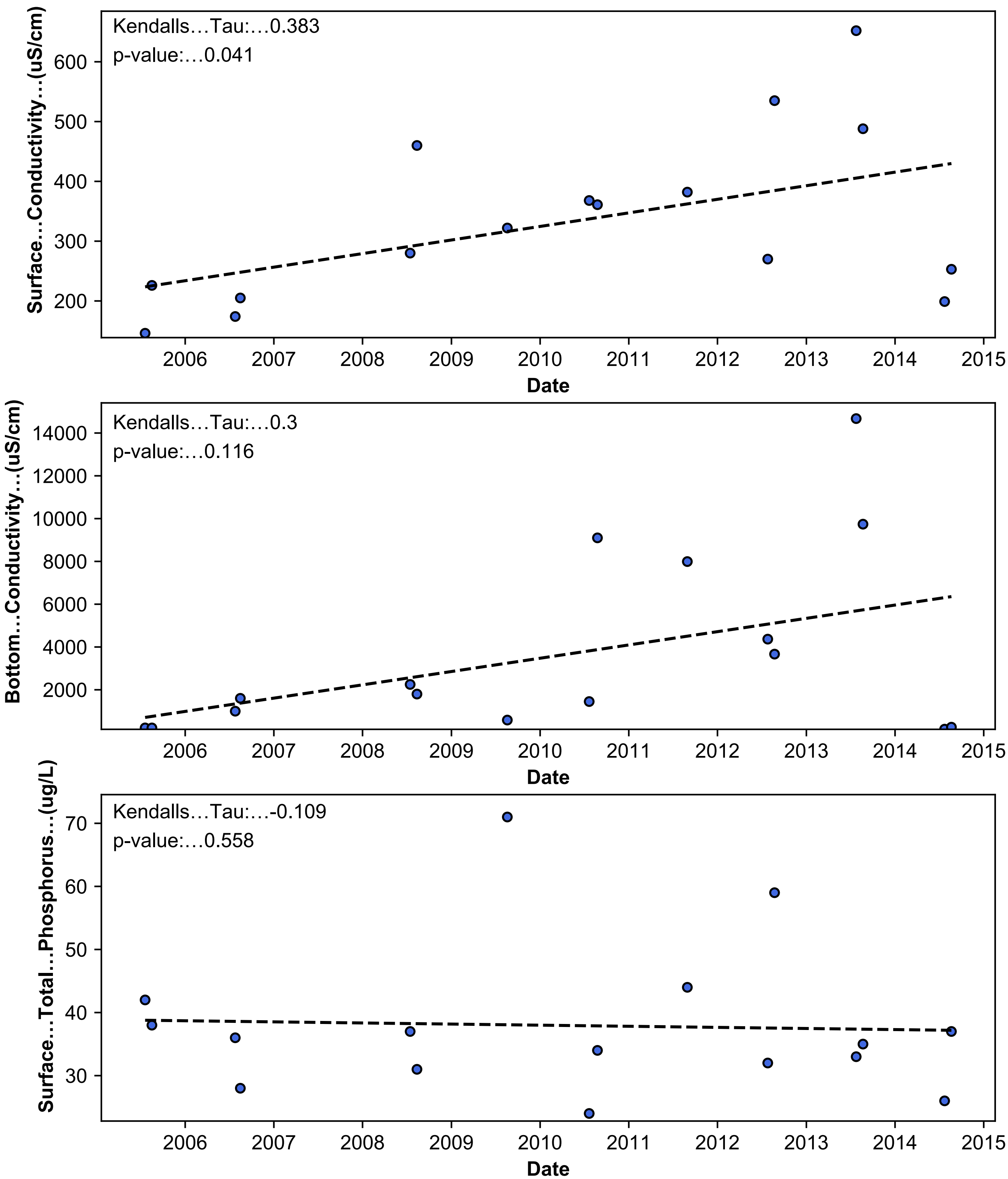
Kendalls…Tau:…-0.316
p-value:…0.055
Surface…Total…Nitrogen…(mg/L)
Date
Kendalls…Tau:…0.277
p-value:…0.091
Secchi…Depth…(m)
Date
Kendalls…Tau:…-0.338
p-value:…0.04
Chlorophyll…(ug/L)
Date

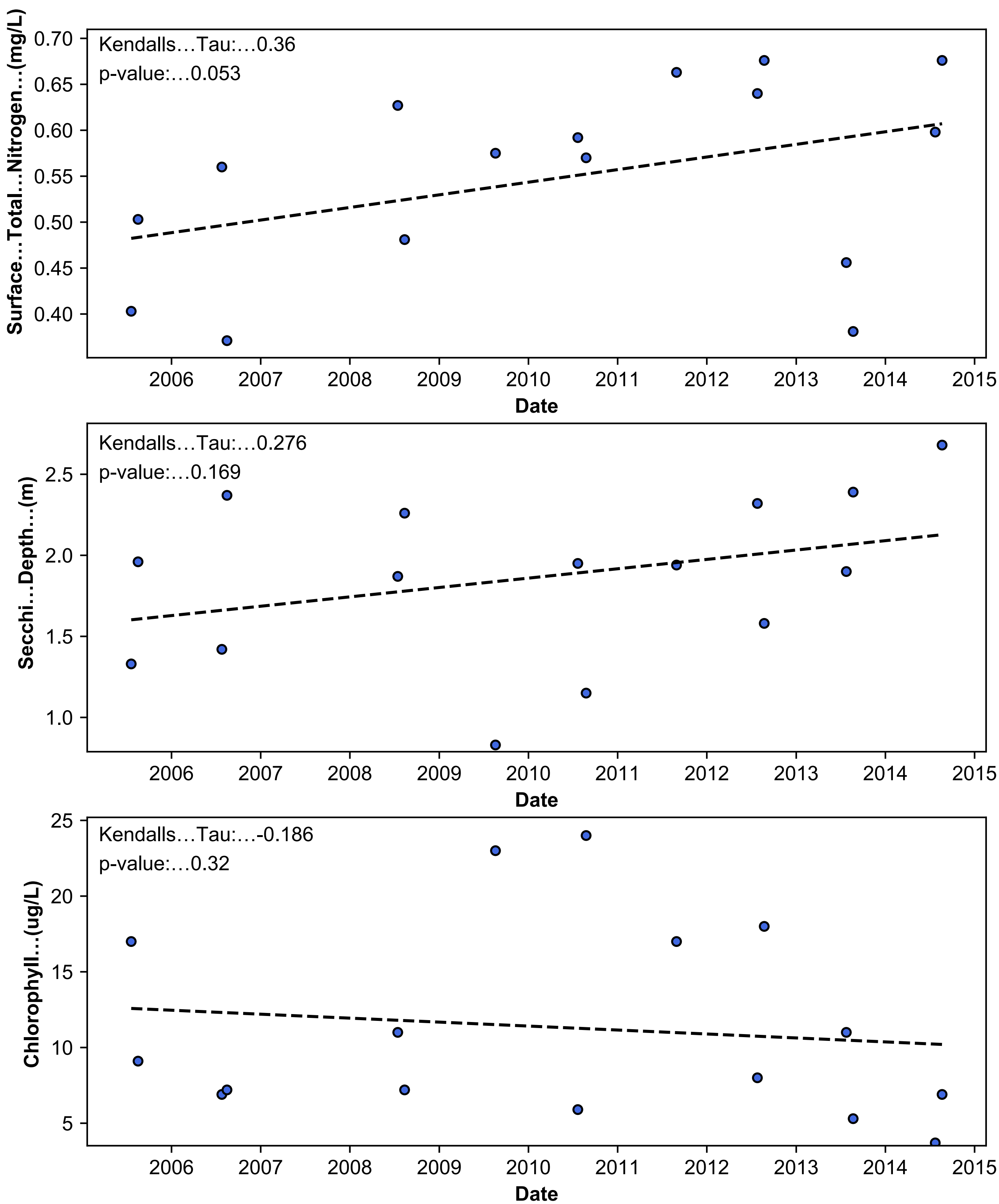

Kendalls…Tau:…-0.218
p-value:…0.183
Pheophytin…(ug/L)
10
8
6
4
2
2004
2006
2008
2010
2012
2014
Date



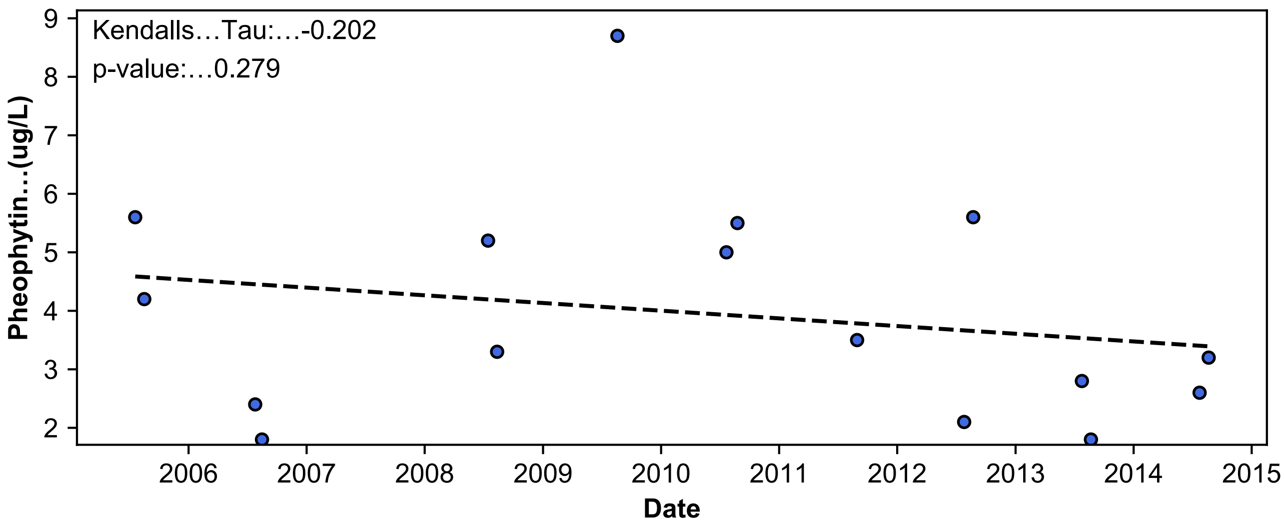
Kendalls…Tau:…-0.5
p-value:…0.006
Surface…Temperature…(C)
26
24
22
20
18
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…0.059
p-value:…0.752
Bottom…Temperature…(C)
21
20
19
18
17
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…-0.485
p-value:…0.01
Surface…pH
9.5
9.0
8.5
8.0
7.5
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date

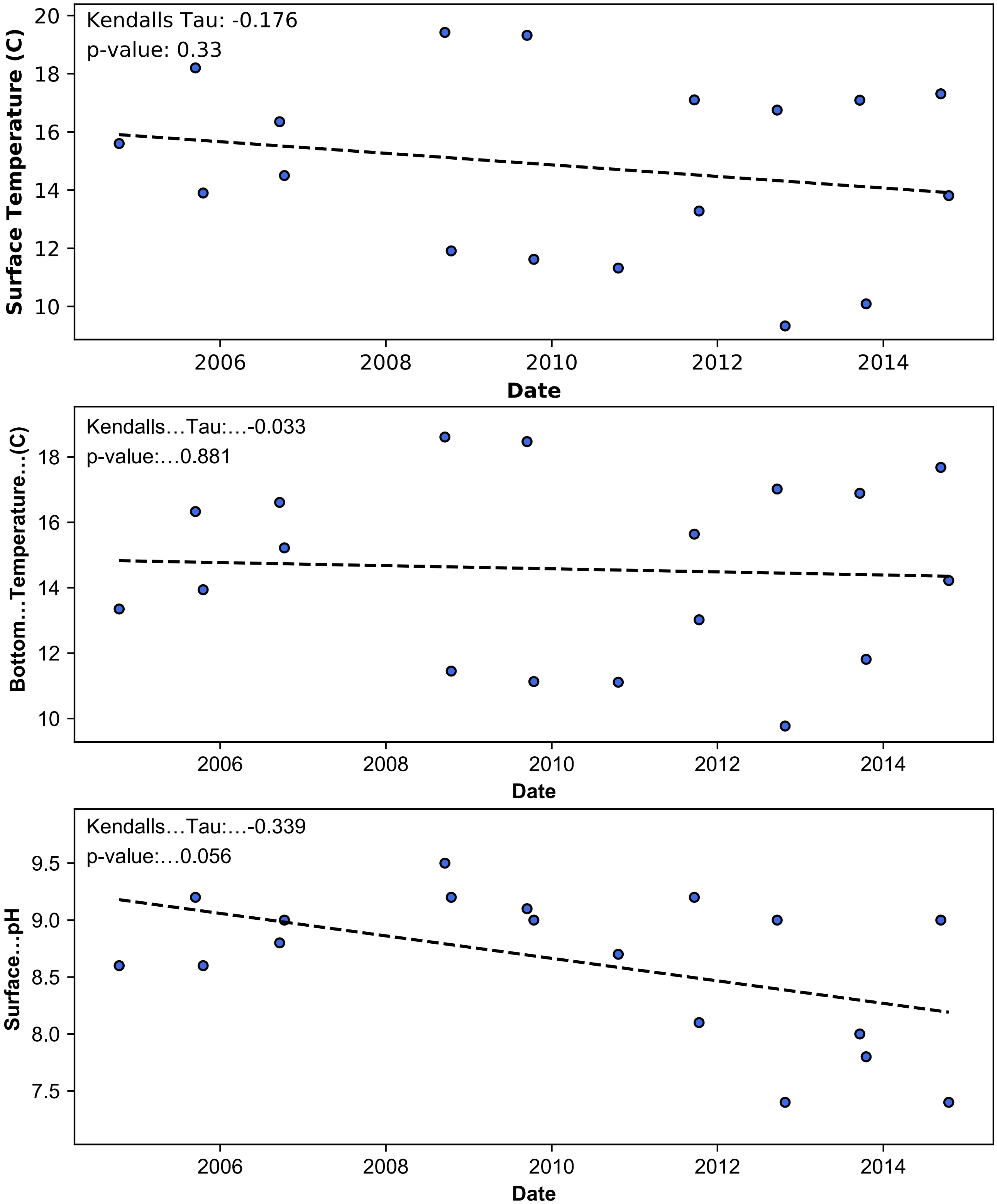

Kendalls…Tau:…-0.155
p-value:…0.413
Bottom…pH
8.5
8.0
7.5
7.0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…-0.267
p-value:…0.165
Surface…DO…(mg/L)
15
14
13
12
11
10
9
Date
Kendalls…Tau:…-0.109
p-value:…0.558
Bottom…DO…(mg/L)
12
11
10
9
8
7
6
Date

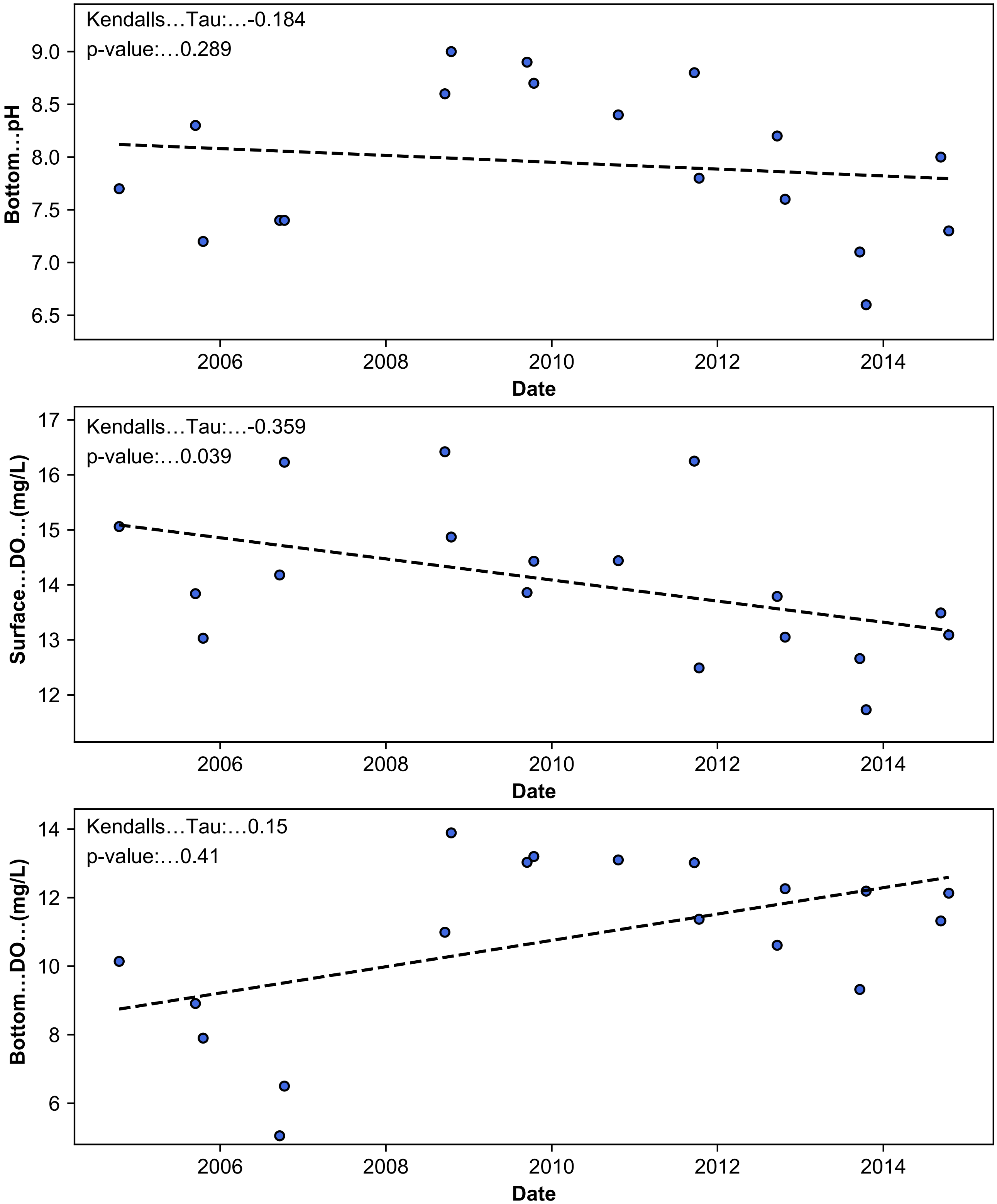

Kendalls…Tau:…0.383
p-value:…0.041
Surface…Conductivity…(uS/cm)
200
300
400
500
600
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…0.3
p-value:…0.116
Bottom…Conductivity…(uS/cm)
2000
4000
6000
8000
10000
12000
14000
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…-0.109
p-value:…0.558
Surface…Total…Phosphorus…(ug/L)
30
40
50
60
70
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date



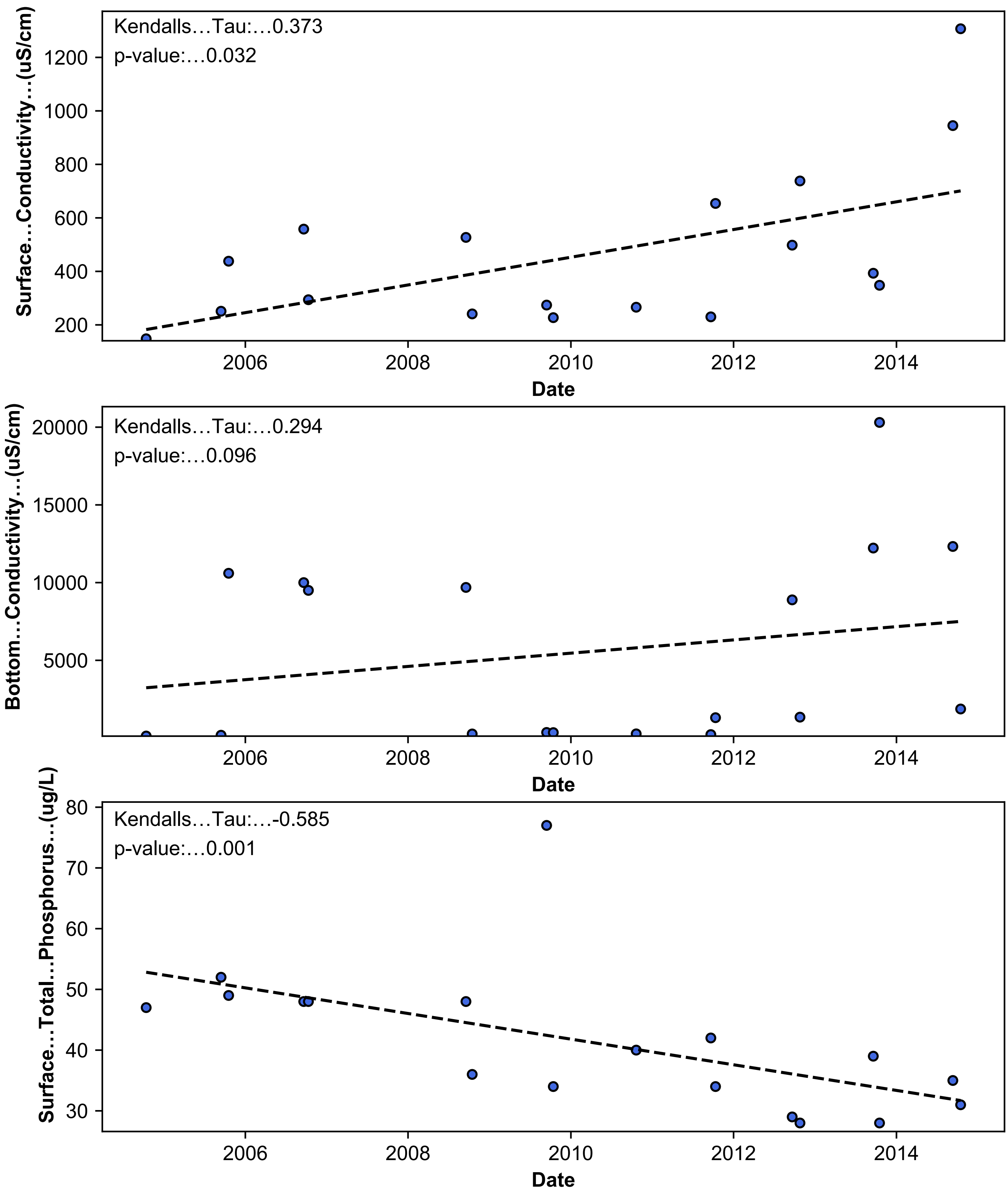
Kendalls…Tau:…0.36
p-value:…0.053
Surface…Total…Nitrogen…(mg/L)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…0.276
p-value:…0.169
Secchi…Depth…(m)
2.5
2.0
1.5
1.0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date
Kendalls…Tau:…-0.186
p-value:…0.32
Chlorophyll…(ug/L)
25
20
15
10
5
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date

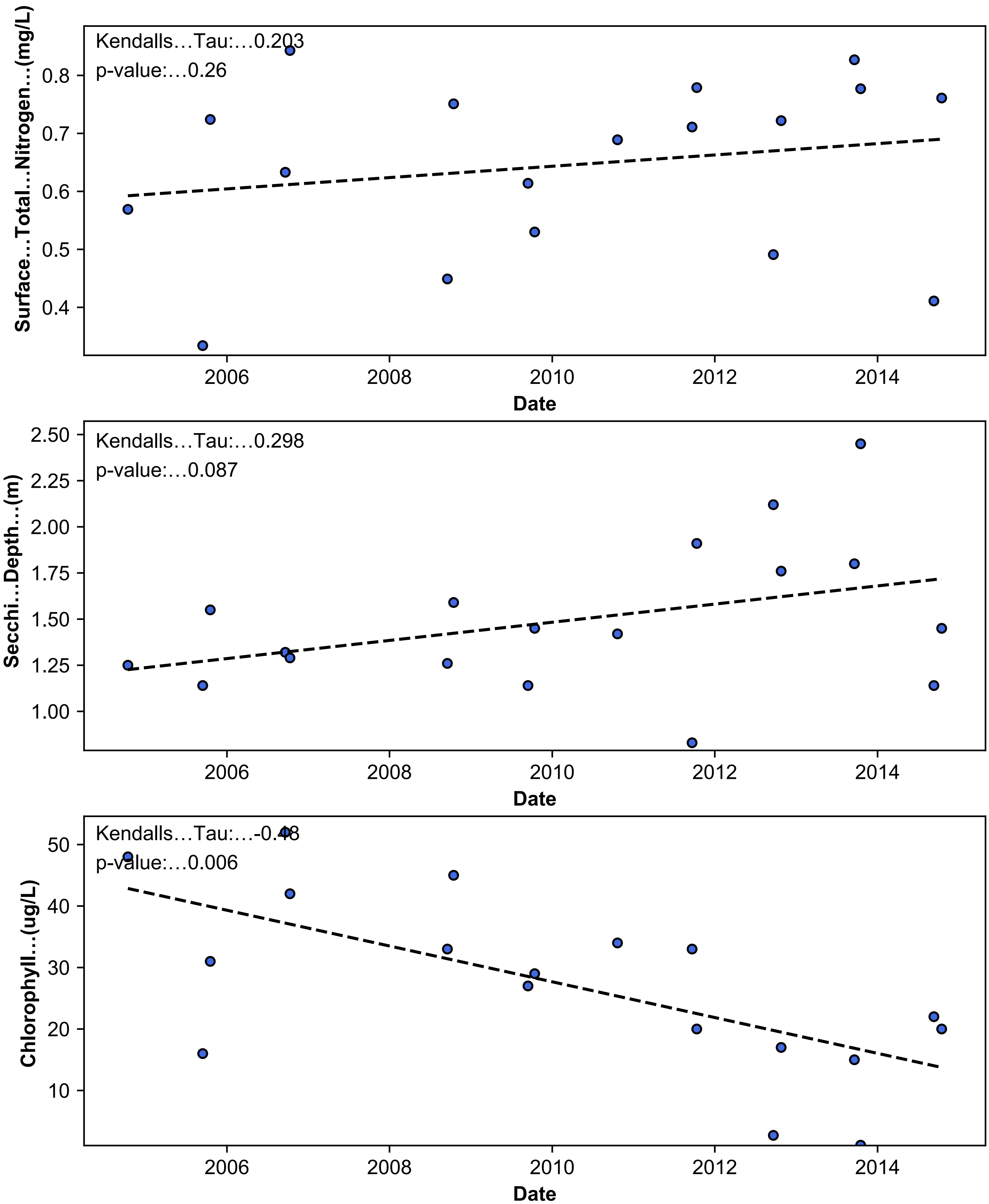

Kendalls…Tau:…-0.202
p-value:…0.279
Pheophytin…(ug/L)
9
8
7
6
5
4
3
2
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Date


Kendalls Tau: -0.176
p-value: 0.33
Surface Temperature (C)
20
18
16
14
12
10
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.033
p-value:…0.881
Bottom…Temperature…(C)
18
16
14
12
10
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.339
p-value:…0.056
Surface…pH
9.5
9.0
8.5
8.0
7.5
2006
2008
2010
2012
2014
Date

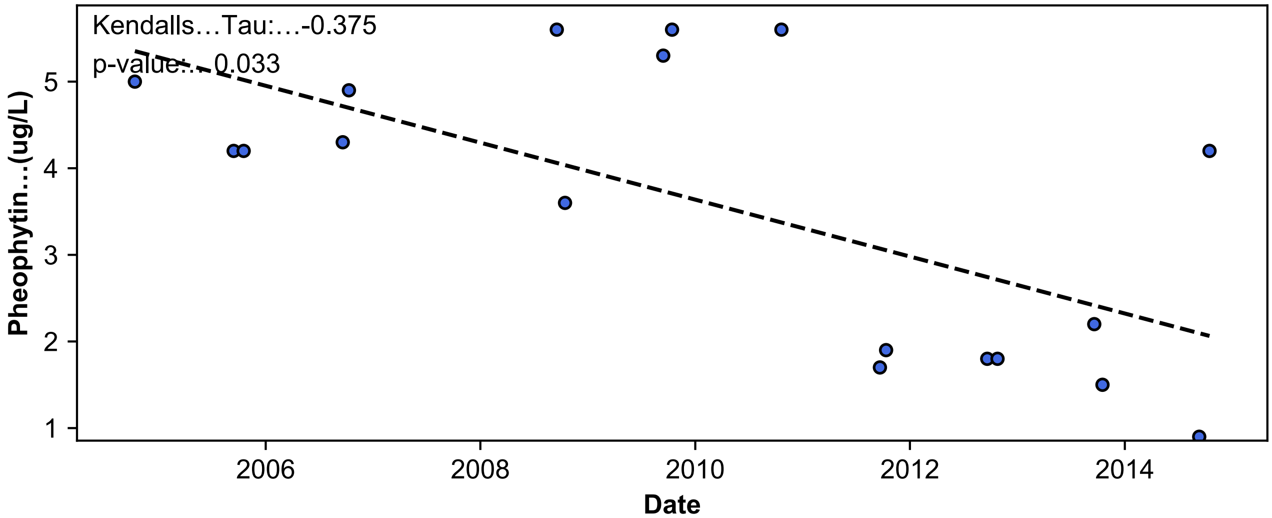


Kendalls…Tau:…-0.184
p-value:…0.289
9.0
8.5
8.0
7.5
7.0
6.5
Bottom…pH
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.359
p-value:…0.039
17
16
15
14
13
12
Surface…DO…(mg/L)
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.15
p-value:…0.41
14
12
10
8
6
Bottom…DO…(mg/L)
2006
2008
2010
2012
2014
Date


Kendalls…Tau:…0.373
p-value:…0.032
Surface…Conductivity…(uS/cm)
200
400
600
800
1000
1200
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.294
p-value:…0.096
Bottom…Conductivity…(uS/cm)
5000
10000
15000
20000
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.585
p-value:…0.001
Surface…Total…Phosphorus…(ug/L)
30
40
50
60
70
80
2006
2008
2010
2012
2014
Date



Kendalls…Tau:…0.203
p-value:…0.26
Surface…Total…Nitrogen…(mg/L)
0.8
0.7
0.6
0.5
0.4
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.298
p-value:…0.087
Secchi…Depth…(m)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
Date
Kendalls…Tau:…-0.48
p-value:…0.006
Chlorophyll…(ug/L)
50
40
30
20
10
Date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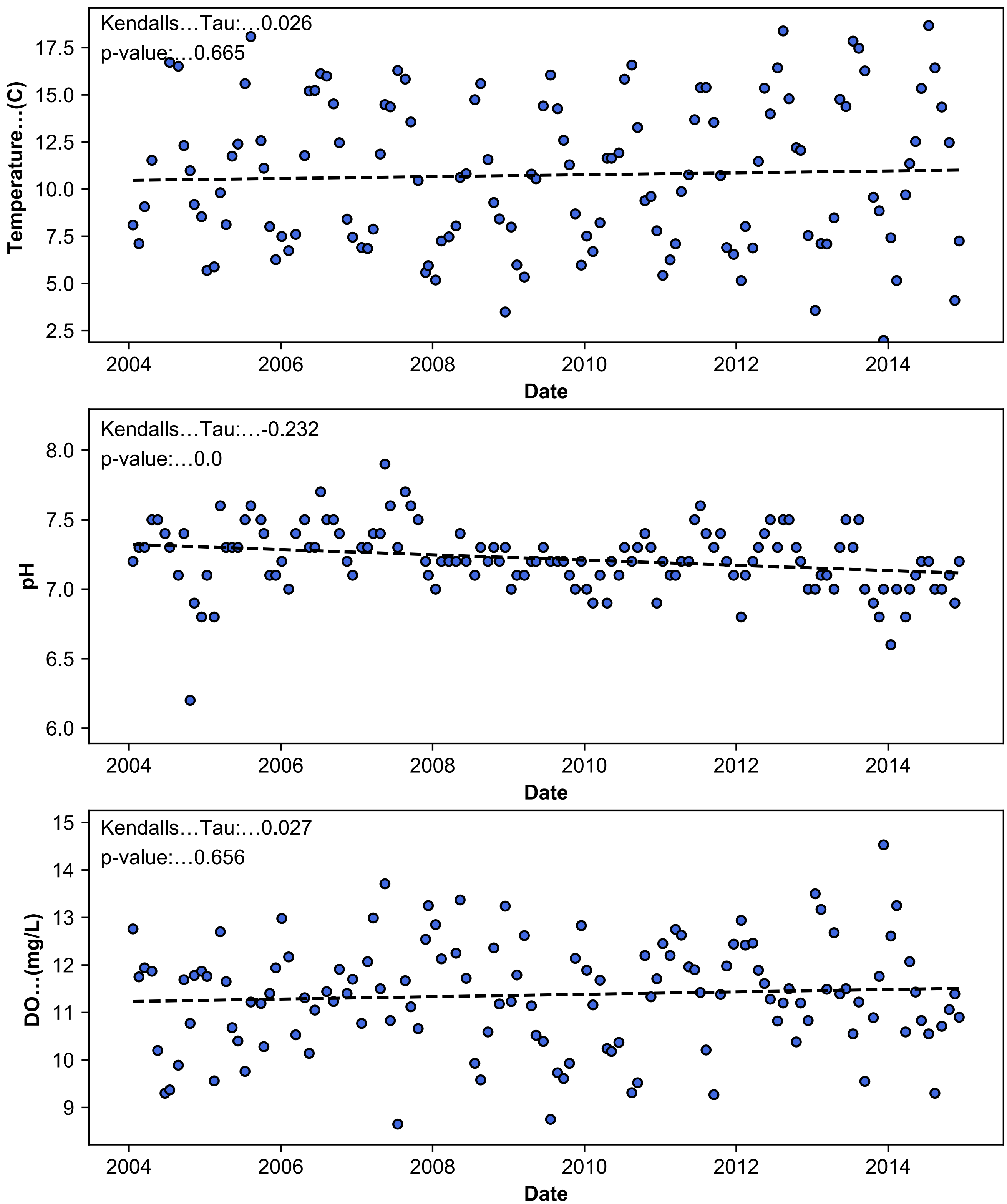
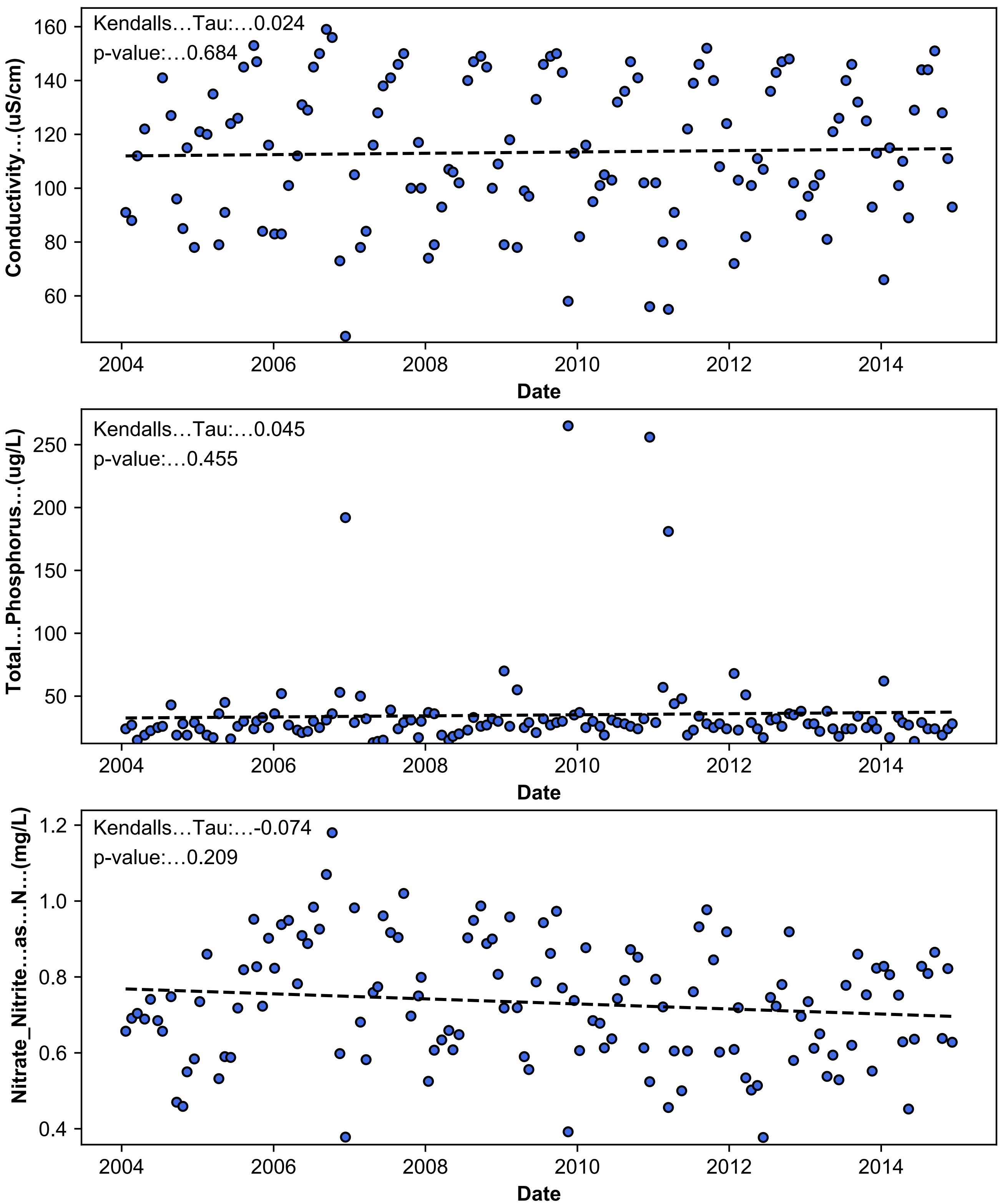
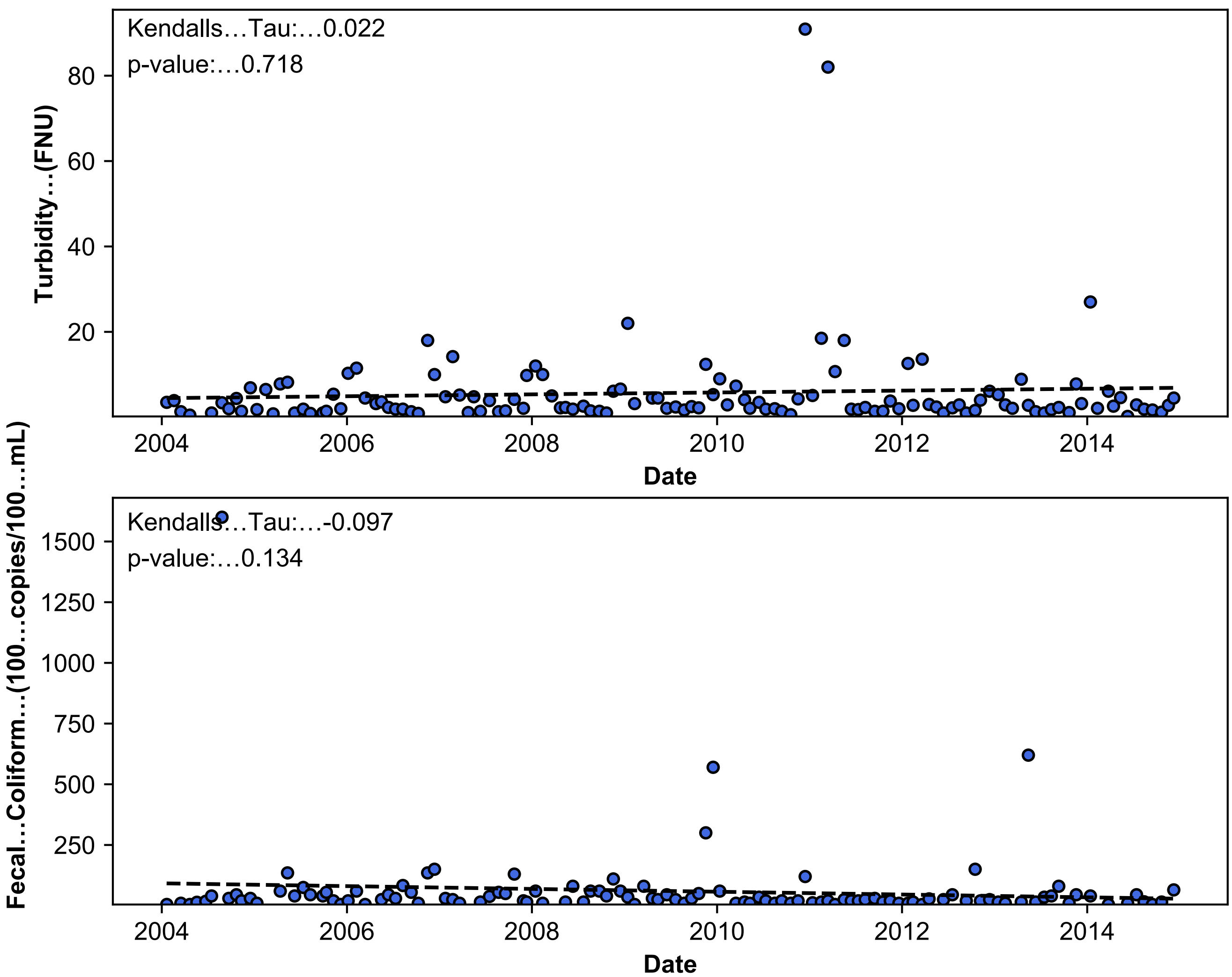
p-value:…0.033
Pheophytin…(ug/L)
1
2
3
4
5
2006
2008
2010
2012
2014
Date



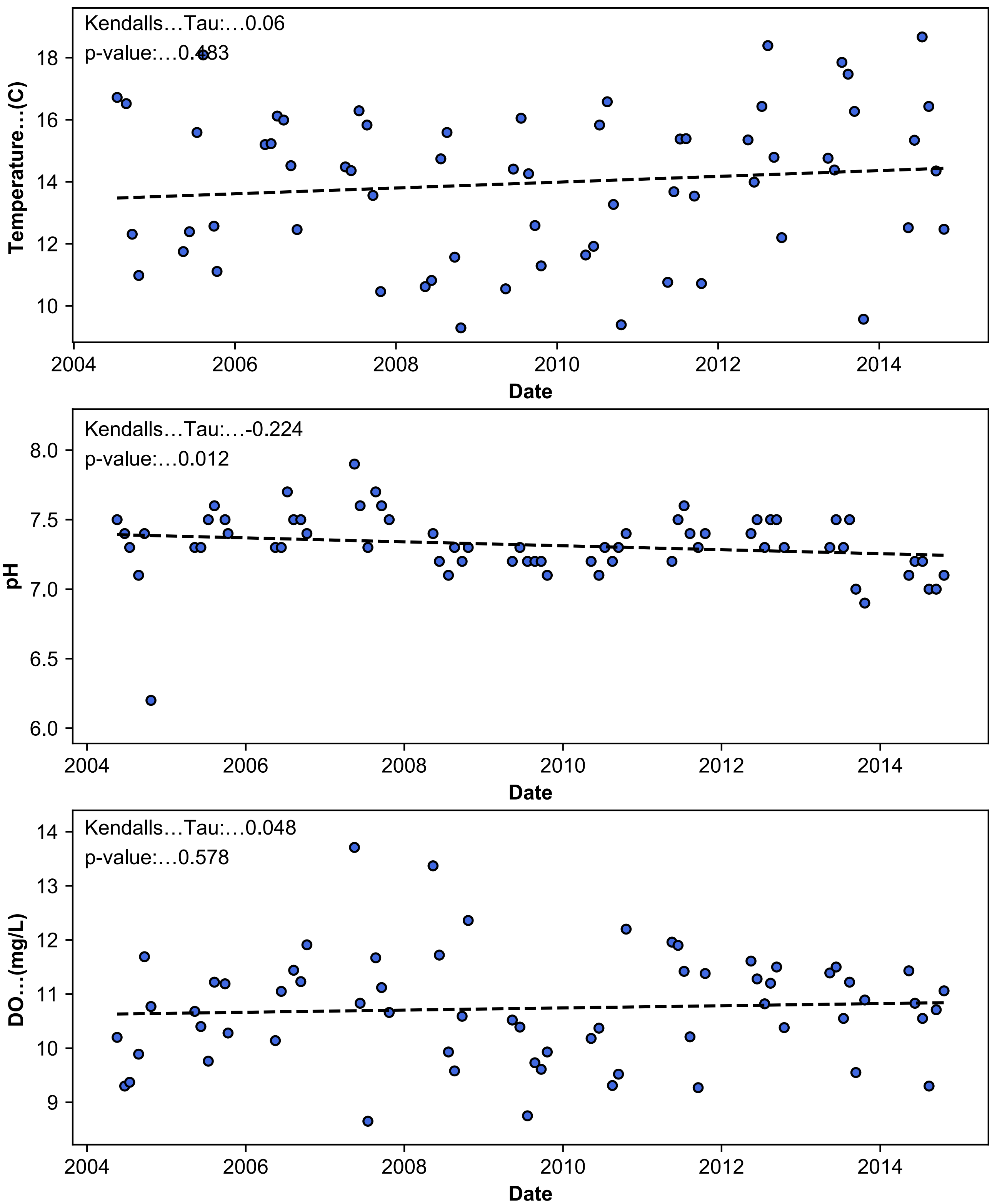
Kendalls…Tau:…0.026
p-value:…0.665
Temperature…(C)
Date
Kendalls…Tau:…-0.232
p-value:…0.0
pH
Date
Kendalls…Tau:…0.027
p-value:…0.656
DO…(mg/L)
Date



Kendalls…Tau:…0.024
p-value:…0.684
Conductivity…(uS/cm)
160
140
120
100
80
60
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.045
p-value:…0.455
Total…Phosphorus…(ug/L)
250
200
150
100
50
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.074
p-value:…0.209
Nitrate_Nitrite…as…N…(mg/L)
1.2
1.0
0.8
0.6
0.4
2004
2006
2008
2010
2012
2014
Date



Kendalls…Tau:…0.022
p-value:…0.718
Turbidity…(FNU)
80
60
40
20
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.097
p-value:…0.134
Fecal…Coliform…(100…copies/100…mL)
1500
1250
1000
750
500
250
2004
2006
2008
2010
2012
2014
Date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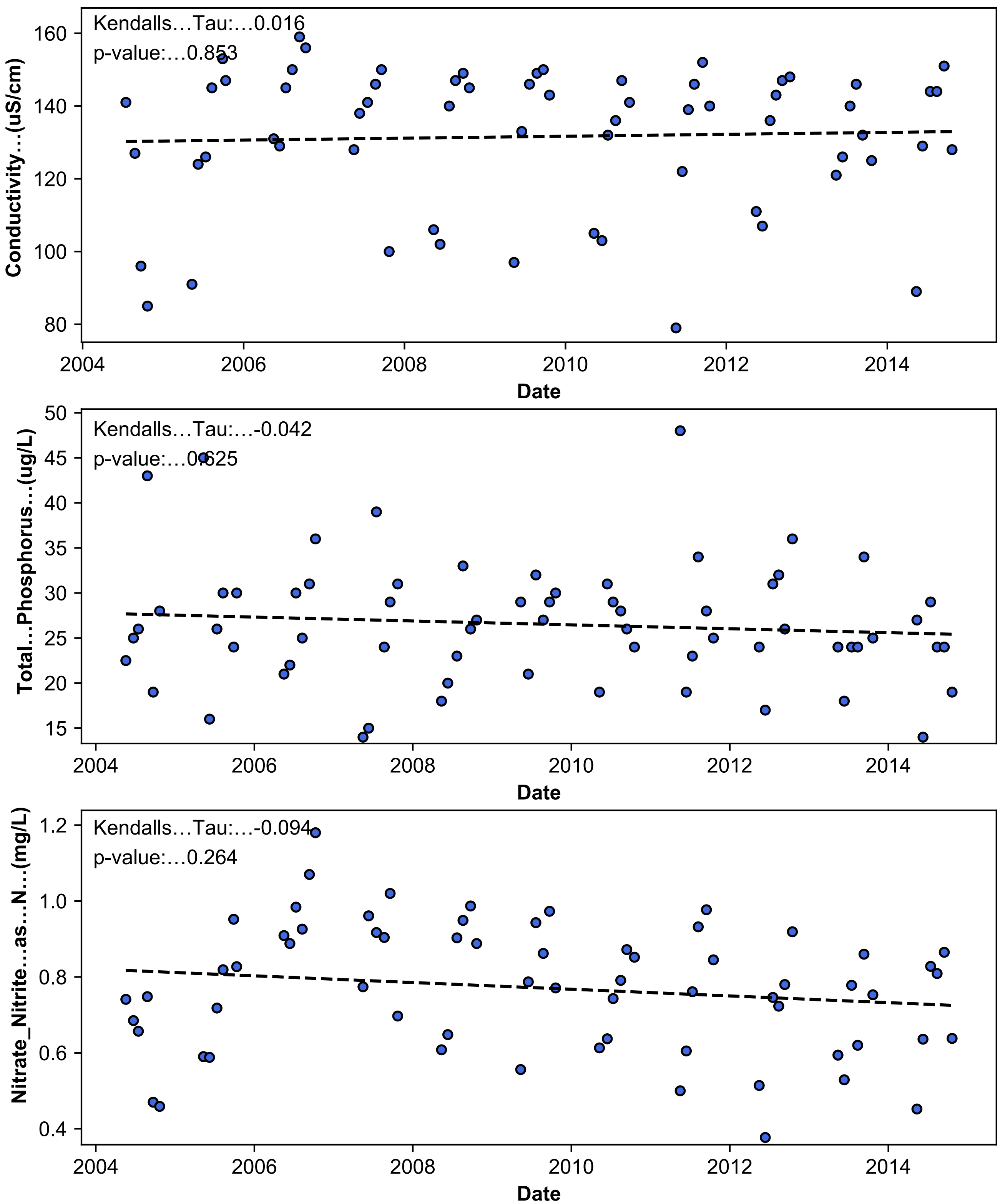
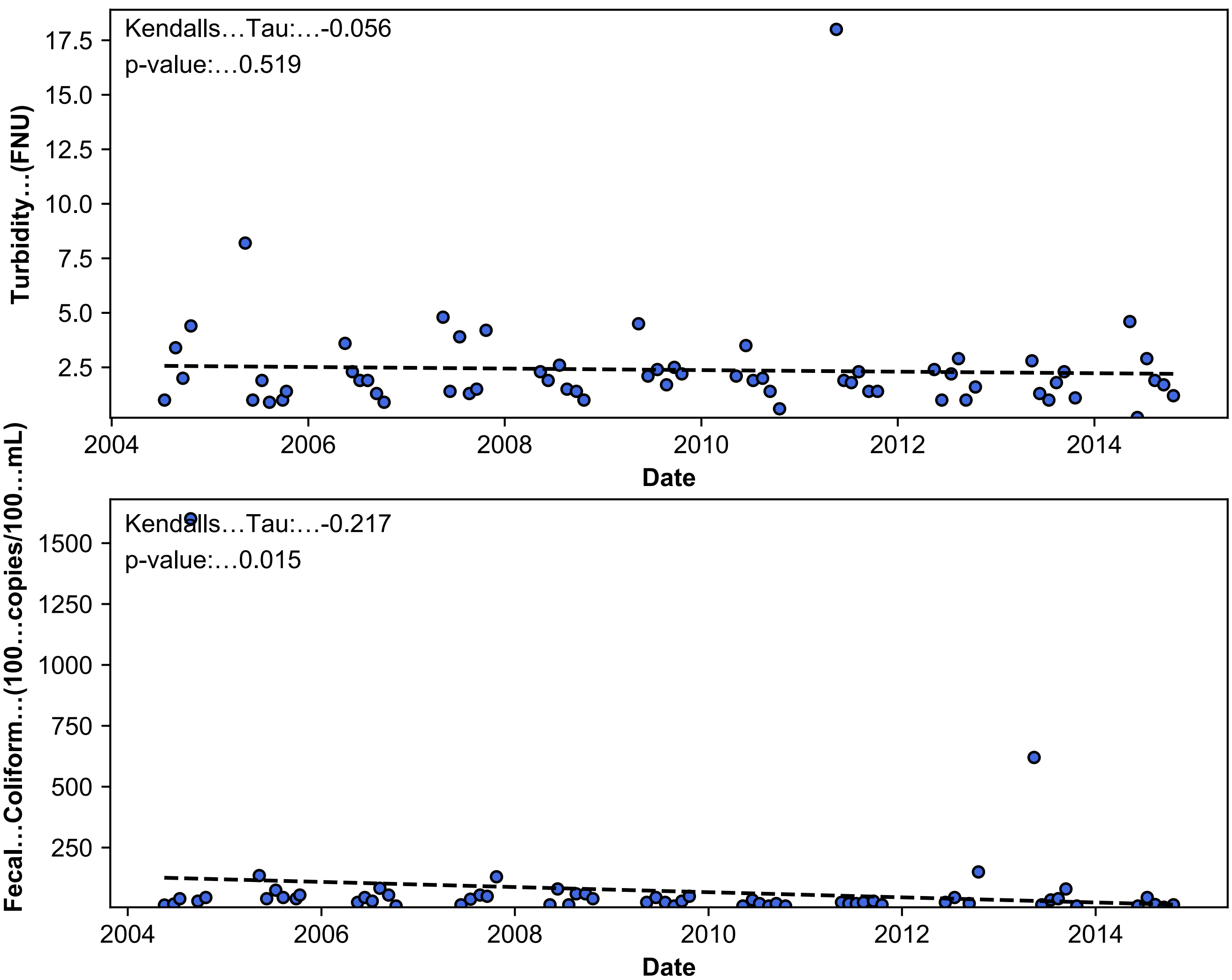
p-value:…0.483
Temperature…(C)
18
16
14
12
10
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.224
p-value:…0.012
pH
8.0
7.5
7.0
6.5
6.0
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…0.048
p-value:…0.578
DO…(mg/L)
14
13
12
11
10
9
2004
2006
2008
2010
2012
2014
Date



Kendalls…Tau:…0.016
p-value:…0.853
Conductivity…(uS/cm)
160
140
120
100
80
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.042
p-value:…0.625
Total…Phosphorus…(ug/L)
50
45
40
35
30
25
20
15
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.094
p-value:…0.264
Nitrate_Nitrite…as…N…(mg/L)
1.2
1.0
0.8
0.6
0.4
2004
2006
2008
2010
2012
2014
Date


Kendalls…Tau:…-0.056
p-value:…0.519
Turbidity…(FNU)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
2004
2006
2008
2010
2012
2014
Date
Kendalls…Tau:…-0.217
p-value:…0.015
Fecal…Coliform…(100…copies/100…mL)
1500
1250
1000
750
500
250
2004
2006
2008
2010
2012
2014
Date

Appendix E Freshwater Pool Analysis

CAPITOL LAKE – DESCHUTES ESTUARY
Long-Term Management Project Environmental Impact Statement

Freshwater Reflecting Pool Analysis

Prepared for:

Washington State Department of Enterprise Services

1500 Jefferson Street SE
Olympia, WA 98501

Prepared by:

Herrera Environmental Consultants, Inc.

February 19, 2021

Final

Executive Summary

This analysis evaluates the feasibility of operating a freshwater reflecting pool as part of the Hybrid Alternative for the Capitol Lake – Deschutes Estuary Long-Term Management Project. The Capitol Lake – Deschutes Estuary includes the 260-acre Capitol Lake Basin, located on the Washington State Capitol Campus, in Olympia, Washington. Long-term management strategies and actions are needed to address issues in the Capitol Lake – Deschutes Estuary project area. An Environmental Impact Statement (EIS) is being prepared to document the potential environmental impacts of various alternatives and determine how these alternatives meet the long-term objectives identified for the watershed.

Various elements of the environment have been evaluated for the No Action Alternative, as well as three build alternatives: Managed Lake, Estuary, and Hybrid. Water quality impacts of the alternatives are described in the Water Quality Discipline Report. Water quality impacts were evaluated for the Hybrid Alternative based on creation of a saltwater reflecting pool by constructing a barrier wall to retain a 45-acre reflecting pool in the eastern portion of the North Basin of Capitol Lake. Tide gates in the barrier wall would allow high inflow and outflow of saltwater from the estuary through the pool and continuously provide a full pool of saltwater for aquatic habitat and recreational use.

This freshwater pool analysis examines the feasibility of maintaining a freshwater reflecting pool as an alternative to the saltwater reflecting pool evaluated for the Hybrid Alternative in the Water Quality Discipline Report. A hydrologic budget and simple phosphorus model were developed for the freshwater pool based on expected inputs from shallow groundwater inflow from local artesian wells, direct precipitation on the reflecting pool surface, and stormwater runoff from the adjacent properties. The hydrologic budget results show that the quantity of available freshwater inputs is sufficient to maintain full pool conditions all year. The phosphorus model indicates that stormwater and groundwater inflows contain high concentrations of total phosphorus that would need to be treated to the maximum extent practicable to reduce phosphorus concentrations in the summer and prevent algae blooms. Treatment would be performed by one or more of the 19 technologies approved for phosphorus treatment in Washington State. The saltwater reflecting pool would receive the same high stormwater and groundwater phosphorus inputs, but these inputs would not result in summer algae blooms because the nutrients and algae would be flushed from the pool at a high rate with each high tide to yield a residence time of less than 10 days.

Model results further indicate that inflow treatment would not be sufficient to fully prevent algae blooms. Therefore, treatment of the water within the freshwater pool would also be needed in perpetuity. Phosphorus inactivation using aluminum sulfate or Phoslock would be needed each year to sufficiently reduce phosphorus concentrations enough to fully support recreation and ecological function within the freshwater pool. An adaptive pool management plan would be needed to identify how best to reduce phosphorus and algae concentrations to meet water quality objectives.

Impacts of the freshwater pool alternative on water quality would be similar to those described in the Water Quality Discipline Report for the saltwater pool associated with the Hybrid Alternative. Assuming that the freshwater pool alternative includes treatment of groundwater, stormwater, and pool water in perpetuity, overall, there would be **less than significant impacts** to water quality in Budd Inlet from the freshwater pool compared to existing conditions or the saltwater pool.

In comparison to the saltwater reflecting pool in the eastern portion of the North Basin, the freshwater reflecting pool would likely produce more algae and have higher fluctuations in dissolved oxygen, temperatures, and fecal bacteria. More algae would be expected because of the increased residence time (reduced flushing rate) and the high phosphorus concentrations in stormwater and groundwater inflows to the pool. However, if managed properly with treatment of stormwater, groundwater and reflecting pool water in perpetuity, the freshwater reflecting pool would be mesotrophic and not experience more algae blooms than the existing North Basin.

Summer dissolved oxygen concentrations likely would be lower in bottom waters of the freshwater reflecting pool than the saltwater reflecting pool or existing conditions in the North Basin. Surface water temperatures could become elevated in the freshwater reflecting pool during the summer when they are heated by warm air and the cool groundwaters plunge to the bottom. However, high temperatures in surface waters and low dissolved oxygen concentrations in bottom waters are not expected to be exceptionally different that those observed in other lakes in Thurston County.

Fecal bacteria concentrations could be become elevated in the freshwater reflecting pool compared to the saltwater reflecting pool and existing lake because of the lower flushing rate (higher residence time). Although fecal bacteria inputs from the drainage basin would be reduced by stormwater treatment, the freshwater reflecting pool may have higher duck and geese populations than a saltwater pool. Aquatic plant growth would likely be greater in a managed freshwater reflecting pool than a saltwater reflecting pool, which would attract more herbaceous ducks and geese and also would provide better habitat for other aquatic organisms. Excessive invasive or native aquatic plant growth would be managed to prevent recreational impacts.

Overall, the managed freshwater reflecting pool, with treatment infrastructure and management operations, would have **less than significant impacts** to water quality when compared to existing conditions and the saltwater reflecting pool or the existing lake.

Active management would be imperative to improve water quality conditions for supporting recreation and ecological functions. If water quality is not managed within the freshwater reflecting pool and its inputs, severe algae blooms would likely occur during the summer to the extent that all recreational uses would be severely impacted. Without active management, it is likely that public health would be impacted by toxic algae blooms, aquatic life would be impacted by low dissolved oxygen concentrations during bloom crashes, aquatic habitat would be impacted by a lack of submersed plants from light limitation, and aesthetic values would be impacted by the accumulation of rotting algae along the shoreline. The saltwater reflecting pool would not require active management to substantially improve water quality compared to existing conditions.

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List of Acronyms and Abbreviations

Acronyms/ Abbreviations	Definition
µg/L	micrograms per liter
BMPs	best management practices
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
Enterprise Services	Washington State Department of Enterprise Services
FW	Freshwater
gpm	gallons per minute
Herrera	Herrera Environmental Consultants
LOTT	Lacey, Olympia, Tumwater and Thurston County Wastewater Management Partnership
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
TP	Total phosphorus
WQDR	Water Quality Discipline Report

1.0 Introduction and Project Description

1.1 PROJECT DESCRIPTION

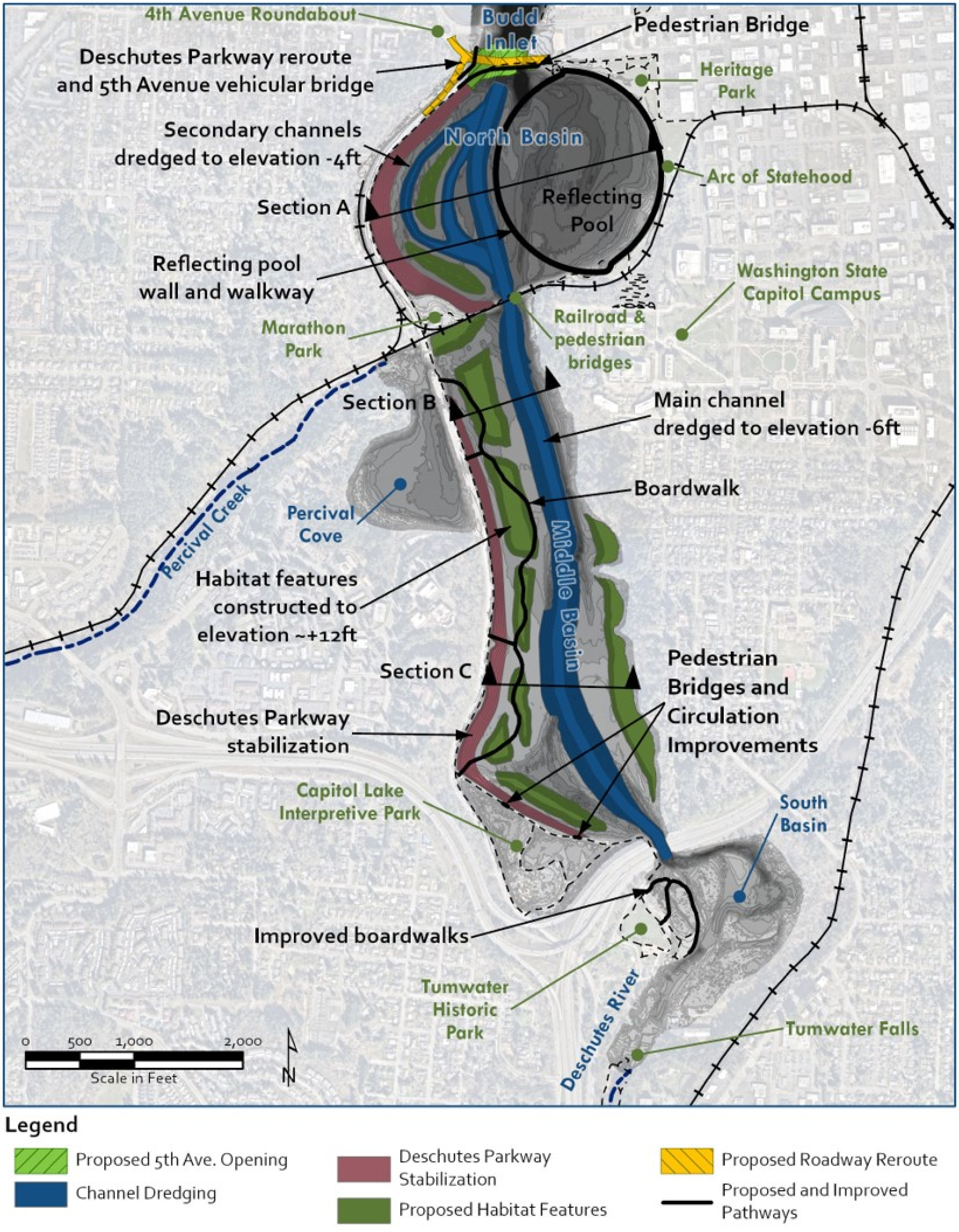
The Capitol Lake – Deschutes Estuary includes the 260-acre Capitol Lake Basin, located on the Washington State Capitol Campus, in Olympia, Washington. The water body has long been a valued community amenity. Capitol Lake was formed in 1951 following construction of a dam and provided an important recreational resource. Historically, the Deschutes Estuary was used by local tribes for subsistence and ceremonial purposes. Today, the expansive water body is closed to active public use. There are a number of environmental issues including the presence of invasive species, exceedances of water quality (WQ) standards, and inadequate sediment management.

In 2016, as part of Phase 1 of long-term planning, a diverse group of stakeholders, in collaboration with the state, identified shared goals for long-term management and agreed an Environmental Impact Statement (EIS) was needed to evaluate a range of alternatives and identify a preferred alternative. In 2018, the state began the EIS process. The EIS evaluates four alternatives, including No Action, Managed Lake, Estuary, and Hybrid Alternatives. Water resource impacts of the alternatives are described in the Water Quality Discipline Report (WQDR). The long-term management alternatives are evaluated against the shared project goals of improving water quality, managing sediment accumulation and future deposition, improving ecological functions, and enhancing community use of the resource.

1.2 FRESHWATER REFLECTING POOL ANALYSIS

Under the Hybrid Alternative (Figure 1.1), the 5th Avenue Dam would be removed, and an approximately 500-foot opening would be established in its place. Tidal hydrology would be returned to the western portion of the North Basin and to the Middle and South Basins. Within the North Basin, a barrier wall would be constructed to create an approximately 45-acre saltwater reflecting pool adjacent to Heritage Park. Construction and maintenance of the smaller reflecting pool, in addition to restored estuarine conditions in part of the Capitol Lake Basin, gives this option its classification as a hybrid. Sediment would be managed through initial dredging in the Capitol Lake Basin and recurring maintenance dredging within Budd Inlet. In the Middle and South Basins, constructed habitat areas

Figure 1.1. Hybrid Alternative Design Map.



would promote ecological diversity, though mudflats would be the predominant habitat type. Boardwalks would be constructed for community use. Adaptive management plans would be developed to maintain water quality in the saltwater reflecting pool and to improve ecological functions.

This freshwater reflecting pool analysis examines the feasibility of maintaining a freshwater reflecting pool as an alternative to the saltwater reflecting pool evaluated for the Hybrid Alternative in the WQDR. Rather than allowing tidal inflow to fill the pool, the main water supply to the pool would be groundwater naturally present within the watershed, direct precipitation, and stormwater. Water from the Deschutes River would not be diverted to the pool because that is significantly more complex from a technical and regulatory perspective than a groundwater-fed reflecting pool. Additionally, a river-fed reflecting pool has not been proposed by project stakeholders and its complexities can be avoided with the groundwater-fed system, which is determined to be a feasible freshwater source.

This analysis primarily consists of developing a hydrologic budget (Section 2) and simple phosphorus model (Section 3) to predict water quality conditions in the freshwater pool. This report also discusses the need and options for water quality management (Section 4) and the potential water quality impacts and mitigation measures for the freshwater pool (Section 5). The primary objectives of this freshwater pool analysis include:

- Identify the minimum freshwater pool inflow rate needed to maintain full pool elevation during the summer months, accounting for losses by evaporation and seepage.
- Summarize groundwater quality and potential groundwater yield (flow rate) from historical information and project monitoring data gathered and summarized for the WQDR.
- Estimate the range of seasonal water quality conditions expected in the freshwater reflecting pool for each water source, focusing on trophic state parameters of total phosphorus, chlorophyll-a, and Secchi depth water transparency for aesthetics but also including temperature and dissolved oxygen for fish habitat.
- Identify freshwater reflecting pool management goals for beneficial uses and water quality, consistent with those established for the Managed Lake Alternative in the WQDR.
- Identify water management needs for reducing the phosphorus loading or other improvements to each water source to meet water quality goals for the freshwater reflecting pool.
- Evaluate and briefly summarize feasible water quality management techniques to meet the water quality goals for each water source and develop up to three management scenarios representing a range of relative cost and effectiveness.

1.3 AREA OF INTEREST

The area of interest for the freshwater reflecting pool analysis consists of the freshwater reflecting pool itself and its surrounding urban watershed (Figure 1.2). The freshwater reflecting pool area at full pool is 49.3 acres and its drainage basin is 77.5 acres. This reflecting pool area was measured from the area shown in Figure 1.2 and is 10% larger than the 45 acres reported for the saltwater reflecting pool in the Basis of Design (Moffatt & Nichol 2020). The stormwater drainage system within the basin is comprised of three major networks delineated for the 2005 Stormwater Strategy by the Thurston Regional Planning Council (TRPC 2004), which include the Heritage Park subbasin, 7th Avenue subbasin, and the Columbia Street subbasin. Storm drains associated with each of these three subbasins are shown in Figure 1.2 where most of the basin drains from the Heritage Park subbasin (approximately 50%) and the 7th Avenue subbasin (approximately 40%). The Heritage Park subbasin drains to 17 separate outfalls, while the other two subbasins each drain to one outfall: the 7th Avenue subbasin drains to outfall 10 and the Columbia Street subbasin drains to outfall 12 (see Figure 1.2). The basin's land use is predominantly commercial land use in addition to park use, with 59.6% of the surfaces being impervious. Most of the commercial land use and impervious surfaces are in the 7th Avenue and Columbia Street subbasins, while the Heritage Park subbasin is primarily park use and pervious surfaces.

Under the Hybrid Alternative it is not expected that the freshwater reflecting pool will be initially dredged. Therefore, the freshwater reflecting pool's initial bathymetry is assumed to be the same as its current condition in Capitol Lake. It is also assumed in this analysis that the freshwater reflecting pool will be managed to maintain full pool at approximately 10 feet NAVD88 (Moffatt & Nichol 2020).

Stormwater outfalls to the lake are shown in Figure 1.2 and detailed in Table 1.1. In total, there are 19 stormwater outfalls in the freshwater reflecting pool that vary and size and flow rate (TRPC 2004). Many of the smaller outfalls discharge into the waterbody from the Arc of Statehood retaining wall on the east shore of what is currently Capitol Lake. Larger outfalls extend into the lake and discharge directly to the water body. It is assumed that no changes to the existing stormwater outfalls or discharge amounts would be required for either the saltwater or freshwater reflecting pool because changes to outfall structures or discharge rates are not needed to meet water quality objectives for either reflecting pool alternative. Swimming is not a projected use of either reflecting pool alternative. If swimming was allowed in an area of the reflecting pool, then stormwater outfalls may be relocated outside the swimming area to reduce potential public health impacts from stormwater discharges.

The artesian wells in and around the basin are also shown in Figure 1.2 and described in Table 1.2. Information regarding these wells was obtained from a groundwater study conducted for the LOTT Wastewater Resources Management Plan (Robinson & Noble 1999), which is the most recent groundwater study of the basin and surrounding area and included well information previously reported by the City of Olympia. Four wells were identified within or near the stormwater drainage basins draining to the lake and are assumed to currently drain to the reflecting pool area for this study. Flow rates were estimated for each of these wells that could be located by Robinson & Noble (1999) and compared to rates reported from previous surveys by Thurston County and the City of Olympia. The flow rates varied widely from zero for valved wells (Well 6 and Well A+B) to a maximum of 80 gallons per minute (gpm) reported historically for Well 29. None of these wells are used or would ever be used for water supply, and it is assumed that valved wells could be fully opened to provide water to the freshwater reflecting pool. One additional well (Well 30) was described as discharging directly into the lake from a submerged pipe that was not located by Robinson & Noble (1999), but was reported to flow at 50 gpm before it was capped and assumed to resume flow when the pipe was subsequently damaged. A flow rate of 350 gpm was reported for Well 30 more recently by 2005 Stormwater Strategy by the Thurston Regional Planning Council (TRPC 2004), and is assumed for this study to be currently discharging into the lake at this rate. While it is reasonable to assume that uncapped well flow rates have not changed substantially over time, the well flow rates reported historically are wide ranging and based on estimates with a high degree of uncertainty.

Table 1.1. Freshwater Reflecting Pool Stormwater Outfall Descriptions.

Outfall No.	Size (Inches)	Type	Description	Comments
1	8	PCSP	5th Ave.	South of East WA Butte
2	12	CONC	Yashiro St.	
3	12	CONC	Yashiro St. & 5th Avenue	
4	6	NA	West GA Parking Lot	
5	12	NA	5th Ave. & GA Parking Lot	
6	8	NA	East GA Parking Lot	
7	6	CONC	Correction Building	
8	12	NA	5th Ave., Sylvester St., HP Fountain & HP	Fountain Outfall
9	12	NA	Heritage Park	West of Bathhouse
10	36	CMP	7th Ave. North of Campus	7th Ave. Outfall
11	12	NA	Heritage Park	
12	24	HDPE	Columbia St., GA Building & Campus	Columbia St. Outfall
13	8	NA	EDC Parking Lot	
14	NA	NA	Heritage Park & BNSF Railroad	
15	8	PVC	Heritage Park & BNSF Railroad	Discharges Mid-Island
16	36	CONC	Heritage Park & BNSF Railroad–Artesian	South of Island
17	12	NA	Heritage Park & BNSF Railroad	South of South-Overlook
18	12	CONC	Heritage Park & BNSF Railroad	
19	8	NA	Heritage Park	

NA = Not available PCSP = Pressure Cast Steel Pipe CONC = Concrete Pipe
CMP = Corrugated Metal Pipe PVC = Polyvinyl Chloride Pipe HDPE = High-Density Polyethylene Pipe

Figure 1.2. Area of Interest to Freshwater Pool Analysis.

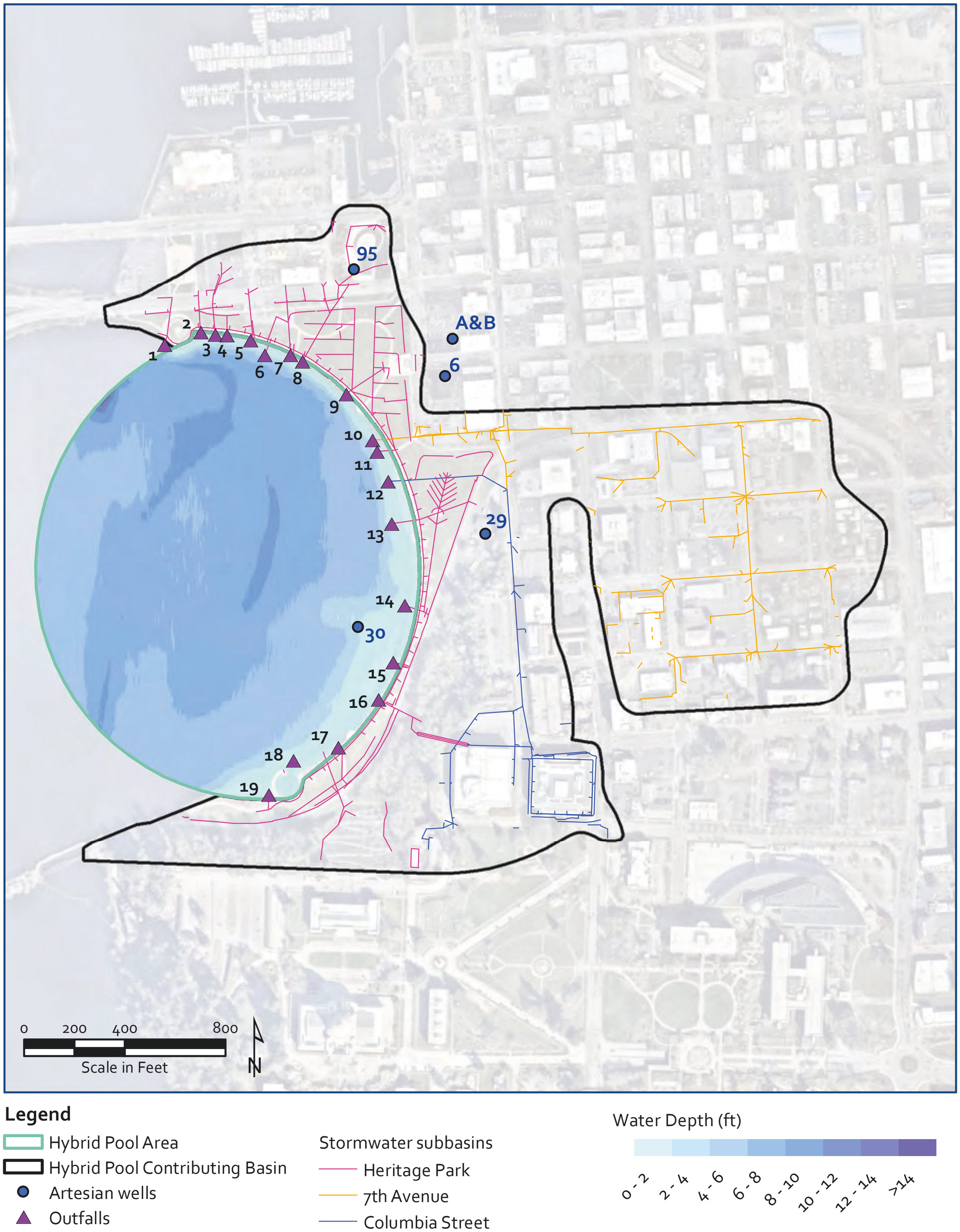


Table 1.2. Descriptions of Artesian Wells in the Freshwater Reflecting Pool Basin.

Well No.	Name	System Discharged To	System Outfall	Flow Estimate (gpm)
6	American Legion	Stormwater	Capitol Lake	0–67.5 (valved)
29	Old Northern Pacific Depot	Drainage System	Capitol Lake	20–80
30	Capitol Lake	Lake	Capitol Lake	350[a]
95	Heritage Park	Not Located	Unknown	0
A+B	Wells A and B	Drainage System	Capitol Lake	0–30

Source: Robinson & Nobel 1999

[a] Higher flow reported by TRPC (2004) for Well 30.

2.0 Hydrologic Budget

A hydrologic budget was developed using available data and is presented in this section to provide sufficient information to complete some of the analysis objectives. The hydrologic budget is an essential foundation for the phosphorus budget described in Section 3. The primary goals of this section are to identify major sources and losses of water to the reflecting pool, confirm that full pool can be maintained annually, and estimate the range of detention times seasonally.

2.1 METHODS

The hydrologic budget was developed for this analysis under the assumption that the Deschutes River would not contribute to water in the freshwater reflecting pool. For consistency with the WQ DR (Herrera 2020a), this analysis was performed at monthly time steps for the same 5-year period from water years 2008 through 2012. The hydrologic budget consists of the following equation and components:

$$Precipitation + Stormwater + Groundwater - Evaporation - Outflow = \Delta\, Storage$$

Precipitation: Daily precipitation data were available from the Olympia Airport Weather Station over the entire analysis period. Monthly total volumes were calculated as the precipitation amount (depth) multiplied by the pool area.

Stormwater: Using the monthly precipitation amounts, the Simple Model (Schueler 1987) was used to estimate the fraction of rainfall (i.e., runoff coefficient) within the basin that drains to the pool. A runoff coefficient of 0.59 was applied to the entire basin based on its impervious fraction of 59.6 percent. The Simple Model was used for the Capitol Lake hydrologic budget (Herrera 2020a).

Groundwater: Groundwater inputs to the reflecting pool were estimated from five known artesian wells located within or adjacent to the freshwater pool basin. Flow rates are based on estimates reported by Robinson & Noble (1999) and assumed to be constant throughout the study period. For wells 29 and A+B, the midpoint of the range of flows is used resulting in flows of 50 and 15 gpm, respectively. Well 95 is assumed to be capped with no flow. Well 6 is assumed to be fully open at 67.5 gpm. As specified in Table 1.2, Well 30 is assumed to be 350 gpm, which is based on the flow more recently reported by TCRC (2005) because it is located in the lake and was not located by Robinson & Nobel (1999). The total groundwater input is equal to 482.5 gpm, which was rounded up to 500 gpm to account for other unidentified sources. For the Capitol Lake hydrologic budget (Herrera 2020a), the total groundwater input was assumed to be 300 gpm based on 10 wells at 30 gpm used for the previous hydrologic budget by Entranco (1984) that was primarily based on groundwater inflow to the east shore of the North Basin. Thus, the total groundwater input to the freshwater reflecting pool assumed for this study is within an order of magnitude of the input assumed for the Capitol Lake hydrologic budget. The total groundwater input used for they hydrologic budget is very approximate and additional measurements would be needed to verify the assumptions, particularly for Well 30 which is submerged in the lake and represents 70 percent of the total input.

Evaporation: Evaporation was calculated using a simplified Penman formula for lakes which is a function of temperature, dewpoint, latitude, and elevation (Linacre 1997). Meteorological data for these calculations were obtained from the Olympia Airport Weather Station.

Outflow: Pool outflow was calculated as the residual from the hydrologic budget based on all the sum of other sources/losses and assuming a contrast water level of 10 feet NAVD88. Outflow is assumed to occur through a tide valve at the pool surface that would allow pool outflow at low tides and prevent saltwater inflow at high tides. Pool outflow may also include uncontrolled seepage through, around, or under the constructed pool barrier wall during low tides. The hydraulic pressure by the full pool is assumed to prevent saltwater seepage into the pool through, around, or under the pool barrier wall.

Δ Storage: Pool level is assumed to be at full pool (10 feet NAVD88) for the entire study period (Moffatt & Nichol 2020). The approximate pool storage volume is estimated to be 20 million cubic feet (Moffatt & Nichol 2020). Therefore, over monthly time steps there is no change in storage volume and total inputs equal total output. The only circumstance where the pool level would drop below this level would be if evaporation and uncontrolled seepage exceeded freshwater inputs to the pool.

2.2 RESULTS

The hydrologic budget is presented on an average annual and summer basis in Table 2.1 and Figure 2.1. Monthly volumes for each component are presented for the entire 5-year period in Appendix B. Monthly detention times are presented in Figure 2.2.

The hydrologic budget is dominated by groundwater input, which accounts for approximately 68 and 84 percent of the total water input on an annual and summer (May-October) basis, respectively.

Table 2.1. Freshwater Reflecting Pool Hydrologic Budget Results.

Input/Output		Annual Monthly Average Volume (acre-feet)	Annual Monthly Average Percent of Total	Summer (May–October) Monthly Average Volume (acre-feet)	Summer (May–October) Monthly Average Percent of Total
Input	Precipitation	16.9	17%	6.8	9%
	Stormwater	14.0	14%	5.6	7%
	Groundwater	67.2	68%	67.2	84%
	Total Input	98.2	100%	79.6	100%
Output	Evaporation	4.1	4%	4.9	6%
	Outlet	94.1	96%	74.7	94%
	Total Outlet	98.2	100%	79.6	100%

Groundwater comprises a larger portion of the total input during summer because there is less rainfall during this period. Stormwater and precipitation inputs are similar in magnitude, together accounting for the remaining 32 percent on an annual basis and 16 percent on a summer basis (see Table 2.1). Water loss by evaporation is much less than direct precipitation at 4 percent on an annual basis and 6 percent on a summer basis. Evaporation never exceeds the total water input for any month because of the high groundwater inflow rates (see Appendix A).

One unknown water loss not accounted for in the hydrologic budget is the seepage of freshwater through, around, or under the constructed reflecting pool barrier wall. Although the outlet flow would be reduced by the barrier wall seepage loss, it is unlikely that seepage loss would exceed the groundwater seepage input, which is over 10 times the evaporation loss. Also, the phosphorus model is not affected by whether water is lost by pool outflow or barrier wall seepage. Seepage of estuarine waters into the pool is assumed to be negligible because the hydraulic pressure by the full pool would prevent such seepage during high tides.

The hydraulic retention time (residence time) is calculated for water bodies by dividing the volume of the water body by the total inflow rate. The retention time of the reflecting pool ranged from 3 months in winter months to 7 months in summer months (see Figure 2-2) due to differences in monthly precipitation amounts since groundwater input is constant. The average annual retention time for natural lakes is 9 months (the geometric mean hydraulic retention time for 309 lakes in Cooke et al. 2005), but retention times vary widely among lakes and generally depend on the watershed area relative to the lake volume. Local lake retention time examples in Seattle include 2.3 years for Lake Washington, which is a short time contributing to its excellent water quality (King County 2020), and 2.5 years for the 259-acre Green Lake (Herrera 2015), which has been increased by diverting stormwater runoff to the surrounding combined sewer system. The estimated retention times for the freshwater reflecting pool are much longer than the 14-day average retention time estimated for Capitol Lake (Herrera 2020a) and the 10-day retention time needed to manage algae blooms by flushing algae out of lakes faster than they can grow (Welch and Jacoby 2004).

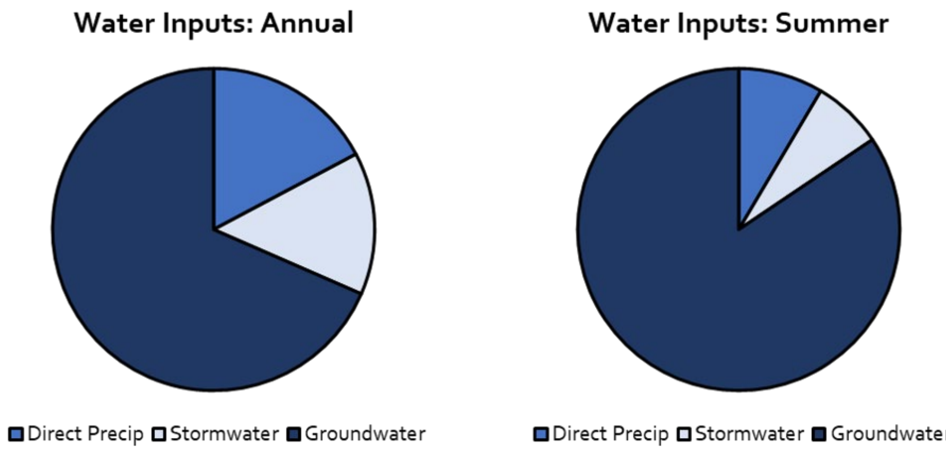


Figure 2.1. Freshwater Reflecting Pool Water Inputs Annually and During Summer Months (May–October).

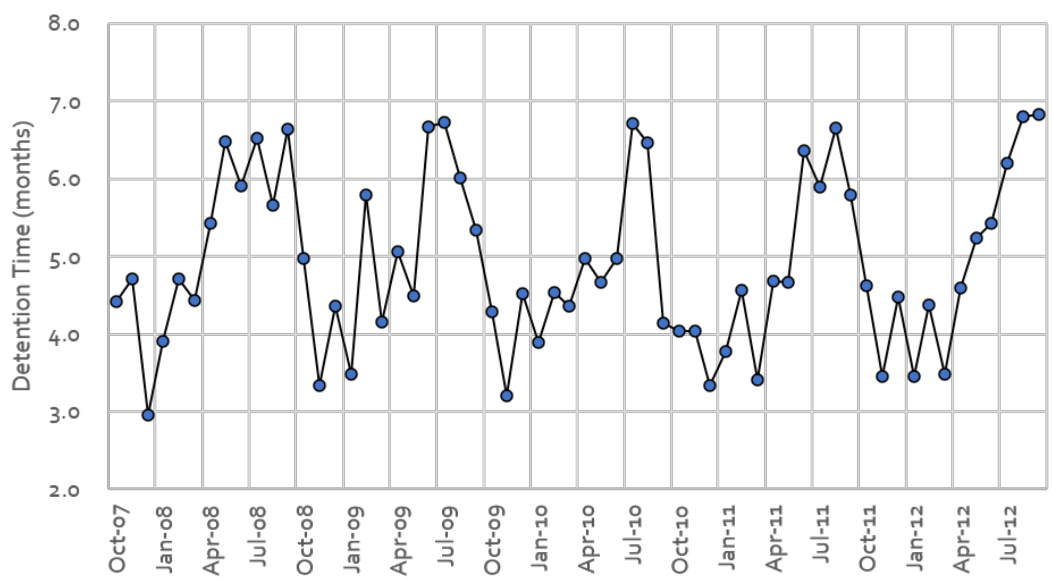


Figure 2.2. Monthly Freshwater Reflecting Pool Detention Time Over the Analysis Period of Water Years 2008 through 2012.

3.0 Phosphorus Model

Using the hydrologic budget, a simple phosphorus model was also developed for estimating the total phosphorus (TP) concentration in the freshwater reflecting pool. Phosphorus is typically the limiting nutrient for algae growth in freshwater systems, meaning that algae are more responsive to changes in phosphorus concentrations than changes in nitrogen or other nutrients. Therefore, phosphorus concentrations are commonly used to predict algae growth and their effects on water clarity, dissolved oxygen, and other water quality conditions in freshwater systems (Welch and Jacoby 2004). TP concentrations were required to be modeled over the study period because the freshwater reflecting pool is a proposed system without any existing water quality data. No TP data are available for stormwater runoff from the City of Olympia (Eric Christensen, City of Olympia Water Resources Director, personal communication) or the groundwater wells used for drinking water by the City of Olympia (Cheri Reimers, City of Olympia Water Quality Specialist, personal communication).

The primary goals of the TP model are to predict the magnitude of each TP source and sink, observe the seasonal variability of in-pool TP concentrations, and model conditions for best- and worst-case groundwater TP loading scenarios in comparison to TP objectives for maintaining good water quality.

3.1 METHODS

The phosphorus model was developed using the results from the hydrologic budget with the respective TP concentrations to calculate TP loads for each source and sink to the freshwater reflecting pool. All sources and sinks were accounted for, making the in-pool TP concentration the only unknown. Therefore, the in-pool concentration was modeled as the residual as detailed below. The mass balance is described in the equation below followed by a description of each component. The phosphorus model was developed over the same period as the hydrologic budget (water years 2008-2012) using the following mass balance equation and components:

$$[Precipitation + Stormwater + Groundwater - Sedimentation - Outflow = \ Pool\ Mass]$$
$$/Pool\ Volume = Pool\ Concentration$$

Precipitation: TP concentration in rainfall was set as a constant at 24 µg/L based on the average of rainfall TP data compiled for phosphorus budget for Lake Loma, Washington (Ecology 2013). TP concentration was multiplied by precipitation volume to yield TP mass.

Stormwater: It was assumed that the entire watershed was commercial land use with a constant TP concentration of 200 micrograms per liter (µg/L). This average concentration is based on a combination of typical TP concentrations for commercial stormwater of 220 µg/L from the National Stormwater Quality Database (Pitt et al. 2004) and 190 µg/L from the Washington State Phase I Municipal Stormwater Permit (Ecology 2011). This average TP concentration was reduced to 133 µg/L by assuming much of the stormwater would be treated for phosphorus removal by an average of 33.3 percent, as described in Section 4.1. Stormwater draining to the lake is currently not being treated (Eric Christensen, City of Olympia Water Resources Director, personal communication), but is assumed phosphorus removal would be constructed and operated to the extent possible by Enterprise Services for the freshwater reflecting pool to achieve water quality objectives for its public use. TP concentration was multiplied by stormwater inflow volume to yield TP mass. A similar stormwater TP concentration of 260 µg/L was used for the Capitol Lake phosphorus budget presented in the WQDR (Herrera 2020a).

Groundwater: Varying groundwater TP concentrations are reported by different sources that significantly affect the modeled in-pool TP concentrations. A range from low to high TP concentrations, representing best-case conditions of lower TP and algae bloom potential to worse-case conditions of higher TP and algae bloom potential, were used from two sources. At the low end, an average TP concentration of 65 µg/L in groundwater was used from Moxlie Creek monitoring in water year 2012 (Thurston County 2020) because Moxlie Creek is primarily fed by groundwater used for the City of Olympia's drinking water supply. According to Robinson & Noble (1999), water quality from the wells should be similar and quite good because they tap portions of aquifer systems which are highly confined and in which the natural flow direction is generally upward and protected from land use activities in the downtown area. The low-end TP concentration is similar to the 76 µg/L used for the phosphorus budget by Entranco (1984), which was based on a sample from the City of Olympia's drinking water well. At the high end, a TP concentration of 323 µg/L was used from a water quality sample collected from Well 29 in July 2020 (ARI 2020). This compares to a groundwater TP concentration of 435 ug/L that was used for the Capitol Lake phosphorus budget reported in the WQDR based on an average in samples collected from Well 29 and Well 46 (which is located outside the pool basin and not used for this study). The average low and high TP concentrations were reduced to 61 and 302 µg/L, respectively, by assuming some of the groundwater draining to stormwater system would be treated for phosphorus removal by an average of 6.5 percent, as described in Section 4.1. The TP concentration was multiplied by groundwater inflow volume to yield TP mass load.

Sedimentation: Phosphorus sedimentation in the pool was proportional to a second order decay rate and calculated as a function of detention time, incoming concentration, and dissolved phosphorus fraction of TP (Walker 1987). Dissolved phosphorus fractions were set to be 0.58 for precipitation (Migon and Sandroni 1999), 0.50 for stormwater (Pitt et al. 2004), and 0.32 for groundwater (based on Well 29 sample collected in 2020; ARI 2020). Sedimentation was subsequently estimated as a fraction of the total TP mass input for the given month that varied with the amount of stormwater input.

Outflow: Outflow concentration was set as the modeled in-pool TP concentration from the previous month. TP concentration was multiplied by outflow volume to yield TP mass.

Pool Concentration: The pool TP concentration was calculated by summing the input and output masses and dividing by the constant pool volume for each month.

3.2 RESULTS

The phosphorus budget was developed for the best- and worst-case scenarios described above where the only difference between the two scenarios is the assumed TP range in groundwater concentrations. The two model scenarios were based on this range in groundwater TP concentrations because they likely represent the greatest uncertainty in the model compared to inflow rates or TP concentrations in precipitation and stormwater. A relatively low amount of uncertainty is associated with the average precipitation and stormwater TP loadings predicted by the model because they are based on large datasets from similar types of basins. Precipitation and stormwater TP loadings and groundwater flow represent additional uncertainty were not varied for the best- and worst-case scenarios. Additional groundwater flow and TP monitoring data would be needed to reduce the model uncertainty, but the wide range of groundwater TP loadings estimated by the model represent the mostly likely range of conditions expected for a freshwater reflecting pool. The monthly TP inputs and outputs for the 5-year period are tabulated for each scenario in Appendix A.

The TP model results show that TP inputs to the freshwater reflecting pool are dominated by groundwater (Table 3.1 and Figure 3.1). Although the model's stormwater TP concentration of 133 ug/L is within the range of groundwater TP concentrations (61 µg/L for best-case scenario and 302 µg/L for worst-case scenario), groundwater inflow makes up a substantially higher portion of the inflow volume throughout the year (68% for groundwater versus 14% for stormwater; see Table 2.1), and especially in the summer (84% for groundwater versus 7% for stormwater; see Table 2.1) which is of most concern for water quality impacts from excess algae growth. Groundwater was predicted to account for 82 to 96 percent of the summer TP load, depending on its TP concentrations assumed for the best- to worst-case scenarios. Stormwater flows are predicted at 4 to 15 percent of the summer TP load. Precipitation TP load is negligible during summer months under any scenario. Sedimentation was a significant sink of phosphorus to the system at 25 to 50 percent for the best- to worst-case scenarios.

Table 3.1. Range of Phosphorus Model Results for Best- to Worst-Case Scenarios for the Freshwater Reflecting Pool in Water Years 2008-2012.

Source/Sink		Full Year: Monthly Average Conc. (µg/L)	Full Year: Monthly Average Load (kg)	Full Year: Monthly Average Percent of Total	Summer Months (May–October): Monthly Average Conc. (µg/L)	Summer Months (May–October): Monthly Average Load (kg)	Summer Months (May–October): Monthly Average Percent of Total
Source	Precipitation	24	0.5	2–6%	24	0.2	1–3%
Source	Stormwater	133	2.3	8–29%	133	0.9	4–15%
Source	Groundwater	61–302	5.0–25.0	64–90%	61–302	5.0–25.0	82–96%
Source	Total Input	65–230	7.9–27.8	100%	65–230	6.2–26.2	100%
Sink	Sedimentation	–	2.0–12.9	25–46%	–	1.6–12.2	25–50%
Sink	Outlet	–	5.9–15.3	54–75%	–	4.6–12.1	50–75%
Sink	Total Outlet	–	7.9–28.2	100%	–	6.2–24.2	100%

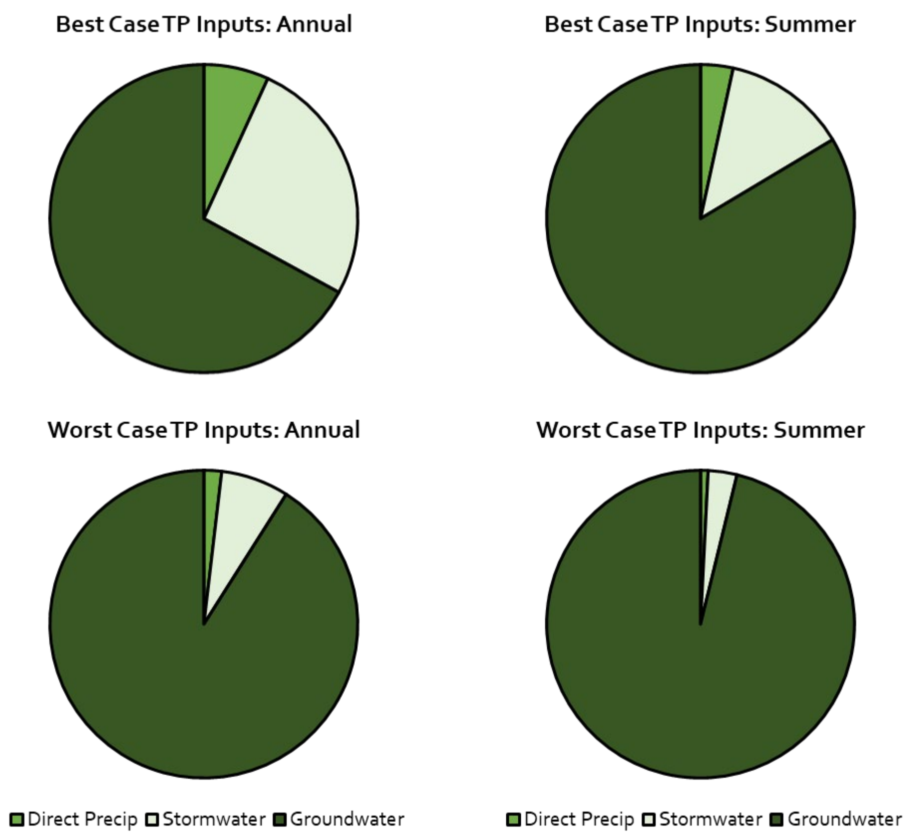


Figure 3.1. Total Phosphorus (TP) Loads Annually and During Summer Months (May–October) for the Freshwater Reflecting Pool in Water Years 2008–2012.

The modeled in-pool TP concentrations for both scenarios are presented for water year 2008-2012 in Table 3.2 and Figure 3.2. Summer average TP concentrations ranged from 50 to 131 µg/L depending on the modeled scenarios. The annual and summer averages were nearly the same under both scenarios. These model predictions clearly show that the freshwater reflecting pool would be hypereutrophic even under the best-case scenario, as discussed in Section 4. As a result, the freshwater reflecting pool alternative would require ongoing management actions to address the high phosphorus inputs and resulting algae blooms. Without water quality management of the reflecting pool, severe algae blooms would occur during the summer to the extent that all recreational uses would be severely impacted. It is likely that public health would be impacted by toxic algae blooms, aquatic life would be impacted by low dissolved oxygen concentrations during bloom crashes, aquatic habitat would be impacted by a lack of submersed plants from light limitation, and aesthetic values would be impacted by the accumulation of rotting algae along the shoreline. Potential public health impacts from fecal bacteria inputs by stormwater inflows and waterfowl droppings would be minor in comparison to toxic algae blooms that can persist well into the winter months.

Monthly in-pool TP concentrations vary seasonally for the worst-case scenario where TP concentrations increase during summer months due to the high groundwater TP concentrations and decrease in winter from lower TP concentrations in precipitation and stormwater (see Figure 3.2). TP concentrations do not vary seasonally with any of the water sources, but the pool TP varies seasonally when high groundwater TP concentrations are diluted by precipitation and stormwater input. There is essentially no seasonal variability in the best-case scenario because the lower TP concentration in groundwater (61 µg/L) is similar to the average TP concentration for precipitation (24 µg/L) and stormwater (133 µg/L) that inflow to the pond in similar amounts (see Figure 2.1). Thus, inflow of high TP in stormwater runoff is diluted by a similar volume of low TP in direct precipitation to an average concentration that is similar to that present in the pool during the winter.

Internal TP loading from sediment phosphorus release was not included in the phosphorus model based on pool morphometry. The freshwater reflecting pool is not likely to thermally stratify because it is shallow (less than 15 feet deep) and is expected to completely mix vertically under light wind conditions. As the system is mixed it would not allow for an anoxic hypolimnion to develop or allow iron-bound phosphorus in sediments to dissolve into the water column under anoxic conditions. However, anoxia can develop in surface sediments with high organic matter content regardless of oxygen presence in the overlying water column. Therefore, some internal phosphorus loading may occur but is likely to be insignificant relative to the prominent and consistent groundwater TP loading. The proposed maintenance dredging of the freshwater reflecting pool (Moffatt & Nichol 2020), assumed at 15 years after construction, would remove the existing organic-rich surface sediments and likely reduce the potential for internal phosphorus loading in the future.

Internal TP loadings from aquatic macrophyte decay and waterfowl feces were not included in the phosphorus model. It is expected that water quality management to reduce algae blooms would result in sufficient light penetration for aquatic macrophyte growth throughout the freshwater reflecting pool during all but the winter months. Aquatic macrophytes obtain phosphorus from both sediments and water, and release phosphorus into the water for algae uptake from plant decay throughout their growth cycle. In addition, waterfowl may contribute a substantial amount of TP in fecal deposits throughout the year. For example, Green Lake TP budgets for 1992-1994 predicted that dense aquatic macrophytes (85% coverage by Eurasian watermilfoil) contributed 39-45% of the annual TP budget and waterfowl contributed 27-34% of the annual TP budget (Herrera 2015). Thus, the TP model for the freshwater reflecting pool may substantially underestimate the total TP loading to the pool and the TP concentrations in the pool.

Table 3.2. Range of Phosphorus Concentrations for the Best- and Worst-Case Scenarios for the Freshwater Reflecting Pool in Water Years 2008-2012.

Case	Groundwater Concentration (µg/L)	Annual Average In-Pool TP Concentration (µg/L)	Summer (May–October) Average In-Pool TP Concentration (µg/L)
Best	61	51	50
Worst	302	129	131

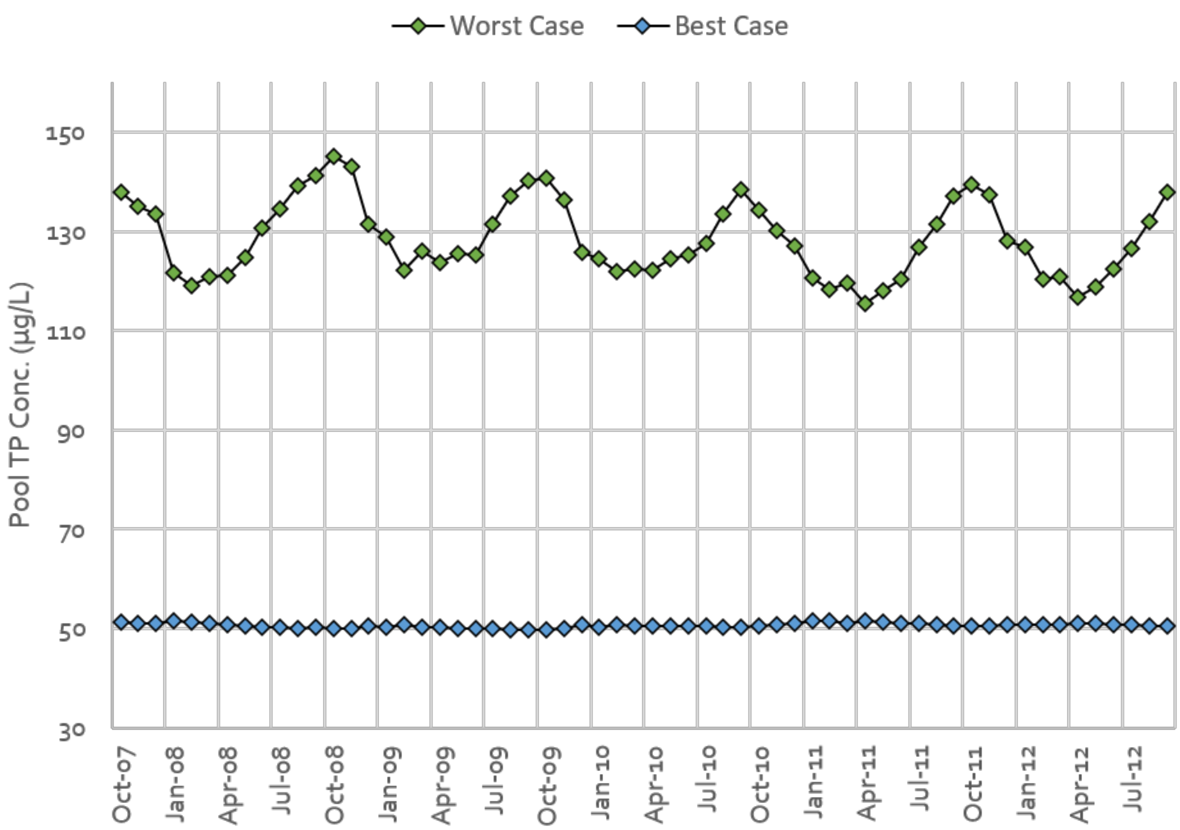


Figure 3.2 Modeled In-Lake Total Phosphorus Concentrations under Varying Best-Case and Worst-Case Groundwater Input Concentrations for the Freshwater Reflecting Pool in Water Years 2008–2012.

4.0 Water Quality Management

Water quality management methods are described for phosphorus treatment of stormwater and groundwater sources to the freshwater reflecting pool. Pool water quality is then assessed in relation to water quality objectives for supporting beneficial uses of the freshwater reflecting pool. Based on the water quality assessment, in-pool management techniques for reducing algae blooms from excess phosphorus inputs are briefly described with the assumption they would be further developed as part of an adaptive management plan, if the Hybrid Alternative was selected as the Preferred Alternative.

4.1 STORMWATER AND GROUNDWATER TREATMENT

For the phosphorus model it was assumed that a portion of the incoming stormwater and groundwater would be treated to reduce the TP load to the freshwater reflecting pool. TP removal varies depending on the treatment method, influent TP concentrations, and the size of the system relative to inflow rates. For a stormwater treatment system to be approved for phosphorus treatment in Washington State it must remove at least 50 percent of TP based on influent TP concentrations ranging from 100-500 µg/L (Ecology 2018). Currently, there are 19 approved phosphorus treatment systems and they usually exceed this minimum threshold. In addition, a coarse sand filter amended with alumina would be expected to achieve over 50 percent TP removal (C. Webb, Herrera, personal communication). For the phosphorus model, a conservatively low TP removal of 50 percent is assumed to account for the potentially high influent TP concentrations.

The City of Olympia manages stormwater in accordance with the Western Washington Phase II Municipal Stormwater Permit issued by Ecology, the Drainage Design and Erosion Control Manual prepared by the City of Olympia in 2016, and the Storm and Surface Water Plan adopted by the City council in 2018 (City of Olympia 2021). The Permit requires an ongoing program to reduce stormwater pollutants from runoff associated with new development, redevelopment, and construction site activities. The Permit expires in 2024 when the revision is expected to also require reduction of stormwater pollutants from existing development. The Permit does not require stormwater TP monitoring or specify maximum allowable stormwater TP concentrations.

It is assumed that as much as possible of the stormwater and groundwater inputs would be treated on a voluntary basis to improve water quality of the freshwater reflecting pool. However, some of these sources are not feasible to treat, such as Well 30 that discharges within the lake far from shore (see Figure 1.2). For the sake of the treatment analysis, the following assumptions were made:

- Only the stormwater from 7th Ave and Columbia Street outfalls would be treated at a TP removal of 50 percent. These basins comprise approximately 52 acres or 67 percent of the basin. It is assumed that none of the Heritage Park subbasin would be treated due to the diverse input from numerous outfalls. These assumptions result in a net TP reduction of 33.3 percent for all stormwater inputs.
- The only treatable groundwater is that from Well 29 (which discharges to Columbia Street subbasin drainage system) and Well A+B (which discharges to 7th Street subbasin drainage system). It is assumed that these well waters are sources of base flow in the drainage systems that would be treated along with stormwater sources at a 50 percent TP removal efficiency. Well 29 and A+B together account for 13 percent of all groundwater inflow to the pool, which results in a net TP reduction of 6.5 percent for all groundwater.

If this concept is selected as the Preferred Alternative, additional information about the drainage system would be obtained to select the most effective phosphorus treatment system based on phosphorus concentrations, flow rates, and physical constraints such as pipe slope of the drainage system. In addition to Ecology-approved treatment devices, a coarse sand filter amended with alumina would be expected to achieve over 50 percent TP removal (C. Webb, Herrera, personal communication). A treatment device may provide for easier maintenance but may require greater pipe slope to provide the minimum head loss for effective treatment. Whereas an amended coarse sand filter may be better suited for a drainage system with less head loss. Under extremely low slope, a pump may be required effectively treat the stormwater and groundwater inflows.

The City of Olympia owns the existing stormwater drainage system and would likely support a treatment system retrofit by Enterprise Services. The next revision of the municipal stormwater permit for Phase II jurisdictions, which includes the City of Olympia, is expected to require stormwater treatment retrofits when it becomes effective in 2024. In addition, stormwater treatment retrofit grants are currently readily available from Ecology. The capitol costs for the design and installation of a treatment system is expected to range from $400,000 to $600,000 based on costs for three stormwater phosphorus treatment systems recently designed by Herrera for the City of Bellingham (C. Mitchell, Herrera, personal communication). Operation and maintenance costs would be approximately $1,000 per year.

Phosphorus model results for the treatment of stormwater and groundwater are presented in Section 3. Overall, this treatment resulted in a total TP reduction for all inflows ranging from 7.5 to 11.2 percent for the best- to worst-case scenarios in the summer months. Thus, a relatively small portion of the stormwater and groundwater phosphorus inputs to the freshwater reflecting pool would be removed. Therefore, it may be more cost-effective to not treat any of these inputs and instead implement additional in-lake management to control those sources as described below in Section 4.3.

4.2 POOL WATER QUALITY CONDITIONS

Even with TP reductions from stormwater and groundwater treatment under the best-case scenario, the in-pool TP concentration would still be high and result in high algae growth associated from eutrophic conditions. TP is most commonly the limiting nutrient in least supply for algae growth in freshwater systems, as is the case seasonally in Capitol Lake (Herrera 2020a). Therefore, it is expected that the algae growth in the freshwater reflecting pool would be primarily regulated by the amount of phosphorus as well.

Nitrogen can limit algae growth in freshwaters when phosphorus inputs are unusually high, which could be the case under the worst-case scenario of high groundwater phosphorus concentrations. Although it was not modeled, nitrogen concentrations are also assumed to be similarly high in stormwater and groundwater inflows. For example, average total nitrogen (TN) concentrations are approximately 10 times greater than TP concentrations in both commercial stormwater (Ecology 2011) and in Moxlie Creek (Thurston County 2020), which were used for the best-case scenario. The high groundwater TP concentrations used for the worst-case scenario would likely have a TN:TP ratio less than 10. Based on nutrient relationships observed in 221 lakes, Guildford and Hecky (2000) found that phosphorus-deficient growth occurred consistently at TN:TP ratios greater than 22, and nitrogen-deficient growth occurred consistently at TN:TP ratios less than 9. This guidance suggests that algae growth in the freshwater reflecting pool would be limited by nitrogen under the worst-case scenario and may not be limited by either nitrogen or phosphorus under the best-case scenario if there was no in-lake water quality management to reduce the TP concentrations.

The range of average summer TP concentrations predicted by the phosphorus model for the freshwater reflecting pool are presented in Table 4.1. Ranges in concentrations of other trophic state parameters are also presented in Table 4.1 based on ratios of trophic state criteria for phosphorus to the other trophic state parameter. These results clearly show that the freshwater reflecting pool would be hypereutrophic even under the best-case scenario. Without water quality management of the reflecting pool, severe algae blooms would occur during the summer to the extent that all recreational uses would be severely impacted. It is likely that public health would be impacted by toxic algae blooms, aquatic life would be impacted by low dissolved oxygen concentrations during bloom crashes, aquatic habitat would be impacted by a lack of submersed plants from light limitation, and aesthetic values would be impacted by the accumulation of rotting algae along the shoreline.

Water quality management of reflecting pool waters would be needed to reduce the summer TP average concentration below a target value of 24 µg/L. Achieving this goal would provide mesotrophic conditions in the freshwater reflecting pool that are associated with sufficient algae growth to support a diverse aquatic community and fisheries, but insufficient nutrients to support toxic algae blooms or impact recreational uses and aesthetic values. Summer mean TP concentrations greater than 30 µg/L generally result in undesirable algae growth that interferes with recreational uses of lakes in the Puget Sound region (Gilliom 1983). Water quality management options are addressed in the following section.

Table 4.1. Modeled Trophic Conditions in the Freshwater Reflecting Pool Compared to Trophic State Criteria for Lakes.

	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (m)	Total Nitrogen (mg/L)
Freshwater Reflecting Pool[a]	50–131	20.9–54.9	0.73–1.92	1.25–3.28
Trophic State[b,c]:				
Oligotrophic	< 12	< 2.6	> 4	< 0.35
Mesotrophic	12–24	2.6–7.2	2–4	0.35–0.65
Eutrophic	24–48	7.1–20.1	1–2	0.65–1.2
Hypereutrophic	> 96	> 56	< 0.5	> 1.2

[a] Range of summer mean total phosphorus values from phosphorus model and corresponding values for other tropic state parameters based on typical ratios observed in lakes.

[b] Tropic state criteria for total phosphorus, chlorophyll-a, and Secchi depth from Carlson (1977).

[c] Trophic state criteria for total nitrogen from Welch and Jacoby (2004).

Aquatic plants would likely grow in moderate abundance if the freshwater reflecting pool was managed to mesotrophic conditions where nutrients are in sufficient abundance to support growth and algae are in limited abundance to not limit light penetration to the lake bottom. Ideally, nutrients would be managed at a level where the freshwater reflecting pool is in a stable state of moderate algae and aquatic plant growth to benefit all recreational and wildlife uses. Some aquatic plant management may be needed on occasion, particularly if invasive species are introduced to the reflecting pool.

4.3 POOL WATER QUALITY MANAGEMENT

To achieve mesotrophic conditions, the summer TP concentration would need to be reduced by at least 52 percent under the best-case scenario and 82 percent for the worst-case scenario. Figure 4.1 shows the trophic state effects of reducing summer mean TP concentrations in the freshwater reflecting pool for the modeled best- and worst-case scenarios. This high amount of phosphorus reduction would require continuous water quality management using phosphorus inactivation. Other in-lake management techniques that would not be effective for converting a hypereutrophic reflecting pool to a mesotrophic reflecting pool, include:

- Algaecide (short-term effectiveness and possible aquatic life impacts)
- Aeration (promotes good algae by bubbler mixing but does not reduce overall biomass)
- Solar-powered circulation (promotes good algae by physical mixing but does not reduce overall biomass)
- Nanobubbler (promotes good algae by increasing oxygen and phosphorus reduction from iron oxidization)

- Ultrasonic waves (promotes good algae using ultrasound to impact blue-green algae buoyancy)
- Dilution (adds high amounts of water with phosphorus concentrations less that those currently present in local river or drinking water sources)
- Flushing (washes algae out faster than they can grow requiring prohibitively low detention times of less than 10 days)
- Dredging (removes nutrient rich sediment at high cost and low effectiveness)
- Hypolimnetic oxygenation or withdrawal (reduces internal phosphorus loading from bottom waters in stratified lakes)
- Biomanipulation (minimally reduces algae growth by planting zooplankton or piscivorous fish)

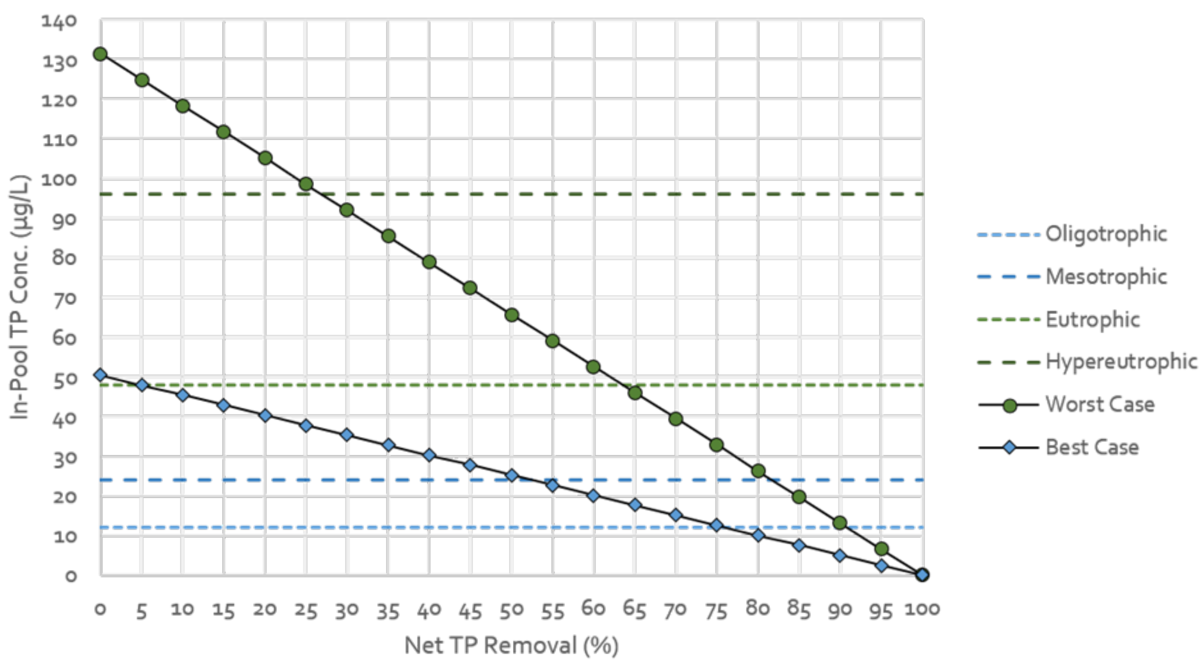


Figure 4.1. Tropic State Effects of Reducing Summer Mean Total Phosphorus Concentrations in the Freshwater Reflecting Pool for the Modeled Best- and Worst-Case Scenarios.

Chemicals inactivation (binding) of phosphorus would be needed to achieve the 52-82% reduction in summer mean TP concentration that is estimated to be needed to meet water quality objectives and support beneficial uses of the freshwater reflecting pool. Phosphorus-binding chemical additives such as aluminum sulfate (alum) and lanthanum-treated bentonite clay (Phoslock) have been shown to reduce the trophic state of lakes by substantially reducing phosphorus concentrations. When applied, these chemicals bind to soluble phosphorus in water column and flocculate algae particles that settle to the bottom where they form a barrier to phosphorus release for the sediments by binding with phosphate ions.

Alum can be applied in large whole-lake doses, multiple smaller in-lake doses, or on a continuous basis through microfloc injection systems. Large whole-lake doses are commonly applied to lakes with high internal phosphorus loading where they are typically effective for at least 10 years (Cooke et al. 2005). Small whole-lake doses of alum are applied to lakes with high external phosphorus loading every year or so to focus more on water phosphorus inactivation than sediment phosphorus inactivation. Alum microfloc injection systems are used to inactivate high phosphorus concentrations in either lake waters or inflow waters. Whole-lake applications are commonly performed in the spring to reduce the algae growth during the following summer months, and typically include the use of sodium aluminate to buffer the alum acidity and maintain a neutral pH for prevention of aluminum toxicity. Alum microfloc injection of lake waters typically occur continuously into the hypolimnion during the summer months and at such low doses that they do not require the added expense of a sodium aluminate buffer. Alum microfloc injection of inflow waters typically occur continuously during the entire inflow period with dosing adjusted to measured inflow rates.

Phoslock is the tradename for a product that is a combination of Lanthanum, a natural but rare element in the earth, and bentonite. Because the lanthanum has a strong affinity for phosphate it is able to chemically inactive phosphate through precipitation and forms a mineral of extremely low solubility; thus permanently binding the phosphorus. Unlike alum it is not a coagulant and so it does not trap and remove particles in the water column. In fact, water can be more turbid in the days immediately following an application but decrease with time, as compared to alum which immediately clears the water. Like alum, Phoslock can be applied in frequent small doses to strip the water column of inorganic phosphorus, but primarily binds phosphate in sediments that would normally be released to the water through decomposition or changes in sediment chemistry. Phoslock has no known toxicity and therefore does not have the application concerns that are associated with use of alum. Like alum it is easy to estimate needed dosage, which is based on a 100:1 ratio of Phoslock to potentially available phosphorus versus a ratio of 10:1 ratio for aluminum to phosphate. One of the key drawbacks to Phoslock is that there are fewer case studies of lake applications to draw from to evaluate effectiveness and duration of treatments.

Alum and Phoslock® treatments have proven to be an excellent management tool for reducing phosphorus levels in lakes. Whole-lake alum treatments have been successfully applied to over 10 other lakes in western Washington (Herrera 2020b). Green Lake in Seattle, Washington is a eutrophic urban lake that has been treated three times with alum over the past three decades to meet the summer phosphorus concentration objective not to exceed 20 µg/L. In the spring of 2016, the third alum treatment resulted in a 44 percent decrease in TP through the water column within 2 weeks after the application that was sustained throughout the summer (Herrera 2017).

Continuous alum injection systems are highly effective and have been seen to reduce TP concentrations even more effectively than single doses. Examples of alum injection system effectiveness were summarized for a similar system proposed for Lake Steilacoom in Washington (Herrera 2010). In the 3-acre Amesbury Pond in suburban Minneapolis, alum was applied through a microfloc injection system and paired with whole-lake treatments to reduce TP concentrations by 75 to 88 percent (from 160 µg/L to 20-40 µg/L). Alum microfloc injection reduced TP by 50 percent in both Mohawk Lake and White Meadow Lake, New Jersey.

Phoslock is used as an alternative to alum in Canada and Europe due to concerns about aluminum toxicity to aquatic invertebrates when the pH of lake waters or sediments is less than 6.5 (Steinman and Spears 2020). Phoslock has been applied to over 250 water bodies around the world and numerous case studies are available from Phoslock Environmental Technologies (2020). Phoslock was first applied in Washington in 2012 to Lake Lorene in Federal Way. Most recently in 2020, Kitsap Lake in Bremerton was treated with the first of three annual Phoslock treatments planned for managing toxic algae blooms.

If the Hybrid Alternative was selected as the Preferred Alternative, additional design, evaluation and community engagement would be needed to develop an effective, acceptable, and adaptive, algae management plan for the freshwater reflecting pool. Alternative phosphorus and algae management techniques most likely to be effective for the high phosphorus concentrations expected in the freshwater reflecting pool include annual whole-lake annual applications of buffered alum or Phoslock, or microfloc injection of alum directly into the reflecting pool. Whole-lake applications of buffered alum or Phoslock are simple to design and easily permitted through the Aquatic Plant and Algae Management General Permit. Either product would be applied to the entire lake surface by boat in one day. A second application may be needed later in the summer to prevent algae blooms if high groundwater phosphorus inputs occur under the worst-case scenario.

Enterprise Services would hire a lake manager to implement the adaptive water quality management plan. The total annual cost for a whole-lake buffered alum treatment would be approximately $5,000 for one annual dose to inactivate 50 ug/L TP for the best-case scenario, and would cost approximately $20,000 for two doses per year to inactivate 330 ug/L TP for the worst-cast scenario. In addition, an adaptive management plan would be needed at an initial cost of approximately $50,000. Permitting costs would be negligible. Whole-lake Phoslock treatments would likely cost approximately 25 percent more than buffered alum treatments.

Alum microfloc injection would likely be more effective than a whole-lake alum or Phoslock application because the phosphorus supply is continuously inactivated during the entire algae growing season. Alum injection may be most effective if the injection tube is inserted far up the Well 30 outfall pipe to allow for floc formation and phosphorus inactivation before the treated groundwater is discharged from the pipe. Pilot testing and monitoring of microfloc injection would likely be needed to ensure proper floc formation and settling within the reflecting pool, and to verify that the treatment is effective and safe without discharge of aluminum from the reflecting pool. Long-term management costs would likely be lower for alum microfloc injection than whole-lake application, primarily due to the high cost of sodium aluminate needed to buffer the whole-lake application but not the low-dose microfloc injection.

Phosphorus inactivation of the freshwater reflecting pool would not have a negative impact on estuary water quality. The alum or Phoslock treatments would be conducted to prevent discharge of the applied chemicals by not discharging any pool waters while the chemical floc settles to the bottom of the reflecting pool. This is a permit condition that is easily met because buffered alum generally settles within a day of application and Phoslock generally settles within a week of application, and the outlet gate of the freshwater reflecting pool would be designed to allow shallow drawdown of the pool prior to treatment. Continuous microfloc injection would be designed and initially monitored to ensure all alum floc settles before reaching the pool outlet.

5.0 Impacts and Mitigation Measures

5.1 FRESHWATER REFLECTING POOL IMPACTS

This section describes the impacts of the freshwater reflecting pool compared to existing conditions and what would occur for the original saltwater reflecting pool planned as part of the Hybrid Alternative. Impact criteria are the same as those used in the WQDR (Herrera 2020a).

5.1.1 Impacts from Construction

Construction impacts of the Hybrid Alternative on water quality would be as described for the Hybrid Alternative in WQDR (Herrera 2020a). Construction impacts of the freshwater reflecting pool would be similar to those described for the saltwater reflecting pool with the exception that the freshwater reflecting pool would require construction of treatment infrastructure for stormwater, groundwater, and potentially within the reflecting pool. It is assumed that the construction of these treatment systems would follow best management practice (BMPs) resulting with a **less than significant** impact to the water quality in the lake basin or Budd Inlet.

5.1.2 Impacts from Operation

The operation impacts associated with the freshwater reflecting pool alternative in relation to the saltwater reflecting pool alternative and existing conditions are primarily associated with nutrient concentrations and algae growth within the reflecting pool. The freshwater reflecting pool would be managed to reduce nutrient concentrations and algae growth from the predicted hypereutrophic state to a mesotrophic state to support all beneficial uses of the pool. Overall, operational impacts of the managed freshwater reflecting pool would be less than the unmanaged saltwater reflecting pool primarily because nutrient loadings to Budd Inlet would be reduced for the freshwater reflecting pool and not the saltwater reflecting pool. Stormwater and groundwater nutrient inputs to Budd Inlet from the pool drainage basin would not be reduced for the saltwater reflecting pool but would be reduced for the freshwater reflecting pool to prevent toxic algae blooms in the freshwater reflecting pool. The reduced nutrient loading to Budd Inlet would contribute to improved dissolved oxygen conditions in Budd Inlet. Failure to properly manage the trophic state of the freshwater reflecting pool, however, could increase the nutrient concentrations and algae growth in the reflecting pool beyond that expected in a higher flushed saltwater reflecting pool or currently present in the North Basin.

The managed freshwater reflecting pool also would be expected to have somewhat higher summer surface water temperatures, lower summer bottom water dissolved oxygen concentrations, and higher fecal coliform bacteria concentrations than the saltwater reflecting pool because of the high flushing rate provided by the saltwater reflecting pool.

5.1.1 Budd Inlet

The expected benefits and impacts associated with the operation of the Hybrid Alternative in Budd Inlet would be similar to those described in WQDR. The freshwater reflecting pool would provide **additional minor benefits** on Budd Inlet water quality from reduced nutrient loading and associated improvement in dissolved oxygen, assuming phosphorous treatment of stormwater, groundwater, and reflecting pool water would reduce inputs of nitrogen and oxygen demanding organic matter.

Because of the relatively small size of the reflecting pool and its drainage basin, the overall reduction in nitrogen loading to Budd Inlet is not likely to be significantly lower under a freshwater reflecting pool concept compared to a saltwater reflecting pool concept. The reflecting pool basin area is only 0.07% of the Budd Inlet watershed area and Puget Sound tidal waters provide additional nitrogen loading to Budd Inlet. Therefore, significant reductions of nutrient loading from the freshwater pool could not have a significant effect on dissolved oxygen concentrations in Budd Inlet.

Surface water discharged from a freshwater reflecting pool managed to maintain mesotrophic conditions would likely contain nearly saturated concentrations of dissolved oxygen that would not impact Budd Inlet water quality. Dissolved oxygen concentrations in pool waters discharged from the pool surface likely would be saturated from extended contact with air or supersaturated from algae growth within the pool during the critical summer months when Budd Inlet water quality is impacted by low dissolved oxygen concentrations in its bottom waters. Groundwaters inherently have low dissolved oxygen concentrations because they are not exposed to air and, therefore, dissolved oxygen concentrations are expected to be low in the groundwater discharged directly into the pool. It is expected that inflowing groundwaters would thoroughly mix with pool waters during the winter when water and air temperatures are similarly cool, but inflowing groundwaters would likely plunge to the bottom of the pool during the summer when air and surface water temperatures are warm because cool groundwaters would be more dense than warm surface waters. Summer surface waters would likely be saturated to supersaturated with oxygen due to algae growth. When surface water temperatures decrease in the fall and the surface and bottom waters mix (i.e., fall turnover), the pond would discharge waters with somewhat low dissolved oxygen concentrations to Budd Inlet. However, the pool discharge likely would not result in a measurable effect on dissolved oxygen concentrations in Budd Inlet due to the low pool discharge rate in relation to the river flow and tidal flushing rate.

Temperatures of the discharged waters would not be exceptionally high because of the high input of cool groundwaters. Surface water temperatures could become elevated in the freshwater reflecting pool during the summer when they are heated by warm air and the cool groundwaters plunge to the bottom. However, the pool discharge likely would not result in a measurable effect on temperatures in Budd Inlet due to the low pool discharge rate in relation to the river flow and tidal flushing rate.

Failure to properly manage the trophic state of the freshwater reflecting pool, however, could increase the nitrogen load to Budd Inlet. Overall, there would be **less than significant impacts** to water quality in Budd Inlet from the freshwater reflecting pool compared to existing conditions or the saltwater reflecting pool because of the small discharge from the freshwater reflecting pool relative to the river and tidal inputs to Budd Inlet. The impacts to water quality in Budd Inlet are not measurably different across these concepts, assuming that the freshwater reflecting pool is properly treated to reduce phosphorus.

5.1.2 Lake Basin

Water quality conditions in the western estuarine portion of the North Basin would be similar to those described in the WQDR for the lake basin under the Hybrid Alternative.

In comparison to the saltwater reflecting pool in the eastern portion of the North Basin, the freshwater reflecting pool would likely produce more algae and have higher fluctuations in dissolved oxygen, temperatures, and fecal bacteria. More algae would be expected because of the increased residence time (reduced flushing rate) and the high phosphorus concentrations in stormwater and groundwater inflows to the pool. However, if managed properly with treatment of stormwater, groundwater and reflecting pool water in perpetuity, the freshwater reflecting pool would be mesotrophic and not experience more algae blooms than the existing North Basin.

Dissolved oxygen concentrations in the well-flushed saltwater reflecting pool would decrease to below the 6 mg/L marine water standard in the late summer or early fall based on existing low oxygen conditions observed in Budd Inlet (see Table 4.12 in the WQDR). Dissolved oxygen concentrations would likely be greater than 8 mg/L in surface waters of the freshwater reflecting pool based on saturated conditions (i.e., 8.2 mg/L at 25 °C) or supersaturated conditions caused by algae growth (photosynthesis). Summer dissolved oxygen concentrations in the freshwater reflecting pool would be high in surface waters from algae growth and low in bottom waters from the plunging of cool groundwaters with low oxygen and the decay of settled organic matter. The mixing of these layers in the fall could result in dissolved oxygen concentrations below the freshwater standard of 6.5 mg/L for indigenous warm water fish species. Thus, summer dissolved oxygen concentrations likely would be lower in bottom waters of the freshwater reflecting pool than the saltwater reflecting pool or existing conditions in the North Basin, which range from 7 to 14 mg/L (see Figure 4.2 in WQDR). However, bottom water dissolved oxygen concentrations in the freshwater reflecting pool would likely be no less than the 1-3 mg/L observed in nearby natural lakes (i.e., Black, Long, and Ward lakes shown in Figure 4.5 of the WQDR).

Surface water temperatures could become elevated in the freshwater reflecting pool during the summer when they are heated by warm air and the cool groundwaters plunge to the bottom. Thus, summer temperatures of surface waters would likely be higher than the freshwater standard of 20 °C for indigenous warm water fish species and those for the existing well-flushed North Basin (which ranges up to 22 °C as shown in Figure 4.2 in WQDR) or a well-flushed saltwater reflecting pool (which ranges up to 20 °C in Budd Inlet as shown in Table 4.12 in the WQDR). Mixing of continuous inputs of cool groundwater with surface waters would likely prevent unusually high temperatures above 25 °C.

Fecal bacteria concentrations could be become elevated in the freshwater reflecting pool compared to the saltwater reflecting pool and existing lake because of the lower flushing rate (higher residence time). Although fecal bacteria inputs from the drainage basin would be reduced by stormwater treatment, the freshwater reflecting pool may have higher duck and geese populations than a saltwater pool. Ducks and geese are major sources of fecal bacteria in lakes with aquatic plants (Herrera 2015) and produce much more feces that saltwater seabirds. Aquatic plant growth would likely be greater in a managed freshwater reflecting pool than a saltwater reflecting pool, which would attract more herbaceous ducks and geese and also would provide better habitat for other aquatic organisms. Excessive invasive or native aquatic plant growth would be managed to prevent recreational impacts.

High temperatures in surface waters and low dissolved oxygen concentrations in bottom waters are not expected to be exceptionally different that those observed in other lakes in Thurston County (see Figure 4.5 in the WQDR). If these conditions are observed to impact beneficial uses, they could be mitigated by water quality management techniques such as aeration, solar-powered mixing, or nanobubble generation (see Section 4.3). In addition, increased fecal bacteria inputs from waterfowl use could be reduced by various deterrent techniques (WDFW 2020) or lethal techniques previously used for resident Canada geese at Capitol Lake (see Aquatic Invasive Species Discipline report by Herrera 2020c).

Overall, the managed freshwater reflecting pool, with treatment infrastructure and management operations, would have **less than significant impacts** to water quality when compared to existing conditions and the saltwater reflecting pool or the existing lake.

It is assumed that if the Hybrid Alternative was selected as the Preferred Alternative, and including the freshwater reflecting pool concept, that groundwater and stormwater inputs would be actively treated to reduce phosphorus, and the reflecting pool water would also be actively treated to meet water quality standards. This active treatment and management would be required in perpetuity at an initial cost of $450,000 to $650,000 and annual cost of $6,000 to $25,000 that would not be incurred by the saltwater reflecting pool.

Active management would be imperative to improve water quality conditions for supporting recreation and ecological functions. If water quality is not managed within the freshwater reflecting pool and its inputs, severe algae blooms would likely occur during the summer to the extent that all recreational uses would be severely impacted. Without active management, it is likely that public health would be impacted by toxic algae blooms, aquatic life would be impacted by low dissolved oxygen concentrations during bloom crashes, aquatic habitat would be impacted by a lack of submersed plants from light limitation, and aesthetic values would be impacted by the accumulation of rotting algae along the shoreline. The saltwater reflecting pool would not require active management to substantially improve water quality compared to existing conditions.

5.2 AVOIDANCE, MINIMIZATION, AND MITIGATION MEASURES

Adaptive management would be required to implement one or more of the in-pool management techniques depending on phosphorus and algae levels in the reflecting pool after its construction. A substantial reduction in amounts of total phosphorus in the source waters and within the reflecting pool itself would be needed to meet water quality objectives for full support of recreational and wildlife uses of the reflecting pool.

An adaptive management plan would be prepared for the freshwater reflecting pool. This plan would establish water quality objectives for meeting beneficial uses, and would include flow and water quality monitoring of existing stormwater and groundwater inputs to the east shore of the North Basin to refine estimates of nutrient loadings and water quality conditions in the freshwater reflecting pool. Treatment of stormwater and groundwater inputs would be designed based on this new information, and the need and feasibility of in-lake management techniques would be evaluated to meet water quality objectives and further reduce the potential for toxic algae blooms. Because of the inherent uncertainty with predicting water management effectiveness, it is likely that the freshwater reflecting pool would be constructed and operated for a year or more before in-lake management techniques would be implemented adaptively in response to water quality conditions observed in the newly constructed freshwater reflecting pool.

No specific mitigation measures were identified for the saltwater reflecting pool in the Hybrid Alternative (Herrera 2020a). As described above, mitigation measures would be needed for the freshwater reflecting pool alternative because of the high nutrient loading rate and lower flushing rate, and those measures would include various adaptive management techniques to meet water quality objectives.

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Appendix A

Monthly Hydrologic and Phosphorus Budgets

FW Pool Water Budget Summary

Month/ Year	Input Volumes (ac-ft)				Storage (ac-ft)		Output Volumes (ac-ft)			Retention Time (months) (Storage / Total Input)
	Direct Precip	Stormwater	Groundwater	Total Input	Current	Change	Evaporation	Outflow/ Seepage	Total Output	
Oct-07	20.0	16.6	67.2	103.9	459.1	0.0	4.4	99.5	103.9	4.4
Nov-07	16.6	13.8	67.2	97.6	459.1	0.0	3.6	93.9	97.6	4.7
Dec-07	48.1	39.9	67.2	155.2	459.1	0.0	4.8	150.4	155.2	3.0
Jan-08	27.5	22.8	67.2	117.5	459.1	0.0	2.3	115.2	117.5	3.9
Feb-08	16.5	13.7	67.2	97.4	459.1	0.0	3.3	94.1	97.4	4.7
Mar-08	19.8	16.5	67.2	103.5	459.1	0.0	3.0	100.5	103.5	4.4
Apr-08	9.6	7.9	67.2	84.7	459.1	0.0	3.2	81.5	84.7	5.4
May-08	2.0	1.6	67.2	70.8	459.1	0.0	4.9	65.9	70.8	6.5
Jun-08	5.8	4.8	67.2	77.8	459.1	0.0	4.8	73.0	77.8	5.9
Jul-08	1.7	1.4	67.2	70.4	459.1	0.0	4.9	65.4	70.4	6.5
Aug-08	7.6	6.3	67.2	81.2	459.1	0.0	5.7	75.5	81.2	5.7
Sep-08	1.1	0.9	67.2	69.2	459.1	0.0	4.5	64.7	69.2	6.6
Oct-08	13.8	11.5	67.2	92.5	459.1	0.0	4.0	88.5	92.5	5.0
Nov-08	38.5	31.9	67.2	137.6	459.1	0.0	4.3	133.3	137.6	3.3
Dec-08	20.7	17.2	67.2	105.2	459.1	0.0	1.8	103.4	105.2	4.4
Jan-09	35.2	29.2	67.2	131.7	459.1	0.0	3.0	128.7	131.7	3.5
Feb-09	6.6	5.5	67.2	79.2	459.1	0.0	1.8	77.5	79.2	5.8
Mar-09	23.6	19.6	67.2	110.4	459.1	0.0	2.5	107.9	110.4	4.2
Apr-09	12.9	10.7	67.2	90.7	459.1	0.0	3.0	87.8	90.7	5.1
May-09	19.2	16.0	67.2	102.4	459.1	0.0	3.7	98.7	102.4	4.5
Jun-09	0.9	0.7	67.2	68.9	459.1	0.0	4.7	64.1	68.9	6.7
Jul-09	0.6	0.5	67.2	68.3	459.1	0.0	4.9	63.4	68.3	6.7
Aug-09	5.0	4.2	67.2	76.4	459.1	0.0	5.1	71.3	76.4	6.0
Sep-09	10.2	8.5	67.2	85.9	459.1	0.0	4.5	81.5	85.9	5.3
Oct-09	21.9	18.1	67.2	107.2	459.1	0.0	4.2	102.9	107.2	4.3
Nov-09	41.4	34.4	67.2	143.0	459.1	0.0	4.4	138.6	143.0	3.2
Dec-09	18.8	15.6	67.2	101.6	459.1	0.0	0.7	100.9	101.6	4.5
Jan-10	27.9	23.1	67.2	118.2	459.1	0.0	4.5	113.7	118.2	3.9
Feb-10	18.6	15.4	67.2	101.3	459.1	0.0	3.2	98.0	101.3	4.5
Mar-10	20.8	17.3	67.2	105.3	459.1	0.0	3.1	102.2	105.3	4.4
Apr-10	13.7	11.4	67.2	92.3	459.1	0.0	4.1	88.2	92.3	5.0
May-10	17.0	14.1	67.2	98.3	459.1	0.0	4.1	94.2	98.3	4.7
Jun-10	13.7	11.4	67.2	92.3	459.1	0.0	5.4	86.9	92.3	5.0
Jul-10	0.7	0.5	67.2	68.4	459.1	0.0	4.9	63.5	68.4	6.7
Aug-10	2.1	1.7	67.2	71.0	459.1	0.0	5.1	66.0	71.0	6.5
Sep-10	23.8	19.7	67.2	110.7	459.1	0.0	5.8	104.9	110.7	4.1
Oct-10	25.5	21.2	67.2	113.9	459.1	0.0	4.7	109.2	113.9	4.0
Nov-10	25.5	21.1	67.2	113.8	459.1	0.0	4.7	109.1	113.8	4.0
Dec-10	38.4	31.9	67.2	137.5	459.1	0.0	4.6	132.9	137.5	3.3
Jan-11	29.9	24.8	67.2	121.9	459.1	0.0	4.7	117.2	121.9	3.8
Feb-11	18.3	15.2	67.2	100.7	459.1	0.0	2.5	98.2	100.7	4.6
Mar-11	37.0	30.7	67.2	134.9	459.1	0.0	4.3	130.5	134.9	3.4
Apr-11	16.9	14.0	67.2	98.1	459.1	0.0	3.8	94.3	98.1	4.7
May-11	17.1	14.2	67.2	98.5	459.1	0.0	4.5	94.0	98.5	4.7
Jun-11	2.8	2.3	67.2	72.2	459.1	0.0	5.5	66.7	72.2	6.4
Jul-11	5.8	4.8	67.2	77.9	459.1	0.0	5.5	72.4	77.9	5.9
Aug-11	1.0	0.9	67.2	69.1	459.1	0.0	5.2	63.9	69.1	6.6
Sep-11	6.7	5.5	67.2	79.4	459.1	0.0	5.0	74.4	79.4	5.8
Oct-11	17.5	14.5	67.2	99.2	459.1	0.0	5.0	94.3	99.2	4.6
Nov-11	36.1	29.9	67.2	133.2	459.1	0.0	3.0	130.2	133.2	3.4
Dec-11	19.3	16.0	67.2	102.5	459.1	0.0	2.7	99.7	102.5	4.5
Jan-12	35.8	29.7	67.2	132.8	459.1	0.0	2.8	130.0	132.8	3.5
Feb-12	20.6	17.1	67.2	104.9	459.1	0.0	3.4	101.5	104.9	4.4
Mar-12	35.2	29.2	67.2	131.6	459.1	0.0	3.8	127.9	131.6	3.5
Apr-12	17.9	14.8	67.2	99.9	459.1	0.0	4.1	95.8	99.9	4.6
May-12	11.2	9.3	67.2	87.7	459.1	0.0	4.1	83.6	87.7	5.2
Jun-12	9.5	7.9	67.2	84.6	459.1	0.0	5.4	79.1	84.6	5.4
Jul-12	3.7	3.1	67.2	74.0	459.1	0.0	5.6	68.3	74.0	6.2
Aug-12	0.2	0.1	67.2	67.5	459.1	0.0	5.1	62.4	67.5	6.8
Sep-12	-	-	67.2	67.2	459.1	0.0	4.1	63.1	67.2	6.8
Average Annual										
Volume (ac-ft)	17	14	67	98	459	0	4	94	98	4.9
Percent	17%	14%	68%	100%	-	-	4%	96%	100%	-
Average Summer (May-Sept)										
Volume (ac-ft)	7	6	67	80	459.1	-	5	75	80	5.7
Percent	9%	7%	84%	100%	-	-	6%	94%	100%	-

FW Pool Total Phosphorus Budget Summary - Best Case										
	Input Loads (kg)				Storage (kg)			Output Loads (kg)		
Month/ Year	Direct Precip	Stormwater	Groundwater	Total Surface Input	Current Conc (ug/L)	Current	Change	Sedimentation	Outflow	Total Output
Oct-07	0.6	2.7	5.0	8.4	51.2	29.0	(0.0)	2.1	6.3	8.4
Nov-07	0.5	2.3	5.0	7.8	51.2	29.0	(0.1)	2.0	5.9	7.9
Dec-07	1.4	6.6	5.0	13.0	51.0	28.8	0.4	3.2	9.5	12.6
Jan-08	0.8	3.8	5.0	9.6	51.6	29.2	(0.2)	2.4	7.3	9.8
Feb-08	0.5	2.2	5.0	7.8	51.3	29.1	(0.2)	2.0	6.0	7.9
Mar-08	0.6	2.7	5.0	8.3	51.1	28.9	(0.1)	2.1	6.3	8.4
Apr-08	0.3	1.3	5.0	6.6	50.9	28.8	(0.2)	1.7	5.1	6.8
May-08	0.1	0.3	5.0	5.4	50.5	28.6	(0.1)	1.4	4.1	5.5
Jun-08	0.2	0.8	5.0	6.0	50.3	28.5	(0.1)	1.5	4.5	6.1
Jul-08	0.1	0.2	5.0	5.3	50.2	28.4	(0.1)	1.4	4.1	5.4
Aug-08	0.2	1.0	5.0	6.3	50.1	28.3	0.0	1.6	4.7	6.3
Sep-08	0.0	0.2	5.0	5.2	50.2	28.4	(0.1)	1.3	4.0	5.3
Oct-08	0.4	1.9	5.0	7.3	50.0	28.3	0.0	1.9	5.4	7.3
Nov-08	1.1	5.2	5.0	11.4	50.0	28.3	0.4	2.8	8.2	11.0
Dec-08	0.6	2.8	5.0	8.5	50.6	28.7	(0.1)	2.2	6.5	8.6
Jan-09	1.0	4.8	5.0	10.9	50.4	28.5	0.2	2.7	8.0	10.7
Feb-09	0.2	0.9	5.0	6.1	50.7	28.7	(0.3)	1.6	4.8	6.4
Mar-09	0.7	3.2	5.0	9.0	50.2	28.4	0.0	2.3	6.7	9.0
Apr-09	0.4	1.8	5.0	7.2	50.2	28.4	(0.1)	1.8	5.4	7.3
May-09	0.6	2.6	5.0	8.2	50.0	28.3	0.1	2.1	6.1	8.2
Jun-09	0.0	0.1	5.0	5.2	50.1	28.4	(0.1)	1.3	4.0	5.3
Jul-09	0.0	0.1	5.0	5.1	49.9	28.3	(0.1)	1.3	3.9	5.2
Aug-09	0.1	0.7	5.0	5.9	49.8	28.2	(0.0)	1.5	4.4	5.9
Sep-09	0.3	1.4	5.0	6.7	49.8	28.2	0.0	1.7	5.0	6.7
Oct-09	0.6	3.0	5.0	8.7	49.8	28.2	0.2	2.2	6.3	8.5
Nov-09	1.2	5.7	5.0	11.9	50.1	28.4	0.4	2.9	8.6	11.5
Dec-09	0.6	2.6	5.0	8.2	50.8	28.8	(0.3)	2.1	6.3	8.4
Jan-10	0.8	3.8	5.0	9.7	50.4	28.5	0.2	2.4	7.1	9.5
Feb-10	0.6	2.5	5.0	8.1	50.7	28.7	(0.1)	2.1	6.1	8.2
Mar-10	0.6	2.8	5.0	8.5	50.6	28.6	(0.0)	2.2	6.4	8.5
Apr-10	0.4	1.9	5.0	7.3	50.5	28.6	(0.0)	1.9	5.5	7.4
May-10	0.5	2.3	5.0	7.9	50.4	28.5	0.0	2.0	5.9	7.9
Jun-10	0.4	1.9	5.0	7.3	50.4	28.6	0.1	1.8	5.4	7.3
Jul-10	0.0	0.1	5.0	5.1	50.6	28.6	(0.1)	1.3	4.0	5.3
Aug-10	0.1	0.3	5.0	5.4	50.3	28.5	(0.1)	1.4	4.1	5.5
Sep-10	0.7	3.2	5.0	9.0	50.2	28.4	0.2	2.2	6.5	8.7
Oct-10	0.8	3.5	5.0	9.3	50.6	28.7	0.1	2.3	6.8	9.1
Nov-10	0.8	3.5	5.0	9.3	50.9	28.8	0.1	2.3	6.8	9.2
Dec-10	1.1	5.2	5.0	11.4	51.0	28.9	0.2	2.8	8.4	11.2
Jan-11	0.9	4.1	5.0	10.0	51.4	29.1	0.1	2.5	7.4	9.9
Feb-11	0.5	2.5	5.0	8.1	51.6	29.2	(0.2)	2.1	6.2	8.3
Mar-11	1.1	5.0	5.0	11.2	51.2	29.0	0.2	2.8	8.2	11.0
Apr-11	0.5	2.3	5.0	7.8	51.5	29.1	(0.1)	2.0	6.0	8.0
May-11	0.5	2.3	5.0	7.9	51.2	29.0	(0.1)	2.0	5.9	7.9
Jun-11	0.1	0.4	5.0	5.5	51.1	28.9	(0.1)	1.4	4.2	5.6
Jul-11	0.2	0.8	5.0	6.0	50.9	28.8	(0.1)	1.5	4.5	6.1
Aug-11	0.0	0.1	5.0	5.2	50.8	28.8	(0.1)	1.3	4.0	5.3
Sep-11	0.2	0.9	5.0	6.1	50.6	28.6	(0.1)	1.6	4.6	6.2
Oct-11	0.5	2.4	5.0	7.9	50.5	28.6	0.1	2.0	5.9	7.9
Nov-11	1.1	4.9	5.0	11.0	50.6	28.7	0.1	2.8	8.1	10.9
Dec-11	0.6	2.6	5.0	8.2	50.9	28.8	(0.1)	2.1	6.3	8.4
Jan-12	1.1	4.9	5.0	11.0	50.7	28.7	0.1	2.7	8.1	10.9
Feb-12	0.6	2.8	5.0	8.5	50.9	28.8	(0.1)	2.1	6.4	8.5
Mar-12	1.0	4.8	5.0	10.9	50.8	28.7	0.2	2.7	8.0	10.7
Apr-12	0.5	2.4	5.0	8.0	51.1	28.9	(0.1)	2.0	6.0	8.1
May-12	0.3	1.5	5.0	6.9	51.0	28.9	(0.1)	1.8	5.3	7.0
Jun-12	0.3	1.3	5.0	6.6	50.8	28.7	(0.0)	1.7	5.0	6.6
Jul-12	0.1	0.5	5.0	5.7	50.7	28.7	(0.1)	1.4	4.3	5.7
Aug-12	0.0	0.0	5.0	5.1	50.6	28.7	(0.1)	1.3	3.9	5.2
Sep-12	-	-	5.0	5.0	50.4	28.5	(0.2)	1.3	3.9	5.2
Average Annual										
Mass (kg)	0.50	2.31	5.0	8	50.6	28.66	(0.01)	2.0	5.9	7.86
Percent	6%	29%	64%	100%	-	-	-	25%	75%	100%
Average Summer (May-October)										
Mass (kg)	0.20	0.93	5.04	6	50.4	28.6	(0.0)	1.6	4.6	6.21
Percent	3%	15%	82%	100%	-	-	-	25%	75%	100%

FW Pool Total Phosphorus Budget Summary - Worst Case

Month/ Year	Input Loads (kg)				Storage (kg)			Output Loads (kg)		
	Direct Precip	Stormwater	Groundwater	Total Surface Input	Current Conc (ug/L)	Current	Change	Sedimentation	Outflow	Total Output
Oct-07	0.6	2.7	25.0	28.4	181.7	102.8	(7.1)	13.1	22.3	35.4
Nov-07	0.5	2.3	25.0	27.8	169.2	95.8	(4.7)	12.9	19.6	32.5
Dec-07	1.4	6.6	25.0	33.0	160.8	91.0	(11.8)	15.0	29.8	44.8
Jan-08	0.8	3.8	25.0	29.6	140.0	79.3	(4.0)	13.7	19.9	33.6
Feb-08	0.5	2.2	25.0	27.8	132.9	75.2	(0.6)	12.9	15.4	28.4
Mar-08	0.6	2.7	25.0	28.3	131.9	74.7	(1.2)	13.2	16.3	29.5
Apr-08	0.3	1.3	25.0	26.6	129.8	73.5	1.1	12.5	13.0	25.5
May-08	0.1	0.3	25.0	25.4	131.8	74.6	2.8	11.8	10.7	22.5
Jun-08	0.2	0.8	25.0	26.0	136.8	77.4	1.6	12.1	12.3	24.4
Jul-08	0.1	0.2	25.0	25.3	139.6	79.0	2.3	11.8	11.3	23.1
Aug-08	0.2	1.0	25.0	26.3	143.6	81.3	0.7	12.2	13.4	25.6
Sep-08	0.0	0.2	25.0	25.2	144.9	82.0	1.9	11.8	11.6	23.3
Oct-08	0.4	1.9	25.0	27.3	148.2	83.9	(1.6)	12.7	16.2	28.9
Nov-08	1.1	5.2	25.0	31.4	145.5	82.4	(6.9)	14.4	23.9	38.3
Dec-08	0.6	2.8	25.0	28.5	133.3	75.5	(1.8)	13.3	17.0	30.3
Jan-09	1.0	4.8	25.0	30.9	130.2	73.7	(4.0)	14.2	20.7	34.9
Feb-09	0.2	0.9	25.0	26.1	123.1	69.7	2.0	12.3	11.8	24.1
Mar-09	0.7	3.2	25.0	29.0	126.7	71.8	(1.4)	13.5	16.9	30.3
Apr-09	0.4	1.8	25.0	27.2	124.3	70.4	1.0	12.7	13.5	26.2
May-09	0.6	2.6	25.0	28.2	126.1	71.4	(0.2)	13.1	15.3	28.5
Jun-09	0.0	0.1	25.0	25.2	125.7	71.2	3.5	11.7	9.9	21.7
Jul-09	0.0	0.1	25.0	25.1	131.9	74.7	3.1	11.7	10.3	22.0
Aug-09	0.1	0.7	25.0	25.9	137.4	77.8	1.8	12.0	12.1	24.1
Sep-09	0.3	1.4	25.0	26.7	140.5	79.5	0.2	12.4	14.1	26.6
Oct-09	0.6	3.0	25.0	28.7	140.8	79.7	(2.5)	13.3	17.9	31.1
Nov-09	1.2	5.7	25.0	31.9	136.5	77.3	(6.0)	14.6	23.3	37.9
Dec-09	0.6	2.6	25.0	28.2	125.9	71.3	(0.7)	13.2	15.7	28.9
Jan-10	0.8	3.8	25.0	29.7	124.7	70.6	(1.5)	13.7	17.5	31.1
Feb-10	0.6	2.5	25.0	28.1	122.0	69.1	0.3	13.1	14.8	27.8
Mar-10	0.6	2.8	25.0	28.5	122.6	69.4	(0.2)	13.2	15.4	28.7
Apr-10	0.4	1.9	25.0	27.3	122.2	69.2	1.3	12.7	13.3	26.0
May-10	0.5	2.3	25.0	27.9	124.5	70.5	0.5	12.9	14.5	27.4
Jun-10	0.4	1.9	25.0	27.3	125.4	71.0	1.2	12.6	13.4	26.1
Jul-10	0.0	0.1	25.0	25.1	127.5	72.2	3.4	11.7	10.0	21.7
Aug-10	0.1	0.3	25.0	25.4	133.6	75.6	2.7	11.8	10.9	22.7
Sep-10	0.7	3.2	25.0	29.0	138.4	78.3	(2.3)	13.3	17.9	31.2
Oct-10	0.8	3.5	25.0	29.3	134.4	76.1	(2.3)	13.5	18.1	31.6
Nov-10	0.8	3.5	25.0	29.3	130.3	73.8	(1.7)	13.5	17.5	31.0
Dec-10	1.1	5.2	25.0	31.4	127.2	72.0	(3.8)	14.4	20.8	35.2
Jan-11	0.9	4.1	25.0	30.0	120.5	68.2	(1.2)	13.8	17.4	31.2
Feb-11	0.5	2.5	25.0	28.1	118.4	67.0	0.7	13.1	14.3	27.4
Mar-11	1.1	5.0	25.0	31.2	119.5	67.7	(2.3)	14.3	19.2	33.5
Apr-11	0.5	2.3	25.0	27.8	115.4	65.3	1.5	12.9	13.4	26.4
May-11	0.5	2.3	25.0	27.9	118.0	66.8	1.3	12.9	13.7	26.6
Jun-11	0.1	0.4	25.0	25.5	120.3	68.1	3.8	11.8	9.9	21.7
Jul-11	0.2	0.8	25.0	26.0	126.9	71.8	2.6	12.1	11.3	23.4
Aug-11	0.0	0.1	25.0	25.2	131.5	74.4	3.1	11.7	10.4	22.1
Sep-11	0.2	0.9	25.0	26.1	137.0	77.6	1.4	12.2	12.6	24.7
Oct-11	0.5	2.4	25.0	27.9	139.5	79.0	(1.2)	12.9	16.2	29.1
Nov-11	1.1	4.9	25.0	31.0	137.4	77.8	(5.3)	14.3	22.1	36.3
Dec-11	0.6	2.6	25.0	28.2	128.0	72.5	(0.7)	13.2	15.7	28.9
Jan-12	1.1	4.9	25.0	31.0	126.9	71.8	(3.6)	14.3	20.3	34.6
Feb-12	0.6	2.8	25.0	28.5	120.5	68.2	0.2	13.2	15.1	28.3
Mar-12	1.0	4.8	25.0	30.9	120.8	68.4	(2.3)	14.2	19.0	33.2
Apr-12	0.5	2.4	25.0	28.0	116.7	66.0	1.2	13.0	13.8	26.8
May-12	0.3	1.5	25.0	26.9	118.8	67.3	2.1	12.5	12.3	24.8
Jun-12	0.3	1.3	25.0	26.6	122.6	69.4	2.3	12.3	12.0	24.3
Jul-12	0.1	0.5	25.0	25.7	126.6	71.7	3.1	11.9	10.7	22.6
Aug-12	0.0	0.0	25.0	25.1	132.1	74.8	3.2	11.7	10.2	21.8
Sep-12	-	-	25.0	25.0	137.8	78.0	2.6	11.7	10.7	22.4
Average Annual										
Mass (kg)	0.50	2.31	25.0	28	131.8	74.61	(0.37)	12.9	15.3	28.22
Percent	2%	8%	90%	100%	-	-	-	46%	54%	100%
Average Summer (May-October)										
Mass (kg)	0.20	0.93	25.04	26	131.2	74.3	1.9	12.2	12.1	24.21
Percent	1%	4%	96%	100%	-	-	-	50%	50%	100%