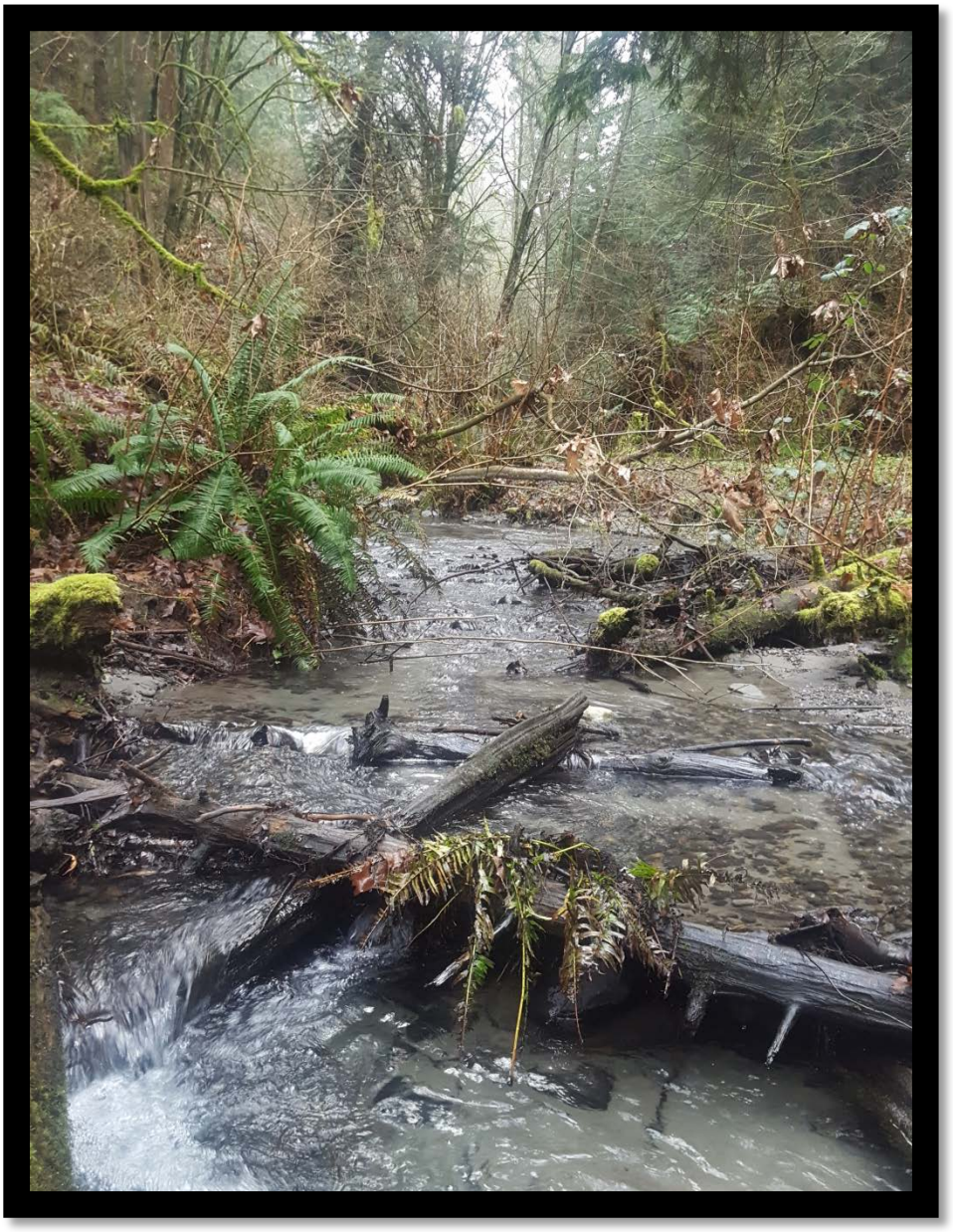
2016 FRESHWATER ASSESSMENT REPORT

State of Water Quality in Shoreline Streams and Lakes



2016 FRESHWATER ASSESSMENT REPORT

State of the Water Quality in Shoreline Streams and Lakes

November 2017

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STATE OF THE WATER QUALITY IN SHORELINE STREAMS AND LAKES

1 EXECUTIVE SUMMARY

The City of Shoreline's Surface Water and Environmental Services Division within the Public Works Department routinely monitors the quality of stream systems and surface waters within the City of Shoreline. This report summarizes the results of water quality data collected between the 2010 and 2015 water years[1] and compares them to the results of the 2009 Freshwater Assessment Report, referred to as the 2009 report (Shoreline 2010).

The findings of this report will help to compare the condition of the City's freshwater resources, determine if current water quality programs are effective, inform decision making, and foster a broader awareness within the community of the City's water quality issues.

For this report, water quality parameters were assessed in local streams and lakes collectively referred to as waterbodies. Six streams with seven sampling locations were assessed: Boeing Creek (with two sampling locations), Thornton Creek, Littles Creek, McAleer Creek, Cedarbrook Creek, and Storm Creek. Two lakes with three sampling locations were assessed: Echo Lake (with two sampling locations) and Hidden. Data from a total of 10 sampling locations were assessed.

The water quality assessment indicates that five of seven stream sampling locations are degraded and did not meet at least one water quality standard in the Aquatic Life Designated Use category. Previously, all stream sites were considered degraded. While four sampling sites failed to meet all water quality standards, most sites improved from the 2009 report. However, all streams still have elevated fecal coliform levels. Five of the seven stream sampling locations had "poor" ratings in the Primary Contact Recreation Designated Use category. The Boeing Creek sites were the only sites to receive a "fair" rating.

As for the two lakes sampled, the results are far less favorable for both the Aquatic Life Designated Use and Primary Contact Recreation Designated Use categories. Only one site at Echo Lake was measured for the Aquatic Life Designated Use category. This site

[1] Water years begin from October of the previous year to September of the current year.

failed to meet water quality standards and ranged between "poor" and "fair" ratings. The ratings have not changed since the 2009 report. Under the Primary Contact Recreation Designated Use category, Echo Lake ranged between "fair" and "good" from 2010 to 2013. However, in recent years Echo Lake has received a "poor" rating. Hidden Lake has consistently received a "poor" rating since 2010.

Water quality ratings ranged from good to poor for individual parameters. Water quality parameters can be affected both by human-induced or natural influences. According to the Washington State Department of Ecology, stormwater is the number one water pollution problem in the urban areas of our state. Since natural influences cannot be controlled, the City will focus on improving the adverse effects on water quality due to human activities. By reducing the volume of stormwater runoff flowing into the City's natural waterbodies or the amount of contaminants contained in it, water quality can be improved. To reduce the impacts of stormwater, the City implements programs and projects designed to control the source of contaminants on the ground that can be carried away by runoff as well as the amount of runoff being produced. The City already has programs in place such as the Illicit Discharge Detection and Elimination Program, the Adopt-A-Drain Program, the Soak It Up Low Impact Development (LID) Rebate Program, and the Private Facility Storm Drainage System Inspection Program. Examples of capital projects that have played a role in improving water quality include the re-graded Pan Terra Regional Stormwater Facility, Boeing Creek Park improvements, the Cromwell Park Stormwater Facility, the Greenworks/Surface Water Small Works Program (LID stormwater retrofit program), and the North Fork Thornton Creek LID retrofit project.

Although water quality has improved in some streams, the City must go beyond current NPDES requirements in the areas surrounding Thornton Creek, Echo Lake, and Hidden Lake. Recommendations are included in this report, including increasing community engagement, increasing habitat improvement efforts, and overall program growth opportunities.

This report presents the current water quality conditions of freshwater in Shoreline. It will assist in tracking measurable improvements and will help to guide future management activities. To get the best overall picture of water body health and trends, data must be tracked over many years. The City will continue to monitor water quality in the waterbodies identified in this report. Future data will be compared to the findings of this report and will help determine if current water quality programs and regulations are effective in maintaining or improving water quality; as a result, the City will be able to improve existing programs, create new programs and capital projects, and provide potential regulatory recommendations to improve the water quality within Shoreline and its downstream neighboring jurisdictions.

2 DEFINITIONS AND ACRONYMS

Anadromous fish use - Habitat used by fish that are born in freshwater, spend most of their life at sea, and then returns to freshwater to spawn.

Aquatic Life Designated Use - Designated use category determined by the Washington State Department of Ecology where fish would benefit from the water supply.

Basin - The portion of land that drains into a stream or river.

Core Summer Salmonid Habitat - A designated use category where summer salmonid spawning, emergence, or holding occur. This is also important for foraging adults.

Geometric mean - The central number in a geometric progression.

Headwaters - The source of streams or rivers.

NPDES - National Pollutant Discharge Elimination System.

Nephelometric Turbidity Unit (NTU) - Unit of measure for turbidity.

Primary Contact Recreation Designated Use - A designated use category for recreational use. In this case primary opposed to secondary.

Riparian zone - The areas bordering river and other bodies of water. These zones include floodplains.

Salmonid Spawning, Rearing, and Migration - A designated use category where salmonid spawning or emergence occur outside of the summer season.

Stormwater runoff - The rainfall that flows on ground surface.

Surface water runoff - The water that flows on the ground surface, including stormwater, meltwater, or other sources of flows.

3 INTRODUCTION

3.1 Geographic Area and History of Development

The City of Shoreline is located in the northwestern corner of King County along the shores of Puget Sound. Shoreline is generally bounded by the City of Lake Forest Park to the east, the City of Seattle to the south, Puget Sound to the west, and Snohomish County to the north (including the cities of Mountlake Terrace, Edmonds, and the Town of Woodway). Puget Sound is the City's only "shoreline of statewide significance," as defined by the Washington State Shoreline Management Act, but the City has several lakes and ponds including Echo Lake, Hidden Lake, Ronald Bog, and Twin Ponds[2]. Numerous small streams and creeks are also found within or adjacent to the City. Three of the most significant basins within the City are Boeing Creek Basin, Thornton Creek Basin, and McAleer Creek Basin (Figure 1).

Over many years, urban development in the City has drastically altered the City's watersheds. Previously forested areas and wetlands have been replaced with residential and commercial land uses. Limited areas of open space remain. The City's development history began with original settlements dating back to the late 1800s. As the City developed over time, most of this development took place prior to the implementation of stormwater mitigation regulations in the 1970s. Currently, the City is substantially developed, with only about one percent of the total land area remaining vacant.

The City is primarily residential in character and over 55 percent of the households are single family residences. Commercial development is predominantly located along Aurora Avenue N, with other neighborhood centers located at intersections of primary arterials, such as N 175th Street at 15th Avenue NE and N 185th Street at 8th Avenue NW. There is limited industrial development within City limits. Currently, development within the City is primarily in the form of redevelopment and infill. Urban development has produced a large amount of impervious surface, including streets, sidewalks, parking lots, and roofs. When rain falls on these impervious surfaces, the stormwater runoff flows directly into streams and local waterbodies instead of being naturally absorbed into the ground or retained by wetlands. Stormwater runoff picks up soil, chemicals, and other pollutants and carries them into our lakes, rivers, and marine waters. This large amount of impervious surface in the City greatly affects the condition of surface waters.

[2] Ronald Bog and Twin Ponds are not currently sampled.

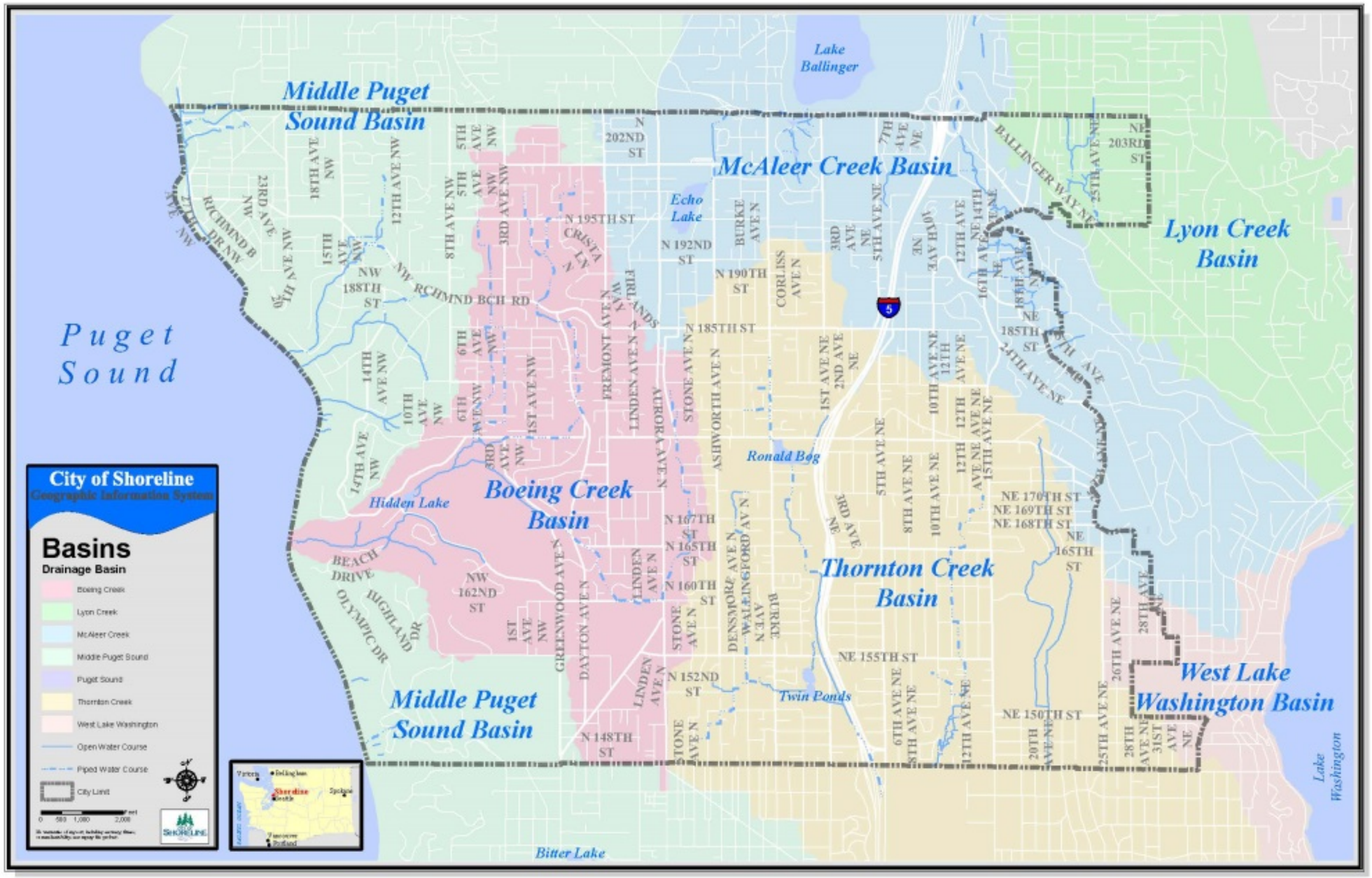

Figure 1 – City of Shoreline Drainage Basins

3.2 Purpose

The City of Shoreline's Vision 2029 framework goals document states that the City is committed to conserving and protecting environment and natural resources as well as encouraging restoration, environmental education, and stewardship. As done in the 2009 report, performance measures used in this report are assessed based on the percent of compliance to Washington State water quality standards. This report will provide comparisons to the 2009 report and show where water quality has improved or where the City continues to have degraded waterbodies.

The findings of this report will help to:

- Document the current condition of the City's freshwater resources and provide a comparison for past and future water quality studies.
- Determine whether water quality improvement programs are effective and current practices sustain or improve conditions.
- Assist City Staff with the prioritization of restorative actions, the generation of program policy and rules, and inform the 2018 Surface Water Master Plan.
- Foster a broader awareness within the community of the current conditions of the City's water resources and the need to manage the aquatic environment and pollution sources to improve water quality.

Stormwater runoff is the number one urban water pollution problem in the state, according to the Washington State Department of Ecology. Streams and local waterbodies are usually the first aquatic system to receive stormwater runoff, and their water quality can be compromised by the pollutants it contains (CWP 2003). The City is a highly urbanized area and a large amount of stormwater runs off urban surfaces and enters local waterbodies during rain events. Considering the known impact of stormwater on water quality, the City regularly monitors local surface waters to help determine the level of impairment. To track the condition of the City's surface waters over time, the City has been conducting monthly stream water quality monitoring since 2002. In 2004, the City began weekly swim beach monitoring, which occurs from May to September of each year, and biweekly lake stewardship monitoring, which occurs from May to October of each year.

This report presents the current conditions of water quality in the City, expressed in percent compliance with water quality standards under the Surface Waters of the State of Washington (Chapter 173-201A WAC), as updated by the Department of Ecology on August 1, 2016, for fresh water supporting Core Summer Salmonid Habitat, Salmonid Spawning, Rearing, and Migration, and Primary Contact Recreation.

The five water quality parameters identified in the standards are:

- **Temperature** - Fish and aquatic organisms must live in an environment that is within a certain temperature range. Specifically, temperatures that are above the upper limit for development and survival can result in a reduction of these aquatic populations. Indirectly, higher temperatures can affect other conditions that lead to harmful aquatic environments. For example, higher temperatures can increase algae growth, which can lead to decreased dissolved oxygen levels when the algae decomposes.

- **Dissolved oxygen** - Fish and aquatic organisms cannot live without having enough oxygen available to them in the water.

- **pH** - Aquatic organisms have adapted over time to survive and reproduce in a relatively narrow pH range. They survive and reproduce best below a pH of 8, which is the neutral value, but above a pH of 6. In water that is very acidic (low pH values), the concentration of heavy metals ions (copper, aluminum, etc.) increases and this in turn has negative effects on the health of aquatic organisms. In water that is very basic (high pH values), aquatic organisms are susceptible to damaged gills and skin.

- **Turbidity** - High turbidity indicates that there is a greater amount of sediment in the water than normal. Suspended sediment can choke the gills of fish, settle on fish spawning beds rendering them unusable, and smother fish eggs and aquatic organisms on the bottom of the water body.

- **Fecal coliform** - Fecal coliform bacteria is mainly a concern for human health. High bacteria levels indicate a higher potential for transmission of harmful pathogens. Pathogens can make humans sick if they drink or come in contact with the water.

If the water quality parameters identified are not within certain limits (water quality standards), they can have an adverse effect on beneficial uses and freshwater habitat.

In addition to the City's water quality program, in 2007 the City also began estimating the water quality condition at seven stream monitoring stations using the Department of Ecology Water Quality Index (WQI) scoring method (Ecology 2002). Collected water quality data was entered into the formula spreadsheet and a water quality "score" for that stream was calculated. The WQI score is a unitless number ranging from 1 to 100; a higher number is indicative of better water quality. In general, stations scoring 80 and above met expectations for water quality and are of "lowest concern;" scores 40 to 80 indicate "marginal concern;" and water quality at stations with scores below 40 did not meet expectations and are of "highest concern." Table 8 (Appendix C) shows the stations for which a WQI score was calculated and the resulting score.

This report will serve as a comparison between the 2009 report and future reports. Continued monitoring of these parameters is needed to document progress towards meeting water quality goals. The City currently implements policies, programs, and capital improvement projects to help reduce water pollution. Current programs include the Illicit Discharge Detection and Elimination Program, the Adopt-A-Drain Program, and the Private Facility Storm Drainage System Inspection Program. Examples of capital projects that have played a role in improving water quality include the re-graded Pan Terra Regional Stormwater Facility, Boeing Creek Park improvements, Cromwell Park Stormwater Facility, the Greenworks Program (low impact development (LID) stormwater retrofit program), and North Fork Thornton Creek LID retrofit project. New policies and programs will be implemented, according to the schedule set forth in the Western Washington Phase II Municipal Stormwater Permit (i.e., the National Pollutant Discharge Elimination System (NPDES) Phase II permit) issued by the Washington State Department of Ecology and according to priorities determined by City staff and the City Council within the Surface Water Master Plan. Future water quality reports can be compared to the current conditions in this report to determine program effectiveness and shape future programs and projects aimed at improving water quality.

4 DESCRIPTION OF WATER RESOURCES

4.1 Basins

There are six drainage basins within the City limits. The significant drainage basins, listed from west to east, are the Boeing Creek, Thornton Creek, and McAleer Creek basins (Figure 1). Small portions of the Lyons Creek and West Lake Washington drainage basins are also within the City limits; however, water bodies are not monitored in the Lyons Creek and West Lake Washington drainage basins and they are therefore not represented in Table 1 below. The Middle Puget Sound and Boeing Creek basins flow west into Puget Sound. Thornton Creek, McAleer Creek, Lyons Creek, and the West Lake Washington basins flow east into Lake Washington. All of the urban streams and lakes within these basins are fed primarily by groundwater and surface water runoff. Surface water runoff inputs are characterized primarily by urban stormwater flows during rain events. Waterbodies within the City boundary support aquatic life uses of Salmonid Spawning, Rearing, and Migration and Core Summer Salmonid habitat. The City's waterbodies are designated for primary contact recreation. The categories are defined in the Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC as updated August 1, 2016.

Table 1 - City of Shoreline Basin Characteristics

	Basin Characteristics				
Basin	**Basin Size (acres)**	**Impervious (%)**	**Roads (mi/mi^2)**	**Lakes/Ponds (acres)**	**Wetland (%)**
Thornton Creek	2,391	44	27.3	14.3[a]	41.7 acres (1.7%)
McAleer Creek	1,344	46	18.6	15.2[b]	31.8 acres (2.4%)
Boeing Creek	1,764	44	20.2	1.7[c]	2.6 acres (0.15 %)
Middle Puget Sound	299	36	19	0	3.7 acres (1.2%)

[a]Ronald Bog is 6 acres and Twin Ponds is 3.9 acres.
[b]Echo Lake is 13 acres.
[c]Hidden Lake is 1.7 acres.

4.2 Streams

Table 2 - City of Shoreline Sampling Stream Characteristics

	Stream Characteristics				
Stream	**Basin**	**Piped (%)**	**Non-Fish Habitat Stream (%)[a]**	**Fish Habitat Stream (%)[b]**	**Non-Typed Habitat Stream (%)**
Thornton Creek	Thornton Creek	46	4	23	27
Littles Creek	Thornton Creek	30	0	70	0
McAleer Creek	McAleer Creek	33	4	18	45
Cedarbrook Creek	McAleer Creek	34	9	0	57
Boeing Creek	Boeing Creek	65	4	14	21
Storm Creek	Middle Puget Sound	38	4	62	0

[a]Non-fish habitat stream segments are perennial/seasonal water flows that may support fish or can be restored.
[b]Stream segments containing fish habitat.

4.2.1 Boeing Creek Basin: Boeing Creek

The Boeing Creek basin is located almost entirely within the City's limits and drains approximately 1,764 acres within the central portion of the City (Table 1). There is a very small portion of the basin that extends south into Seattle. Boeing Creek is the second largest basin within the City. The City's largest natural riparian areas are within the Boeing Creek Basin.

Current land use is dominated by urban development and the entire length of the stream channel has been highly impacted by this development. Much of the stream channel is buried in pipes or placed into artificial open channels. In all, 65 percent of the creek is piped (Table 2). Other modifications include four dams of varying proportions, functionality, and design. Only the first 701 meters of lower reach is accessible to anadromous fish use. The health of the riparian zone declines from the downstream mouth to the more developed upstream reaches of the creek.

A detailed description of the basin can be found in the Boeing Creek Basin Plan (Windward 2013a).

4.2.2 Thornton Creek Basin: Thornton Creek and Littles Creek

The headwaters of the Thornton Creek basin are located in the central portion of the City (Figure 1). Approximately 48 percent of the basin is located within the City's limits. The Thornton Creek basin drains approximately 2,391 acres in the southeast quarter of the City before entering Seattle city limits and ultimately flowing into Lake Washington.

The City monitors the main branch of Thornton Creek. The headwaters of Littles Creek also originate in this basin and the creek eventually merges with Thornton Creek south of the City in Seattle. Since they are separate creeks within the City, they are monitored separately.

Urban development and automobile transportation infrastructure are the dominant land uses in the basin within the City. Riparian zones act as a buffer for streams from nonpoint source pollution (e.g. urban runoff) (EPA 2005). Conditions of the riparian zone are highly fragmented with a lack of high quality habitat. Although this basin has similar levels of impervious surfaces (44 percent) in comparison to the others, it has more road surface (27.3 mi/mi^2) than Boeing, McAleer, and Middle Puget Sound basins.

Two large wetlands exist within the Thornton Creek basin, with a combined area of 41.7 acres. These wetlands, Ronald Bog and Twin Ponds, originated as peat bogs. They were commercially mined beginning in the 1940s and then allowed to go fallow (R. W. Beck. 2009). Each is now within a City Park and functions as a shadow bog. Shadow bogs are systems that have been modified to the extent that their hydrology and vegetation community no longer causes the formation of peat, but peat soils still dominate the wetland soils. Thornton Creek flows freely into both waterbodies and no bog vegetation has been noted. Peat soils still exist at each location, but to what extent the peat deposits remain is unknown.

A detailed description of the basin can be found in the Thornton Creek Watershed Plan (R. W. Beck 2009).

4.2.3 McAleer Creek Basin: McAleer Creek and Cedarbrook Creek

The McAleer Creek basin is located on the east side of the City and drains approximately 4,018 acres upstream of the monitoring station at 196th Street NE (Figure 1). The reach length of McAleer Creek located within the City is 1,200 meters long.

The creek has more than one distinct headwater stream. One of the headwaters originates south of Echo Lake, within the City, and flows north out of Echo Lake and into Lake Ballinger. McAleer Creek flows east out of Lake Ballinger, is joined by the Cedarbrook Creek tributary at the boundary with the City of Lake Forest Park, and flows through the Nile Golf course and the City of Lake Forest Park on the way to Lake Washington.

Urban development dominates McAleer Creek's watershed within the City. The level of impervious surfaces in the watershed is currently at 46 percent (Table 1). The northern part of Aurora Avenue N, Ballinger Way, 205th Street, and part of Interstate 5 represent major urban modifications within the watershed. The length of channel buried in pipes is 33 percent (Table 2). While some high quality forested habitat exists within 50 feet along short reaches of McAleer Creek, the overall quality diminishes with distance from the stream. Some reaches of the stream lack high quality habitat within 50 feet due to existing single-family homes, apartments, and lawns.

The entire main stem of McAleer Creek within the City, up to Interstate 5 (I-5) is utilized by anadromous fish. Little is known about the anadromous use of the various tributaries. Other notable water features include the two lakes, Echo Lake (13.5 acres) and Lake Ballinger (101.4 acres).

A detailed description of the basin can be found in the McAleer Creek Basin Plan (Osborn et al. 2015).

4.2.4 Puget Sound Basin: Storm Creek

The Middle Puget Sound basins (north and south) empty into Puget Sound through dozens of small creeks and storm drainage systems (Figure 1). The portions of the Puget Sound drainages that lie within the City encompass approximately 1,250 acres north of Boeing Creek and about 30 acres south of Boeing Creek. The north and south portions of the Middle Puget Sound basin are hydraulically separated by the Boeing Creek basin. There is record of only one relatively small stream in the southern section of the basin. There are two significant streams, Storm Creek and Barnacle Creek, located within the north section of the basin (Figure 1). There are also several other smaller streams in the basin. The basin extends both north and south past the City boundary into Edmonds and Seattle, respectively.

According to the 2013 Storm Creek Basin Plan, current land use in the basin ranges from a minimum of 16 percent to a maximum of 77 percent of impervious surfaces, with an average of 47 percent (Windward 2013b). Current land use is mostly single-family residential, followed by roads. Small areas are developed as multifamily, schools, commercial, and parks and open space. Commercial areas are primarily along the Richmond Beach Road corridor. In the future, ranges of impervious surfaces could increase to a minimum of 57 percent, a maximum of 79 percent, and an average of 61 percent.

The portion of Storm Creek below NW 191st Street flows southwest through the privately owned Eagle Reserve in Innis Arden, where it drops about 100 feet in elevation, and another rapid drop (approximately 100 feet within 400 feet of horizontal distance) at 17th Place before entering Puget Sound (Windward 2013b).

A detailed description of the basin can be found in the Storm Creek Basin Plan (Windward 2013b).

4.3 Lakes

4.3.1 Echo Lake

Echo Lake is located in the north central portion of the City in the McAleer Creek drainage basin, along Ashworth Avenue N, southwest of the intersection of Ashworth Avenue N and N 200th Street. Echo Lake covers an area of 13 acres and has a maximum depth of 30-feet. The lake is surrounded by private properties, except for a public park and swimming beach located at the north end of the lake. The lake is primarily fed by groundwater, but there is significant inflow to the lake in the form of surface water runoff from surrounding residential roadways, residential and commercial properties, and Aurora Ave N. For approximately 6 to 8 months of the year, the lake is high enough for there to be flow at the outlet. When there is outflow, this water flows north, across the City boundary into Lake Ballinger.

Land use along the lake edge is single family and multi-family development. There is a small City park located at the north end of the lake. Further to the west of the lake is Aurora Ave N and associated commercial developments. Echo Lake receives significant runoff contribution from this heavily developed area. Further north of the lake is a King County Metro Transit Center, a large commercial development, and the City of Mountlake Terrace boundary.

A more detailed description of Echo Lake can be found in the McAleer Creek Basin Plan (Osborn et al. 2015).

4.3.2 Hidden Lake

Hidden Lake is a smaller, man-made lake located in the southwest portion of the City in the Boeing Creek drainage basin, along NE Innis Arden Way on the north side of the roadway. The lake occupies approximately 1.7 acres. To help mitigate stormwater impacts to Boeing Creek, many projects were constructed; however, facility designers did not anticipate the large amount of sediment deposits into Hidden Lake. To combat the deposits, the City dredged the lake biannually from 2002 to 2013. In 2014, City Council approved staff to cease dredging of the lake to begin re-establishing Boeing Creek.

The north end of the lake is accessible from Boeing Creek and Shoreview parks and is visited frequently by dog owners who bring their dogs to swim in the water. Hidden Lake is primarily surrounded by City park land and single-family residential developments. The lake is fed by Boeing Creek and there is a large regional stormwater pond located approximately a quarter mile upstream of the lake. Stormwater contributions to that pond include a large amount of runoff from the Aurora Ave N

commercial zone to the east. The north portion of the lake functions as a settling basin to capture sediment entering the stream and was periodically dredged to retain storage capacity. There is a stormwater structure at the outlet of the lake preventing natural drainage of the lake.

A more detailed description of Hidden Lake can be found in the Boeing Creek Basin Plan (Windward 2013a).

5 METHODS

5.1 Sampling Stations

Ten sampling stations were monitored for this report (Figure 2). Selection of individual sample locations was based on the contributing watershed area of a particular basin/sub-basin or water body and accessibility to the site. For the majority of streams, the monitoring stations selected are relatively close to the mouth of the basin stream network. Each of these sample locations is representative of water quality throughout the basin since, with few exceptions, all creeks in the City are tributaries and contribute runoff that passes through these stations. For lakes, the sampling locations are primarily accessed from shore. The one exception to this is the data collected for the King County Lake Stewardship Program at Echo Lake, which is accessed by boat.

5.1.1 Streams

Stream samples were collected for monthly chemical, physical (ambient), and bacteriological monitoring at the following stations:

5.1.1.a Boeing Creek Sample Location

Two sites (BC-2 and BC-3) are located downstream of the North Pond dam confluence (Figure 2). The site BC-2 is located on the north branch of Boeing Creek. The site BC-3 is located on the south branch of Boeing Creek. The two branches merge approximately 250 feet downstream of the sampling sites.

5.1.1.b Thornton Creek Sample Location

One site (TH-1) is located about 30 feet upstream of the Thornton Creek confluence with Twin Ponds (Figure 2).

5.1.1.c Littles Creek Sample Location

One site (LT-1) is located within Paramount Park and is about a quarter mile upstream of the point where Littles Creek flows across the City of Seattle city limit boundary (Figure 2).

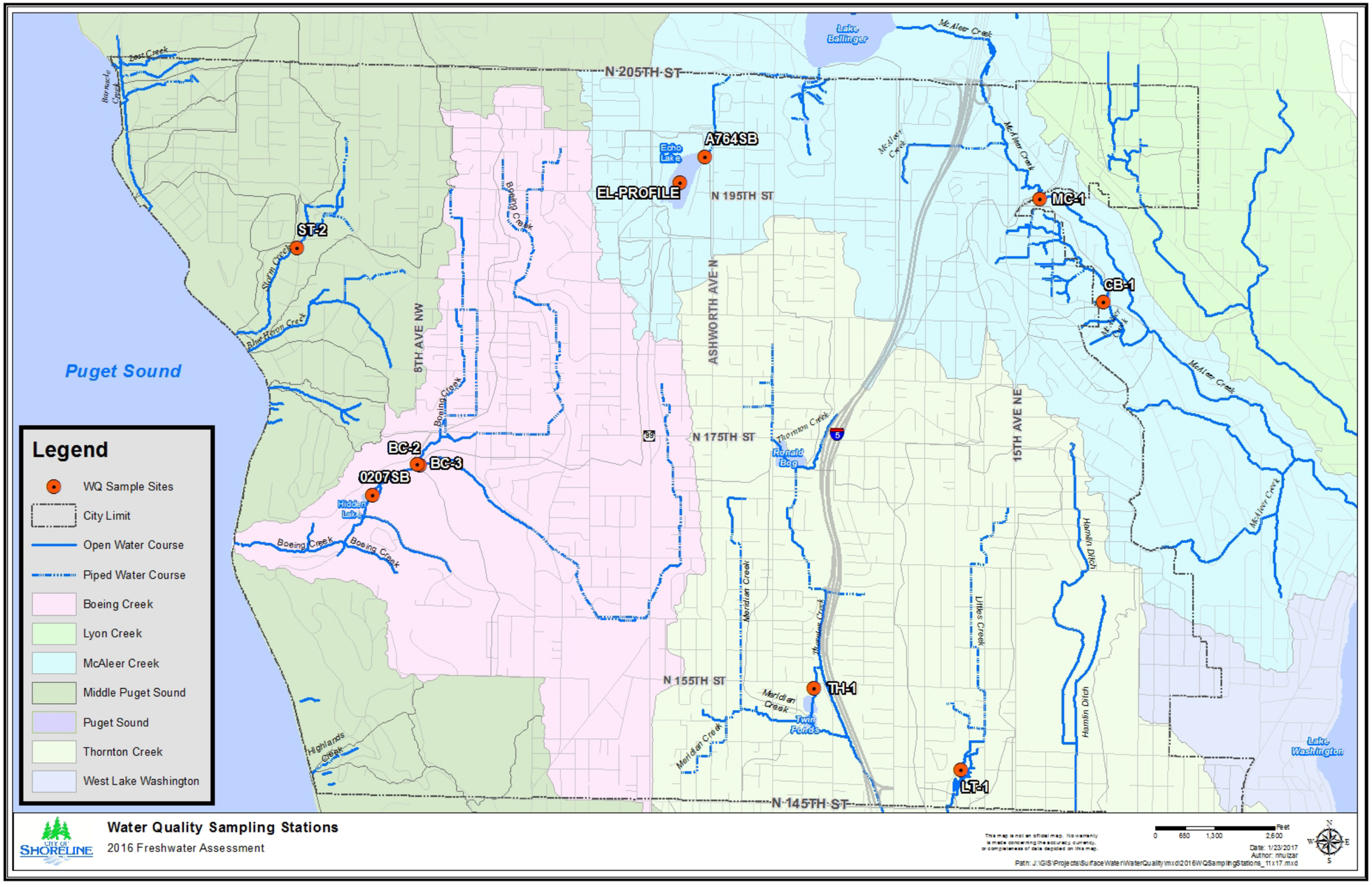

Figure 2 - Sampling Stations

5.1.1.d McAleer Creek Sample Location

One site (MC-1) is located upstream of the NE 196th Street crossing and the dam (Figure 2). The sampling location is located just upstream of the City of Shoreline-City of Lake Forest Park boundary.

5.1.1.e Cedarbrook Creek Sample Location

One site (CB-1) is located along the west side of a residence located at 18709 23rd Avenue NE, adjacent to the intersection of Perkins Way and 23rd Avenue NE. This station is located just east of the City of Shoreline-City of Lake Forest Boundary in the City of Lake Forest Park (Figure 2).

5.1.1.f Storm Creek Sample Location

One site (ST-2) is located immediately downstream of the intersection of 15th Avenue NW and NW 190th Street. This location is approximately half way between the headwaters and the mouth of Storm Creek (Figure 2). Downstream of this sampling station, Storm Creek flows through a primarily natural, riparian area.

5.1.2 Lakes

Lake samples were collected for seasonal (May through October) biweekly chemical, physical (ambient) monitoring and seasonal (May through September) weekly bacteriological monitoring at the following stations.

5.1.2.a Echo Lake Sample Location

Two sites were selected for water quality monitoring at Echo Lake. One site (EL-PROFILE) was selected for seasonal, biweekly chemical, physical (ambient), and bacteriological monitoring and is located in the near center of the lake (Figure 2). The second site (A764SB[3]) was selected for seasonal, weekly bacteriological monitoring. The specific location is adjacent to the Echo Lake park beach on the north end of the lake (Figure 2).

5.1.2.b Hidden Lake Sample Location

One site (0207SB[4]) was chosen for seasonal, weekly bacteriological monitoring and is located adjacent to the shore at the northeast end of the lake.

[3] Sampling site A764SB was referred to as ELO-1 in the 2009 report
[4] Sampling site 0207SB was referred to as HLO-1 in the 2009 report.

5.2 Sampling Frequency

Samples were collected at each stream monitoring station on a monthly basis. From May to October, samples were collected biweekly at the EL-PROFILE sampling location at Echo Lake.

5.3 Water Quality Parameters and Monitoring Methods

5.3.1 Chemical and Physical Parameters

5.3.1.a Temperature

Measurements were collected using a YSI Pro 2030 meter. Temperature was recorded in degrees Celsius.

5.3.1.b Dissolved Oxygen

Measurements were collected using a YSI Pro 2030meter. Dissolved oxygen (DO) measurements were recorded in milligrams per liter (mg/L).

5.3.1.c pH

A Hanna Instruments 991003 meter was used for pH measurements. Results were recorded in pH units.

5.3.1.d Turbidity

An Orbeco-Hellige TB200 portable turbidity meter was used to collect turbidity readings. A sample of water was collected in a clear, glass vial. A cap is placed on top, then the vial is inserted into the meter and a button is depressed to obtain the reading. Results are recorded in Nephelometric Turbidity Units (NTU).

5.3.2 Biological Parameters

Samples were collected at Echo and Hidden lakes on a weekly basis, approximately May through September of each year.

5.3.2.a Bacteria (Fecal Coliform) Monitoring

Fecal coliform samples were collected using grab-sample techniques. Grab samples are water samples that are collected at one discreet moment in time from one discreet location. Following the King County Sampling Protocol (King County 2005), sample containers were submerged below the stream surface, filled to within one inch of the container opening, then capped. Collected samples were then delivered to the King County Environmental Laboratory for analysis. The results were reported to City staff by the laboratory.

Fecal coliform samples were collected at the Thornton Creek (TH-1), Cedarbrook Creek (CB-1), McAleer Creek (MC-1), Littles Creek (LT-1), Storm Creek (ST-2), and Boeing

Creek (BC-2 and BC-3) sampling stations on a monthly basis in conjunction with ambient monitoring.

5.3.3 Quality Assurance and Quality Control of Collected Data

The collection of water quality parameters was performed by the City's Surface Water Quality Specialist and/or Surface Water Technical Assistant. To ensure the accuracy and precision of water quality data collected, all meters were calibrated at a minimum of once per month. Manufacturing suggestions were utilized for the calibration. All data collected in the field was recorded on-site in a field log book and transferred to an Excel database in the office.

Fecal coliform samples that were collected were put on ice and delivered to the King County Environmental Laboratory within six hours of collection. Standard chain-of-custody procedures were followed. The King County Environmental Laboratory conducts an internal QA/QC program.

5.4 State Water Quality Standards and Monitoring Data Analysis

The state freshwater standards apply to the City's urban watercourses and lakes. All of these waterbodies fit the definition of waters of the state. In the State of Washington, waters of the state are protected by the federal Clean Water Act (CWA; 33 U.S.C. 1251 et seq.) and the state Water Pollution Control Act (Chapter 90.48 RCW). The Surface Water Quality Standards (Chapter 173-201A WAC) are the means for implementing these laws.

5.4.1 Determination of Designated Use Support Rating

Waterbodies within the City support aquatic and water contact recreation designated uses. The waterbodies are classified as supporting Core Summer Salmonid Habitat or Salmonid Spawning, Rearing, and Migration designated aquatic life uses. The waterbodies are also designated for Primary Contact Recreation under the fresh water contact recreation bacteria criteria category. The water quality standards for those categories, as defined by these designated uses, are listed in Table 3. Collected water quality data was compared to these standards.

Table 3 - Water Quality Standards

Category (Designated Use)	Temperature (Highest 7-DAD Max) (Section 3.3.2)	Dissolved Oxygen (Lowest 1-DAD Min) (Section 3.3.3)	Turbidity (Section 3.3.5)	pH (Section 3.3.4)	Bacteria Indicator/Fecal Coliform Standards (Section 3.3.6)
Core Summer Salmonid Habitat	16°C	9.5 mg/L	Turbidity shall not exceed 5 NTUs over background when the background is 50 NTU or less	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units	N/A
Salmonid Spawning, Rearing and Migration	17.5°C	8.0 mg/L			N/A
Primary Contact Recreation	N/A	N/A	N/A	N/A	Not more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL Geometric mean not to exceed 100 cfu/100 mL

5.4.2 Water Quality Standards and Compliance

Results of the analysis and comparison to water quality standards are expressed in percent compliance with the water quality standards. The United States Environmental Protection Agency (EPA) recommends using the specific frequency that data *exceed* numeric criteria to assess level of support for each designated use (EPA 1997). In the recommendation, results of the data comparison to water quality standards are expressed in percentage of readings not meeting state standards (percent not in compliance). The water quality condition of the water body or parameter was then rated according to EPA guidelines based on those percentages. If 25 percent or greater of the data exceed any one criterion, support of the specific use was considered "poor". If more than 11 percent but less than 25 percent of the data exceed the criterion, support of the specific use was assessed as "fair". If less than 10 percent of the data exceed the criterion, support of the use was considered "good". Waters that rate fair or poor for any given parameter are considered to be impaired.

For the purpose of this report, the percentages of compliance with standards were expressed as the frequency of data points *meeting* the water quality standards. As shown

in Table 4, the EPA recommended ranges were adjusted and the percentages were reversed for each category. In other words, if the water body complied with standards 90% of the time or greater, then the condition of the water body for that beneficial use was rated as "good". If the water body complied with the standard 75% to 90% of the time, then the condition of the water body for that beneficial use was rated as "fair". If the water body complied with standards less than 75% of the time, then the condition of the water body for that beneficial use was rated as "poor" (Table 4).

Table 4 - Designated Use Support Rating Categories

Percentage of Data Points meeting Water Quality Standards	Designated Use Support Rating
90% or greater	Good
75% to 90%	Fair
Less than 75%	Poor

5.4.2.a Temperature

The water quality standard for temperature is based on the 7-day average of the daily maximum temperature (7-DADmax). The 7-DAD Max is calculated for any given day by averaging the maximum temperature for the specific day as well as the three days prior and three days after the sample date. The data available for this report consists of only one discreet temperature value taken once per month at each location. Therefore, a direct comparison to water quality standards is not possible. For the purpose of this report, each discreet temperature value was compared directly to the water temperature maximum. It was determined, by the previous Water Quality Specialist, that a reasonable assumption could be made by the results of that comparison. The direct comparison would still yield a percentage of temperature readings that are within the limits of the standard. It is assumed that this percentage is somewhat representative of what the results might be if compared to continuous temperature data.

Temperature values were compared to the Aquatic Life Temperature Criteria for Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration of 16^{o}C and 17.5^{o}C, respectively. The values exceeding these temperature limits were considered out of compliance.

5.4.2.b Dissolved Oxygen (DO)

The water quality limit for DO is a discreet value and is expressed as a 1-DAD Max, which means the daily average of DO readings are directly compared to the standard. Because the water quality readings were collected at a discreet time point, there is only one reading per day, per month. For the purpose of this report, each discreet DO value was compared directly to the DO minimum. The direct comparison would still yield a percentage of DO readings that are within the limits of the standard. It is assumed that

this percentage is somewhat representative of what the results might be if compared to continuous temperature data.

Measured values were compared to the Aquatic Life DO Criteria for Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration of 9.5 mg/L and 8.0 mg/L, respectively. The values that were below the DO minimum limits were considered to be not in compliance.

5.4.2.c pH

Measured pH values were compared to the Aquatic Life pH Criteria for Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration. For the Core Summer Salmonid Habitat category, the water quality range for pH is between 6.5 and 8.5, with a human-caused variation within the range of less than 0.2. For the Salmonid Spawning, Rearing, and Migration category, the water quality range for pH is between 6.5 and 8.5 with a human-caused variation within the range of less than 0.5 units. The difference between these two categories is the amount of human-caused variation allowed. For the purpose of this report, the more restrictive of the two categories (Core Summer Salmonid Habitat) was used.

The values that were above or below the allowable pH range were considered to be out of compliance.

5.4.2.d Turbidity

Water quality standards for turbidity are based on background levels of turbidity, or turbidity levels that were present before development or modification of the watershed. The standard limit is relative to that background level. The water quality standard reads that the turbidity level must not exceed 5 NTUs above the background level.

Determining natural background levels of turbidity of urban streams is difficult. Streams and watersheds have been so extensively modified by urban development (in the City, this modification began many years ago, before any kind of monitoring was conducted) that merely sampling will not yield true background levels. No data exists during pre-development, or what might be considered the pre-development conditions, which are necessary for determining the natural background levels of a stream. Although background turbidity for these creeks has not been determined, it is likely similar to the lower range of values observed at the sample stations. A background turbidity that is between 1-5 NTUs is realistic. For the purposes of this comparison, background turbidity levels are assumed to be a conservative value of 1 NTU. Therefore, the recorded turbidity levels above 6 NTU are considered to have exceeded water quality standards.

The values above the turbidity limit, 6 NTUs, were considered to be out of compliance.

5.4.2.e Fecal Coliform

Fecal coliform measured values were compared to the Primary Contact Recreation Bacteria Criteria. The water quality standard in this designated use category states that fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL. The geometric mean value is meant to measure bacteria colony levels for a specific sample time (i.e. four of the most recent samples are used to calculate the geometric mean for September). If geometric means exceeded the standard, additional grab samples were collected as a way to confirm whether the waterbody had high levels or if levels were abnormally high for one day. For the purpose of understanding yearly changes, arithmetic averages were calculated and graphed (Appendix A and B). The values that were above the value of 100 colonies/100 mL were considered to be out of compliance.

6 RESULTS

6.1 Streams

Tables 5 and 6 show the designated use support ratings for each stream monitoring station across all categories. These results are based on percent of compliance. Following the tables is a discussion of scoring results for each stream sampling station and a comparison to the 2009 results. For detailed scoring information at each specific sampling station, please see the tables in Appendix A. For yearly average comparisons on monitoring standards, see the figures in Appendix A.

Overall, the water quality assessment indicates that five of the seven stream sampling locations are degraded and did not meet at least one water quality standard in the Aquatic Life Designated Use category. Previously, all stream sites were considered degraded. While four sampling sites failed to meet all water quality standards, most improved from the 2009 report. However, all streams still have elevated fecal coliform levels. Five of the seven stream sampling locations had “poor” ratings in the Primary Contact Recreation Designated Use category. The two Boeing Creek sites were the only sites to receive a “fair” rating.

A summary of the King County Water Quality Index (WQI) scores is also included for each stream sample site. Collected water quality data was entered into King County’s formula spreadsheet and a water quality “score” for that stream was calculated. The WQI score is a unitless number ranging from 1 to 100; a higher number is indicative of better water quality. In general, stations scoring 80 and above met expectations for water quality and are of "lowest concern," scores 40 to 80 indicate "moderate concern," and water quality at stations with scores below 40 did not meet expectations and are of "highest concern." For detailed scoring, see Table 9 in Appendix C.

Table 5 - Aquatic Life Designated Use Support Ratings for Streams							
	Boeing Creek (BC-2)	**Boeing Creek (BC-3)**	**Thornton Creek (TH-1)**	**Littles Creek (LT-1)**	**McAleer Creek (MC-1)**	**Cedarbrook Creek (CB-1)**	**Storm Creek (ST-2)**
Temperature; Core Summer Salmonid Habitat	Good	Good	Good	Good	Good	Good	Good
Temperature; Salmonid Spawning, Rearing and Migration	Good	Good	Good	Good	Good	Good	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	Fair	Good	Poor	Poor	Fair	Good	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Good	Good	Good	Poor	Good	Good	Good
pH; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Good	Good	Good	Good	Good	Good	Fair
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Good	Good	Fair	Good	Good	Good	Fair

Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

Table 6 - Primary Contact Recreation Designated Use Support Rating for Streams				
Sampling Site	**Year**	**Percent Compliance With Standards**	**Exceeded Water Quality Standard**	**Designated Use Support Rating**
Boeing Creek (BC-2)	2010	90.0%	No	Good
	2011	75.0%	Yes	Fair
	2012	90.0	No	Good
	2013	91.7	No	Good
	2014	91.7%	No	Good
	2015	75.0%	Yes	Good
Boeing Creek (BC-3)	2010	90.0%	No	Good
	2011	83.3%	Yes	Fair
	2012	87.5%	Yes	Fair
	2013	91.7%	No	Good
	2014	91.7%	No	Good
	2015	58.3%	Yes	Poor
Thornton Creek (TH-1)	2010	50.0%	Yes	Poor
	2011	58.3%	Yes	Poor
	2012	37.5%	Yes	Poor
	2013	41.7%	Yes	Poor
	2014	16.7%	Yes	Poor
	2015	50.0%	Yes	Poor
Littles Creek (LT-1)	2010	40.0%	Yes	Poor
	2011	16.7%	Yes	Poor
	2012	50.0%	Yes	Poor
	2013	25.0%	Yes	Poor
	2014	33.3%	Yes	Poor
	2015	16.7%	Yes	Poor
McAleer Creek (MC-1)	2010	60.0%	Yes	Poor
	2011	66.7%	Yes	Poor
	2012	75.0%	Yes	Fair
	2013	91.7	No	Good
	2014	83.3%	Yes	Fair
	2015	41.7%	Yes	Poor

Table 6 - Primary Contact Recreation Designated Use Support Rating for Streams				
Sampling Site	**Year**	**Percent Compliance With Standards**	**Exceeded Water Quality Standard**	**Designated Use Support Rating**
Cedarbrook (CB-1)	2010	36.4%	Yes	Poor
	2011	58.3%	Yes	Poor
	2012	75.0%	Yes	Fair
	2013	83.3%	Yes	Fair
	2014	100%	No	Good
	2015	83.3%	Yes	Fair
Storm Creek (ST-2)	2010	60.0%	Yes	Poor
	2011	50.0%	Yes	Poor
	2012	50.0%	Yes	Poor
	2013	66.7%	Yes	Poor
	2014	33.3%	Yes	Poor
	2015	41.7%	Yes	Poor

Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

6.1.1 Boeing Creek (BC-2)

The Aquatic Life Designated Use Support Ratings at Boeing Creek monitoring station BC-2 were primarily "good". pH rated "good," with less than 5% of exceedances. Turbidity was just above the 5% exceedance mark but was still able to maintain a "good" rating. There were no exceedances for temperature. This station scored "good" in all categories except the Core Summer Salmonid Habitat category for dissolved oxygen, which received a rating of "fair". In the 2009 report, the categories that received a "good" rating maintained this rating. Dissolved oxygen rating for the Core Summer Salmonid Habitat was the only category that was not rated "good," but has since improved from "poor" to "fair".

Boeing Creek station BC-2 received ratings of mostly "good" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform. 2011 was the only year this site received a rating of "poor". This site has maintained a "good" rating since the 2009 report.

According to King County's WQI score, this sites' impairment level has most consistently been "moderate concern" (years 2011, 2012, 2013, and 2015). In 2010 and 2014, the impairment level was considered a "low concern". In 2008 and 2009, this site's impairment levels were "moderate concern".

6.1.2 Boeing Creek (BC-3)

Boeing Creek station BC-3 rated "good" in all the Core Summer Salmonid Habitat and the Salmonid Spawning, Rearing, and Migration aquatic life categories, which is an improvement on the 2009 report's results. This stem of the creek now meets all standards of the Aquatic Life Designated Use category. Dissolved oxygen and pH standards in the Salmonid Spawning, Rearing, and Migration aquatic life category were exceeded less than 5% of the time. There were no exceedances of standards in temperature. Since the 2009 report, the dissolved oxygen rating for Core Summer Salmonid Habitat has improved from "fair" to "good". This site met all other standards in the Aquatic Life Designated Use category.

Boeing Creek station BC-3 received a range of ratings in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform. In the years 2010, 2013, and 2014, the ratings were "good". In 2011 and 2012 the rating was "fair". Most recently in 2015, the site received a rating of "poor". Since 2009, the site appears to have degraded in the Primary Contact Recreation Designated Use category. In the 2009 report, this site received "good" ratings for the years 2007 through 2009.

In 2010 and 2011, BC-3's WQI impairment level was rated as a "low concern". In recent years, from 2012 to 2015, it was rated as "moderate concern". In 2008 and 2009, this site's impairment levels were also "moderate concern".

6.1.3 Thornton Creek (TH-1)

The Aquatic Life Designated Use Support Ratings at the Thornton Creek monitoring station TH-1 ranged from "good" to "poor". This station rated "good" in the temperature and pH categories for the Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration. The rating for dissolved oxygen in the Salmonid Spawning, Rearing, and Migration category was "good" while the rating for Core Summer Salmonid Habitat aquatic life category was "poor". The site received a "fair" rating in both turbidity categories. Since the 2009 report, the dissolved oxygen rating for Salmon Spawning, Rearing, and Migration has improved from "fair" to "good". The rating for dissolved oxygen Core Summer Habitat was also poor in the 2009 report, indicating no improvement.

Thornton Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform. This is consistent with the results from the 2009 report, also indicating no improvement in this category.

King County rated the impairment level of this site as mostly "high concern" (years 2010, 2012, 2013, and 2015). In 2011 and 2014, the site received "moderate concern" with ratings that barely made it out of the "high concern" category. In 2008 and 2009, this site's impairment levels were "high concern".

6.1.4 Littles Creek (LT-1)

The Aquatic Life Designated Use Support Ratings at the Littles Creek monitoring station LT-1 ranged from "good" to "poor". This station rated "good" in the temperature, pH, and turbidity Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration categories. A "fair" rating was received in dissolved oxygen for Salmonid Spawning, Rearing, and Migration. The rating for Core Summer Salmonid Habitat for dissolved oxygen was "poor". There have been no improvements or further impairments in this creek since the 2009 report.

Littles Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform. This is consistent with results from the 2009 report, indicating no improvement in this category.

Almost every year from 2010 to 2015 this site was rated "high concern" for King County's WQI impairment level. In 2012, this site was rated "moderate concern" with a score (42) barely surpassing the minimum numerical score (40). In 2008 and 2009, this site's impairment levels were "high concern".

6.1.5 McAleer Creek (MC-1)

The Aquatic Life Designated Use Support Ratings at the McAleer Creek monitoring station MC-1 ranged from "good" to "fair". This station rated "good" in the temperature, pH, and turbidity Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration categories. The rating for Core Summer Salmonid

Habitat for dissolved oxygen was "fair". The dissolved oxygen rating for Core Summer Salmonid Habitat has have improved since the 2009 report, from "poor" to "fair". The turbidity rating at this site has also improved, from "fair" to "good".

The Primary Contact Recreation Designated Use Support criteria ratings for fecal coliform for McAleer Creek ranged from "good" to "poor". 2013 was the only year this site received a rating of "good". In 2012 and 2014, the site received ratings of "fair" and the other years received ratings of "poor". The inconsistencies of these ratings are similar to data results from the 2009 report. In 2007 the site received a rating of "poor," then "good" in 2008 and then "fair" in 2009.

This site has consistently received an impairment level of "moderate concern" for King County's WQI scoring. In 2008, this site's impairment level was "high concern".

6.1.6 Cedarbrook Creek (CB-1)

Cedarbrook Creek station CB-1 rated "good" in all the Core Summer Salmonid Habitat and the Salmonid Spawning, Rearing, and Migration aquatic life categories, which is an improvement on the 2009 report's results. Core Summer Salmonid Habitat and Salmonid Spawning, Rearing, and Migration standards were exceeded less than 5% of the time. This creek now meets all Aquatic Life Designated Use categories. Previously, this site received "fair" ratings for the turbidity standards and the dissolved oxygen Core Summer Habitat standard.

The Primary Contact Recreation Designated Use Support criteria rating for fecal coliform for Cedarbrook Creek ranged from "good" to "poor". 2014 was the only year this site received a rating of "good". In 2012, 2013, and 2015, this site received ratings of "fair" and then "poor" for the remaining years. In the 2009 report, this site received a "fair" rating in 2007 and 2009, and a "poor" rating in 2008.

This site has consistently received an impairment level of "moderate concern" for King County's WQI scoring. This is consistent with data from the 2009 report.

6.1.7 Storm Creek (ST-2)

The Aquatic Life Designated Use Support Ratings at the Storm Creek monitoring station were either "good" or "fair". This station received a "good" rating in all categories except dissolved oxygen for Core Summer Salmonid Habitat) and pH for Core Summer and Salmonid Spawning, Rearing, and Migration. These areas instead received a rating of "fair". Dissolved oxygen for Core Summer Salmonid Habitat has improved from "poor" to "fair" since the 2009 report. The rating for turbidity, however, has worsened, from "good" to "fair," since the 2009 report.

Storm Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform. In the 2009 report, this site received a "poor" rating in 2007 and "fair" ratings in 2008 and 2009.

This site is now rated as a "moderate concern" from King County's WQI scoring. From 2010 to 2013, this site's WQI impairment level was "high concern". This site received "high concern" impairment levels in 2008 and 2009 as well.

6.2 Lakes

Tables 7 and 8 show the designated use support ratings for the Echo Lake monitoring stations. Following the tables is a discussion of scoring results. Hidden Lake was only sampled for fecal coliform from the years 2010 to 2015. For detailed scoring information at each specific sampling station, please see the tables in Appendix B.

Only one site at Echo Lake was measured for the Aquatic Life Designated Use category. This site failed to meet water quality standards and ranged between "poor" and "fair" ratings. The ratings have not changed since the 2009 report. Under the Primary Contact Recreation Designated Use category, Echo Lake ranged between "fair" and "good" from 2010 to 2013. However in recent years it has received a "poor" rating. Hidden Lake has consistently received a "poor" rating since 2010.

Table 7 - Aquatic Life Designated Use Support Ratings for Echo Lake	
	Echo Lake (ELO-PROFILE)
Temperature; Core Summer Salmonid Habitat	Poor
Temperature; Core Summer Salmonid Habitat	Poor
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Poor
pH; Core Summer Salmonid Habitat **AND** Salmonid	Fair
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Fair

Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

Table 8 - Primary Contact Recreation Designate Use Support Ratings for Lakes

Sampling Site	Year	Percent Compliance With Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Echo Lake (A764SB)	2010	83.3%	Yes	Fair
	2011	90.0%	No	Good
	2012	100%	No	Good
	2013	89.5%	Yes	Fair
	2014	57.1%	Yes	Poor
	2015	45.8%	Yes	Poor
Hidden Lake (0207SB)	2010	26.3%	Yes	Poor
	2011	52.6%	Yes	Poor
	2012	61.1%	Yes	Poor
	2013	61.1%	Yes	Poor
	2014	47.4%	Yes	Poor
	2015	34.8%	Yes	Poor

Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

6.2.1 Echo Lake (EL-PROFILE)

The Aquatic Life Designated Use Support Ratings for Echo Lake water quality ranged from "poor" to "fair". This station received a "poor" rating in all categories except pH and turbidity. For pH and turbidity, the rating was "fair". These results are the same as the results from the 2009 report, indicating no improvement in any of the categories.

The Primary Contact Recreation Designated Use parameters were not measured at this site.

6.2.2 Echo Lake (A764SB)

Aquatic Life Designated Use parameters were not measured at this site.

The Primary Contact Recreation Designated Use Support criteria ratings for fecal coliform for this Echo Lake site ranged from "good" to "fair". In 2011 and 2012, this site received "good" ratings. In 2010 and 2013, this site received "fair" ratings. The ratings have declined to "poor" in 2014 and 2015. Previously, this site was often rated "good". From 2004 to 2009, this site only received a "fair" rating in 2004 and 2006.

6.2.3 Hidden Lake (0207SB)

Aquatic Life Designated Use parameters were not measured at this site.

The Primary Contact Recreation Designated Use Support criteria ratings for fecal coliform for Hidden Lake were poor for all years, 2010 to 2015. The 2009 report used data results from 2004 to 2009. 2005 was the only year this site rated "good". In 2006, 2008, and 2009, Hidden Lake received "fair" ratings, and in 2004 and 2007 the site received "poor" ratings.

7 SUMMARY

7.1 Streams

Streams within the City were rated "good" in most water quality categories under the Aquatic Life Designated Use category. The majority of the streams met standards for temperature, pH, and dissolved oxygen greater than 90 percent of the time for the Salmonid Spawning, Rearing, and Migration Beneficial Use category. The most common water quality exceedance was in the Core Summer Salmonid category for dissolved oxygen. The majority of streams failed to meet the dissolved oxygen standard of 9.5 mg/L more than 25 percent of the time. Turbidity ratings were almost as frequently in the "good" and "fair" categories, demonstrating improvement from the 2009 report.

For the Primary Contact Recreation Designated Use category, the Boeing Creek sampling sites rated mostly "good". Cedarbrook Creek and McAleer Creek sampling sites rated "good" one year, but had a mix of "poor" and "fair" ratings for all other years. Thornton Creek, Littles Creek, and Storm Creek rated "poor" every year from 2010 to 2015.

7.2 Lakes

In most Aquatic Life water quality categories, Echo Lake rated as "fair" or "poor". Echo Lake did not meet standards more than 25 percent of the time in the dissolved oxygen and temperature Core Summer Salmonid Habitat and Spawning, Rearing, and Migration categories. These categories were rated "poor". In the pH and turbidity categories, Echo Lake rated "fair".

In the Primary Contact Recreation Designated Use category, Echo Lake rated "good" or "fair" from 2010 to 2013. More recently in 2014 and 2015, Echo Lake received "poor" ratings. Hidden Lake rated "poor" every year of sampling, from 2010 to 2015.

Echo Lake and Hidden Lake receive water from stormwater runoff, streams, and groundwater, but the percentage of each that the lakes receive is highly varied. Boeing Creek flows all-year-round into Hidden Lake. The lake water is essentially being "flushed" from the lake on a constant basis. Boeing Creek does receive a large amount of stormwater input at the headwaters located along the Aurora Ave N business district. However, that runoff passes through stormwater treatment and detention ponds before continuing to flow into Hidden Lake. The land immediately surrounding Hidden Lake is primarily undeveloped or lightly developed residential parcels. Therefore, Hidden Lake receives little direct stormwater runoff.

In contrast, the inflow to Echo Lake consists mainly of stormwater runoff and groundwater. No streams flow into this lake, so the water contained in the lake primarily remains there until the lake level is high enough for there to be outflow to

Lake Ballinger. The lake receives direct stormwater runoff from the highly-traveled Aurora Ave N to the west. The land surrounding the lake is primarily residential and commercial development.

The monitoring results of the Echo Lake chemical and physical parameters indicate that the lake is moderately to severely impacted by stormwater. Since chemical and physical monitoring was discontinued in Hidden Lake, it is unknown how the two lakes compare. However, bacteria levels in Hidden Lake exceeded water quality standards more often than at Echo Lake. Temperature was collected during swimming beach monitoring and Hidden Lake met standards every year whereas Echo Lake rated "poor" every year.

In 2005, the City began monitoring Echo Lake as part of the King County Lake Stewardship Program. Regular monitoring has continued through 2016. Samples collected are analyzed for total phosphorous, total nitrogen, chlorophyll-*a*, and pheophytin. Temperature is measured at the time of sample collection. Data collected by the City is submitted to King County for analysis. This information is summarized in a report provided to the City. These reports state that, overall, Echo Lake is high in primary productivity (eutrophic) with fair water quality. The parameters that are measured can be related to runoff from the surrounding lands and the fair water quality may indicate that the lake is impacted by that runoff. This assessment is consistent with the findings of this report.

8 CONCLUSION

8.1 Overall Assessment

The findings of this report indicate the water quality in the City's waterbodies is moderately to severely impacted by stormwater. However, through monitoring and implementation of capital improvement projects, there have been improvements in some areas since the 2009 report.

The water quality parameters analyzed in this report can be affected by both natural and artificial inputs. For example, temperature naturally fluctuates with the season and air temperature. The temperature of the water body will be significantly higher in the summer than in the winter and can be significantly affected by hot, dry weather patterns. As noted earlier in the report, areas of slower moving water can be more affected by decaying matter. This decaying matter can have a significant influence on dissolved oxygen and turbidity levels. The City cannot control or significantly influence the natural factors that may affect water quality, but can influence the artificial and human induced, adverse impacts on water quality.

Stormwater is the number one water pollution problem in the urban areas of our state. By reducing the volume of stormwater runoff flowing into the City's waterbodies or the amount of contaminants contained in it, water quality can be improved. To reduce the impacts of stormwater, the City implements programs and projects designed to control the source of contaminants on the ground that can be carried away by runoff and the amount or runoff being produced.

The City already has many programs in place, such as the Illicit Discharge Detection and Elimination Program, the Adopt-A-Drain Program, the Soak It Up LID Rebate Program, and the Private Facility Storm Drainage System Inspection Program. Examples of capital projects that have played a role in improving water quality include the re-graded Pan Terra Regional Stormwater Facility, Boeing Creek Park improvements, Cromwell Park stormwater facilities, the Greenworks/Surface Water Small Works Program (low impact development (LID) stormwater retrofit program), and North Fork Thornton Creek LID retrofit project. By continuing to increase the program and capital project efforts, the City may improve surface water quality conditions.

8.2 Recommendations

This section includes programmatic and educational program recommendations to improve the water quality of the City's water bodies. Each drainage basin has a basin plan that includes a set of recommended strategies, which include capital projects and policy-oriented changes; those recommendations are not included in this report. Included in these recommendations are programmatic changes to improve habitat, community engagement, and overall program efforts. The recommendations in this report will help inform the 2018 Surface Water Master Plan.

8.2.1 Habitat Improvement

The City's streams and the surrounding terrestrial environment provide habitat for fish and other wildlife. Currently, the Boeing Creek sites are the only sites suitable for salmon. The terrestrial environment has the potential to naturally mitigate the effects of urban development on streams. Unfortunately, a number of streams have invasive species along their banks (The Watershed Company 2009). Invasive species along a stream can cause a number of problems, including erosion, water flow constriction, nutrient flux, and more. The following are recommendations for improving habitat.

8.2.1.a Conduct Vegetation Surveys to Improve Riparian Zones

In order to improve overall habitat near freshwater systems, vegetation surveys and streamside plantings should be conducted. Riparian zones play a key role in combating adverse water quality impacts associated with non-point source pollution and offset the need for costly stormwater and flood protection facilities (EPA 2005). To improve the functionality of a stream, invasive plant species should be removed and replaced with native species. This effort would address stream turbidity issues by reducing erosion and the amount of pollutants entering the waterway.

8.2.1.b Conduct Fish Surveys

Fish surveys should be conducted in Boeing Creek, Storm Creek, McAleer Creek, and Thornton Creek. Previously, fish have been observed in these creeks. It is important for the City to have a concrete understanding of fish populations and their abundance in these creeks. Determining whether there are fish in these creeks will also help the City refine programming to meet Washington State Standards.

There are several stormwater outfall pipes that discharge into different segments of all streams that are monitored, allowing different pollutants to enter streams. Pre-spawn mortality in Coho salmon is highly affected by the presence of stormwater, where pre-spawn mortality increases with the presence of stormwater (Scholz et al. 2011). Therefore, it is important to understand the current habitat functions in these streams to narrow in on areas that need the most improvement.

8.2.1.c Install Temperature Loggers

In the future, temperature loggers might be deployed at priority stream sites in order to collect continuous data. It may be possible to calculate the 7-DAD Max and compare that to the water quality criteria in order to obtain a more accurate comparison to temperature water quality standards. This suggestion was also noted in the 2009 report. However, temperature at most sample sites is usually within water quality standards, with the exception of Echo Lake, so the City may not gain much more information.

8.2.1.d Climate Change Mitigation

Climate change is expected to alter the amount of precipitation the Puget Sound region receives annually. Increases in precipitation will increase stormwater runoff, potentially

increase erosion, and increase flood risks. Not only would climate change increase problems for residents, it may also decrease water quality for salmon and other fish by increasing turbidity, temperature, and the amount of pollutants entering the water way.

When planning for future projects or updating the Surface Water Master Plan, the City should consider the effects of climate change. Climate change will amplify current conditions. Some areas throughout the City are already prone to flooding; therefore, when planning improvement projects, the City must consider the increase of rainfall the Puget Sound region is expected to receive in the future (Littell 2009). Areas in the Thornton Creek basin are already prone to flooding; therefore, projects to improve this area should consider the changes of climate change conditions. Solutions to consider for mitigation include:

- Construction and proper maintenance of Green Stormwater Infrastructure (GSI) on City properties.
- Review projected rainfall increases and incorporate them into future planning for programming and capital improvement projects.
    - Prioritize community outreach on flooding.
    - Prepare communities for emergencies. Ensure all areas throughout the City have the tools to be equipped during an emergency.
- Monitor stream riparian zones at sampling sites for existing erosion and restore them with native vegetation. Examine other areas along the stream for high abundances of invasive species. Remove the invasive species and replant with native plant species.
- Identify areas along streams that are not shaded by vegetation. Consider planting trees or larger vegetation to help shade the creek and keep temperatures below the limit of the water quality standards.

8.2.2 Community Engagement

Under the National Pollutant Discharge Elimination System (NPDES) permit, the City is required to provide an education and outreach program that is designed to educate audiences about stormwater problems and provide specific actions they can follow. Audiences include the general public (including school age children), businesses, engineers, contractors, developers, residents, landscapers, and property managers/owners. The following are recommendations for the City to build on from current programming.

8.2.2.a Engage the Community

The NPDES permit includes the requirement to effect behavior change for the general public, residents, landscapers, and property managers/owners. Increasing current relationships with the Shoreline School District, Shoreline Community College, and surrounding businesses would help address behavior changes throughout the City. This can be accomplished by providing additional and more frequent services, such as:

- Host best management practice (BMP) workshops for:
    - General public and businesses: use and storage of automotive chemicals, hazardous cleaning supplies, carwash soaps, and other hazardous materials, equipment maintenance, and prevention of illicit discharges.
    - Residents, landscapers, and property managers/owners: natural yard care workshops, use and storage of pesticides and fertilizers, pet waste management, low impact development (LID) BMPs, and stormwater facility maintenance.
- Classroom presentations:
    - For K-12: teach students about use and storage of automotive chemicals, cleaning supplies, carwash soaps, and other hazardous materials using an Enviroscape watershed model.
    - For Shoreline Community College: teach students about water quality impacts in the City. Build relationships with faculty and provide project opportunities for the Environmental Science program. Projects could include stream monitoring, habitat stewardship, etc.
    - Currently the City has an Adopt-a-Drain program where community members help care for storm drains. This program could be expanded into the school districts. After talking to students about stormwater, introducing a feasible action, like becoming a drain ranger, will boost sense of responsibility in the community.
- Trainings and opportunities for monitoring or stewardship events/programs:
    - Stream Team: Identify waterbodies that would benefit from being monitored, then train students or residents how to monitor water quality.
    - Habitat Stewardship Program: In the basin plans created for the City, poor habitat areas were identified. These areas provide the initial sites for volunteer stewardship opportunities. Volunteer training opportunities include invasive species removal and how to plant and mulch native species.

8.2.2.b Examine the City's Population and Develop Targeted Outreach Strategies

Currently, there is a lack in engagement with youth (ages 18 and under) who, according to the 2015 Census data, account for 19.1 percent of the City's population. To foster a sense of responsibility for the environment, youth need to be exposed to natural areas and learn about human impacts. For adults, engagement could be hosting workshops on asset management. This would give the City the opportunity to talk to residents about the importance of ditches and stormwater ponds as well as promote the City's Adopt-A-Drain and Soak It Up LID Rebate programs.

In addition to current services, informational materials for programs should be translated into other languages (Herrera 2014), specifically the top five most spoken languages in the City.

Community input is important, so as the Surface Water team conducts operations and maintenance, it is important to have adequate representation of the community in the conversation. This is important for water quality because everyone in the community is responsible for helping keep the City's waterbodies healthy. In the 2018 Surface Water Master Plan Level of Services Survey, 63% of the 171 respondents were unfamiliar with what the Surface Water Utility is and what it does.

8.2.2.c Pilot Program in Thornton Creek Basin

As reflected in this report, meeting minimum NPDES requirements is not enough to maintain state water quality standards in the Thornton Creek Basin. Since the 2009 report, the only improvement made at the Thornton Creek sampling site was going from a "fair" to a "good" rating for dissolved oxygen for Salmonid Spawning, Rearing, and Migration standard. Dissolved oxygen for Core Summer Salmonid Habitat ("poor"), turbidity ("fair"), and fecal coliform ("poor") ratings remain the same.

The first step to understanding what is happening is to increase monitoring. It is recommended to add the Ronald Bog inlet back in to the WQI monitoring program. Another sampling site past Twin Ponds could also be added to understand whether the ponds are effectively reducing turbidity by holding sediment from Thornton Creek. If the City is unable to add these monitoring locations into its current workload, the City could instead recruit monthly Stream Team volunteer monitors.

Since the Thornton Creek basin has the most degraded waterways in Shoreline, the City could pilot a variety of programs, such as a pet waste outreach program. Through this type of program the City could:

- Survey constituents to get a starting baseline.
- Conduct outreach on pet waste.
- Provide an incentive for pet owners.
- Conduct a second survey to track behavior change.

Piloting a volunteer habitat stewardship program would also be beneficial in this area. Volunteers could help inform which areas have the most need (e.g. areas with high levels of invasive species present or trash and pollution on or near the waterbody). This would give residents a sense of responsibility and will benefit the overall relationship with constituents. Once that step is completed, restoration events for invasive removal and native plantings could be planned. These events should occur in early spring or fall. Initially, this would serve well as an Earth Day event. If enough stewards are recruited, neighborhoods could host their own restoration events with the technical assistance of a City staff member.

8.2.3 Overall Programming

Broader recommendations for the Surface Water Management program are below.

8.2.3.a Increase Frequency of Reporting

Conduct freshwater assessment reports every five years, possibly more frequently for degraded areas such as Thornton Creek and Littles Creek.

8.2.3.b Implement Enforcement Mechanism for the Private Facility Inspection Program

Previously, properties that were inspected as part of the private facility inspection program were given a 50 percent discount on their surface water management fee if the facility was in compliance. If a facility failed to meet compliance standards, they were charged the full surface water management fee. Starting in 2017, the City no longer offers the discounted surface water management fee incentive. Properties that do not have a stormwater covenant in place will therefore have no incentive or disincentive to maintain their storm drainage system. In order to hold property owners accountable for their storm drainage system, an enforcement mechanism, such as a fine, is recommended. Currently, some businesses do not complete required maintenance to their storm drainage system and this burdens other businesses and residents nearby. Funds from a fine could be used to supply workshop materials, plants for restoration events, or neighborhood grants.

8.2.3.c Increase Staffing Capacity and Technical Assistance

The surface water team as is, cannot take on the additional programming recommended in this report; therefore, at least two additional positions are necessary. The Surface Water Technician would take the place of hiring new Extra Help annually. The onboarding and training of new staff every year burdens other members of the Surface Water and Environmental Services team. It would be beneficial to continually have someone with the knowledge of asset management, the inspection process, and water quality standards.

With the 63% of the surveyed citizens having a lack of knowledge of what the Surface Water Utility does, it is important to have a point person who interacts with the community (e.g. a Community Outreach Coordinator). It is important that the City look to the community to help with surface water and environmental issues. The Shoreline community can provide additional eyes for problems. It is also important to recognize the City cannot improve the state of our freshwater without engaging the people that live in the area.

Increased staffing capacity would allow the City to increase technical assistance for the Environmental Services and Surface Water Management programs. For example, for the Soak It Up LID Rebate Program, staff could provide a design plan for resident rain gardens. The increased staffing capacity would also allow the City to implement all of the previously mentioned recommendations.

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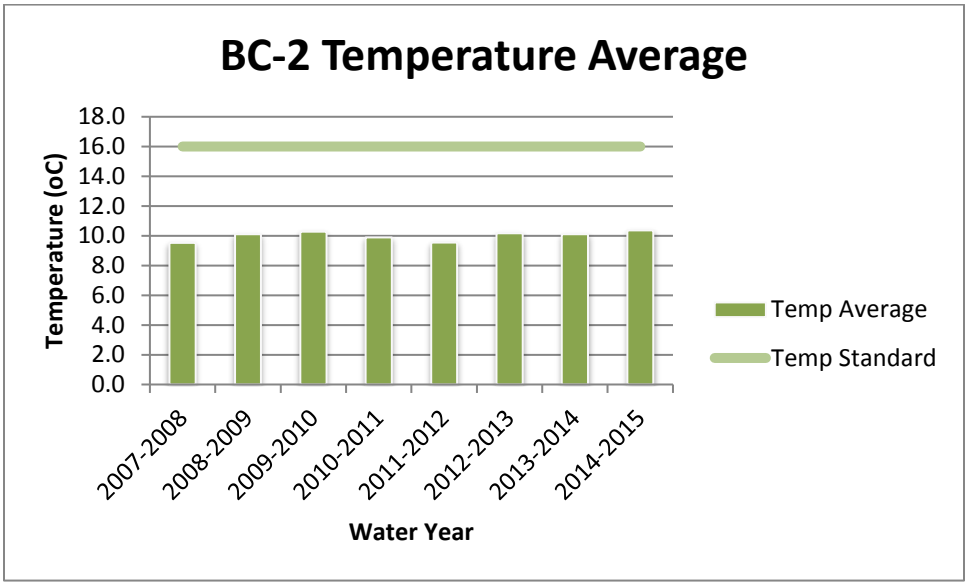
10 APPENDICES

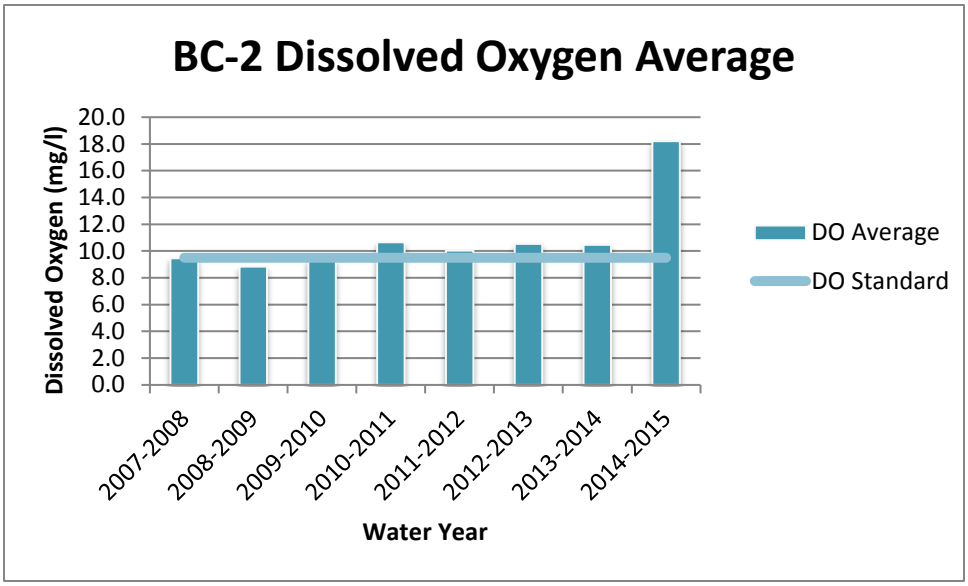
Appendix A. Stream Water Quality Data

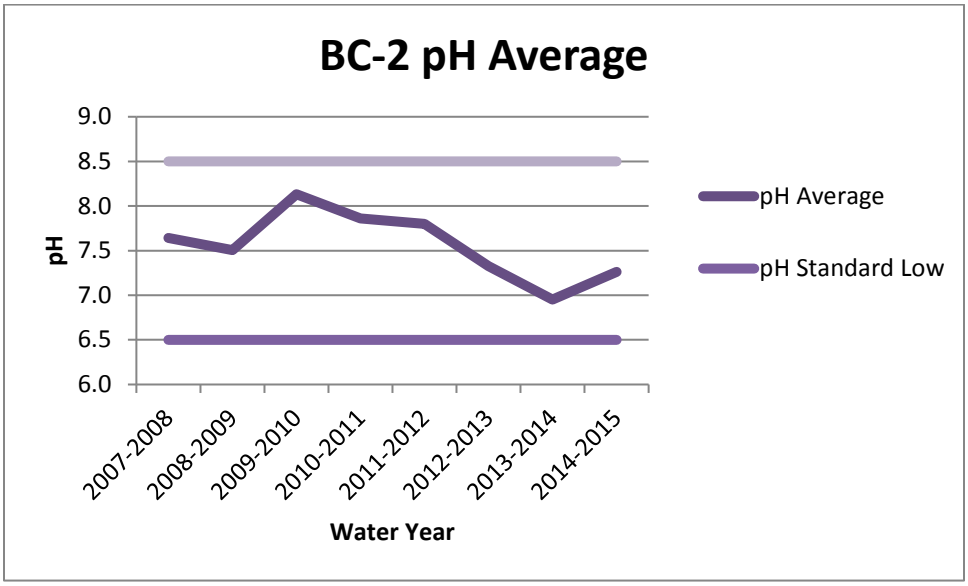
The following tables exhibit percent compliance of water quality standards for each sampling site. The graphs illustrate the water year data averages.

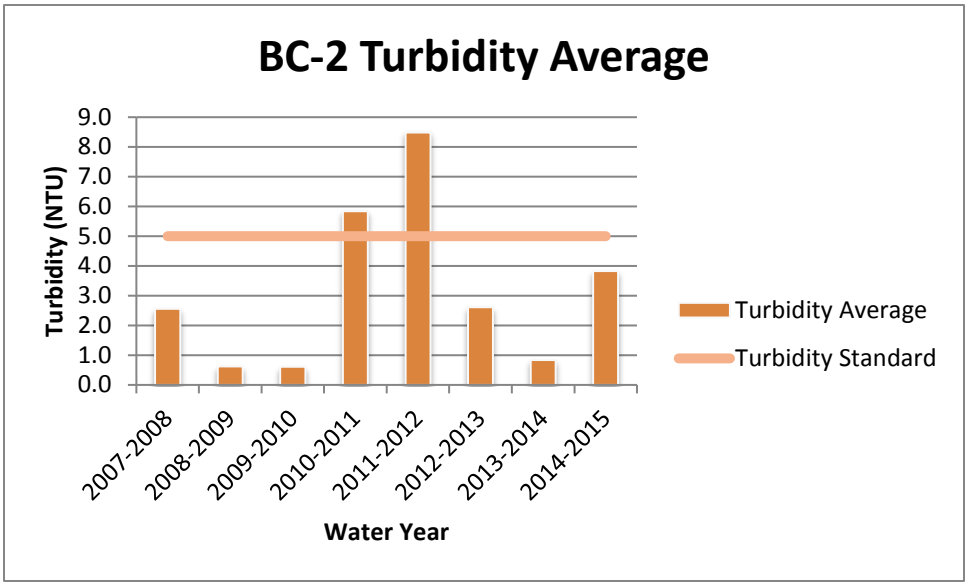
A.1 Boeing Creek (BC-2)

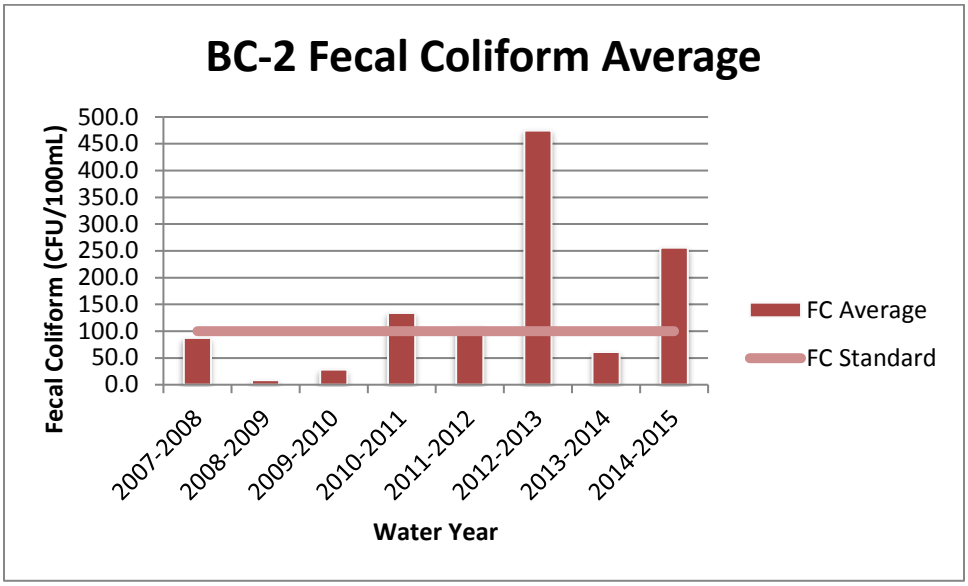
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	85.7%	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	100%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	98.6%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	92.4%	Good




BC-2 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

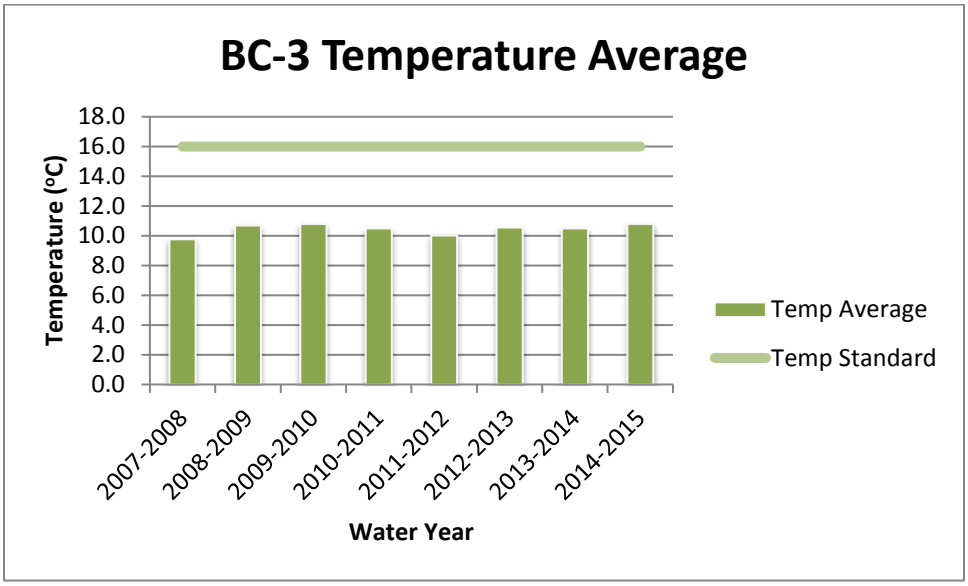

BC-2 pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low

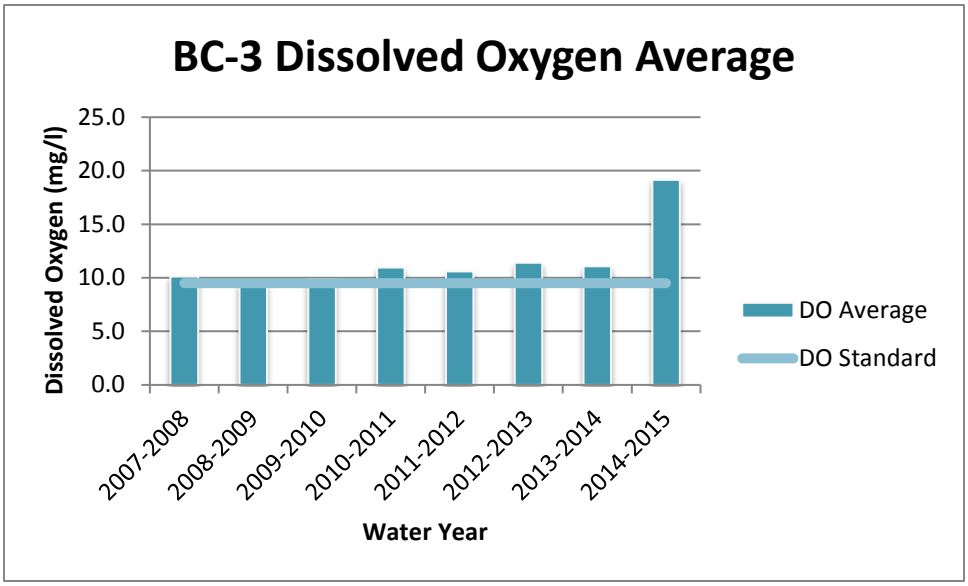

BC-2 Turbidity Average
Turbidity (NTU)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

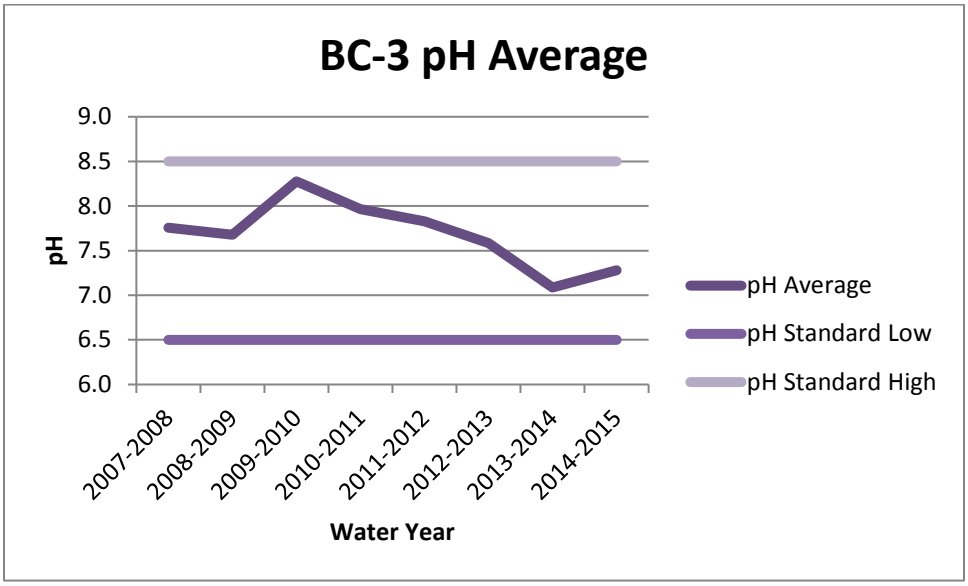

BC-2 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

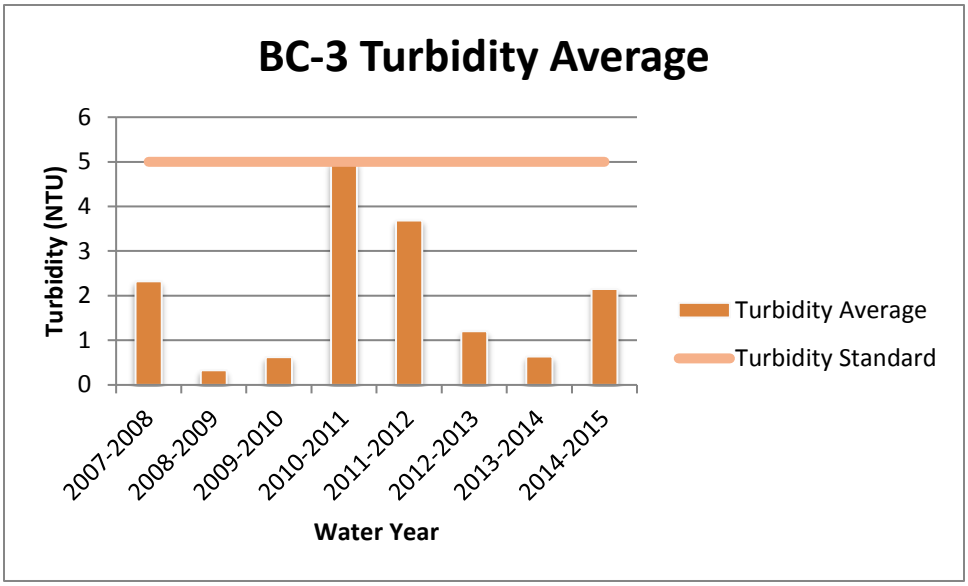
A.2 Boeing Creek (BC-3)

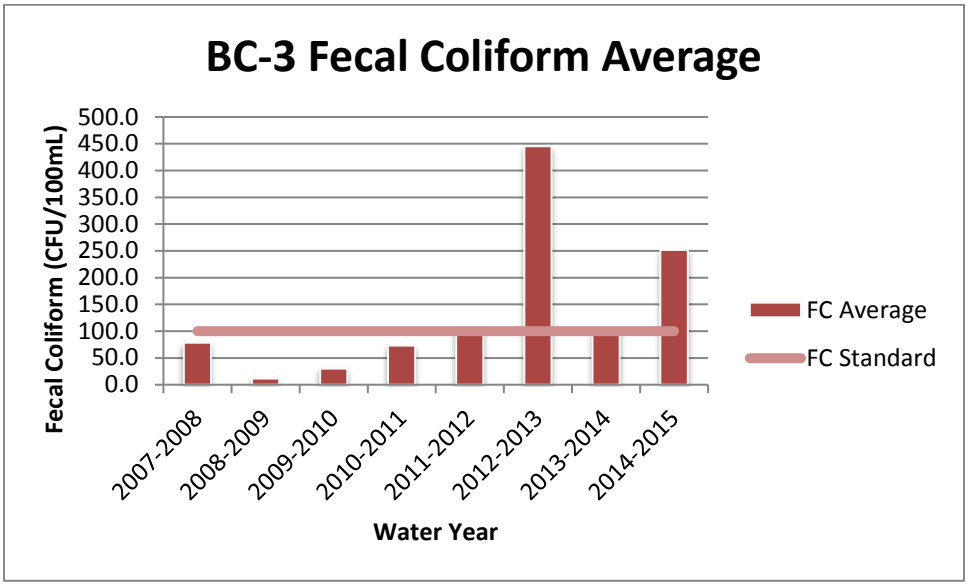
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	94.2%	Good
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	100%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.8%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.1%	Good




BC-3 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

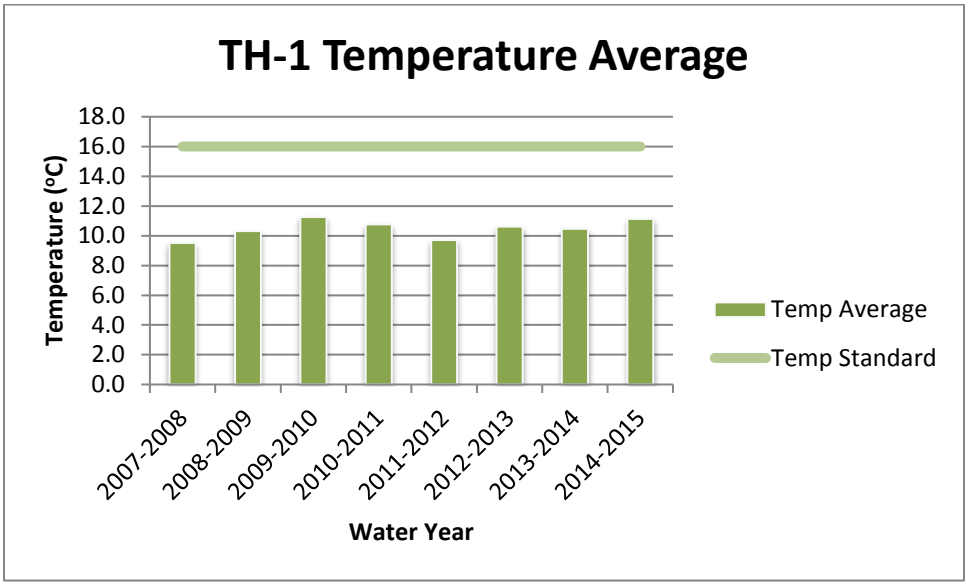

BC-3 pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High

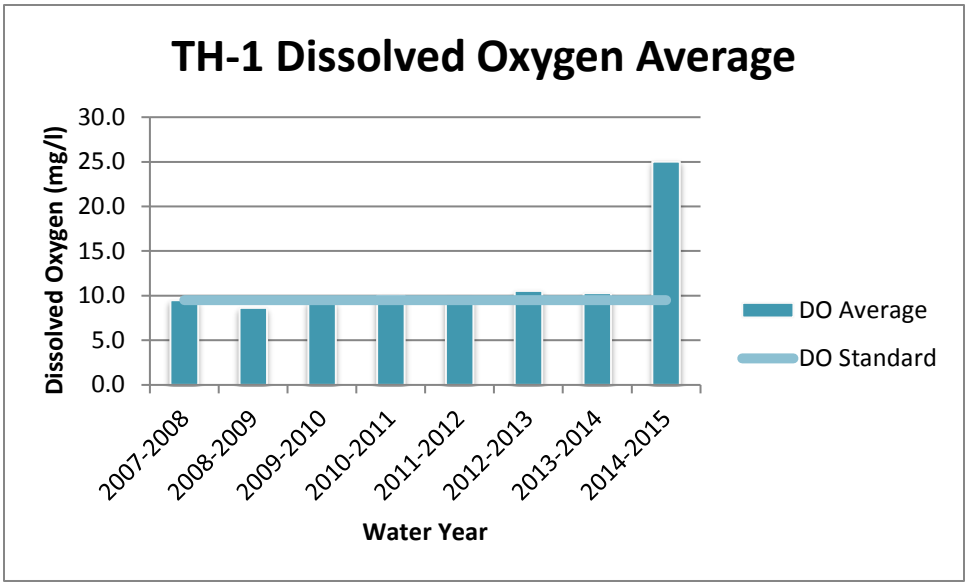

BC-3 Turbidity Average
Turbidity (NTU)
6
5
4
3
2
1
0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

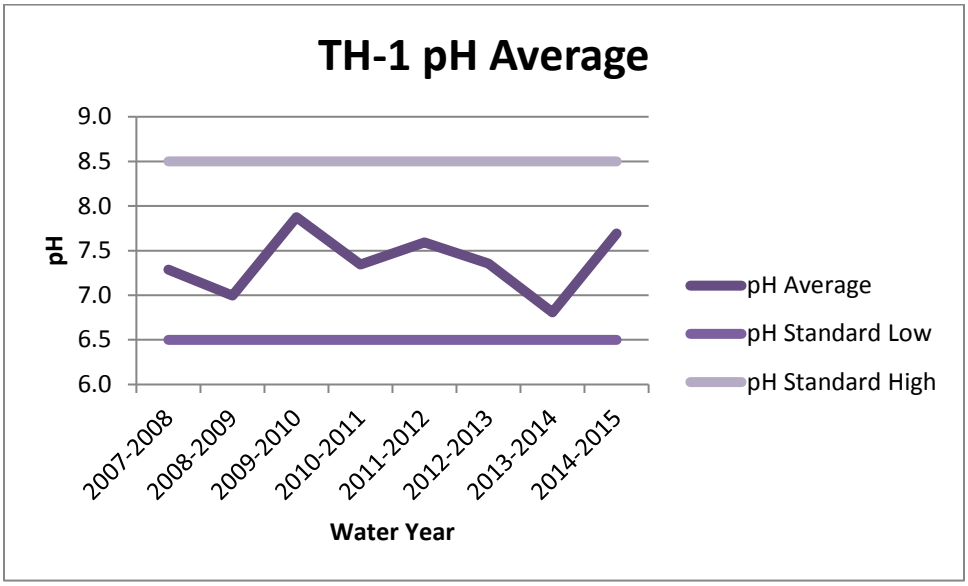

BC-3 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

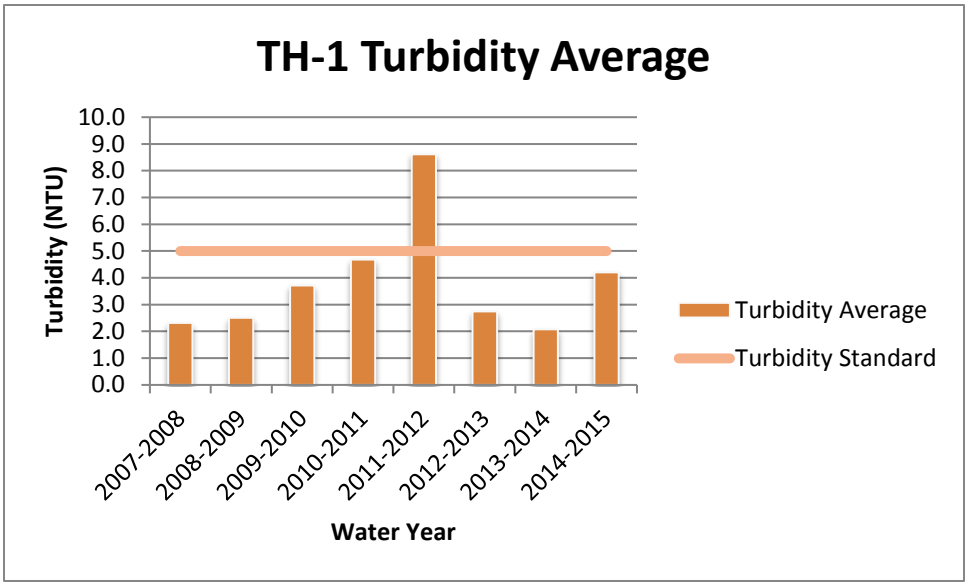
A.3 Thornton Creek (TH-1)

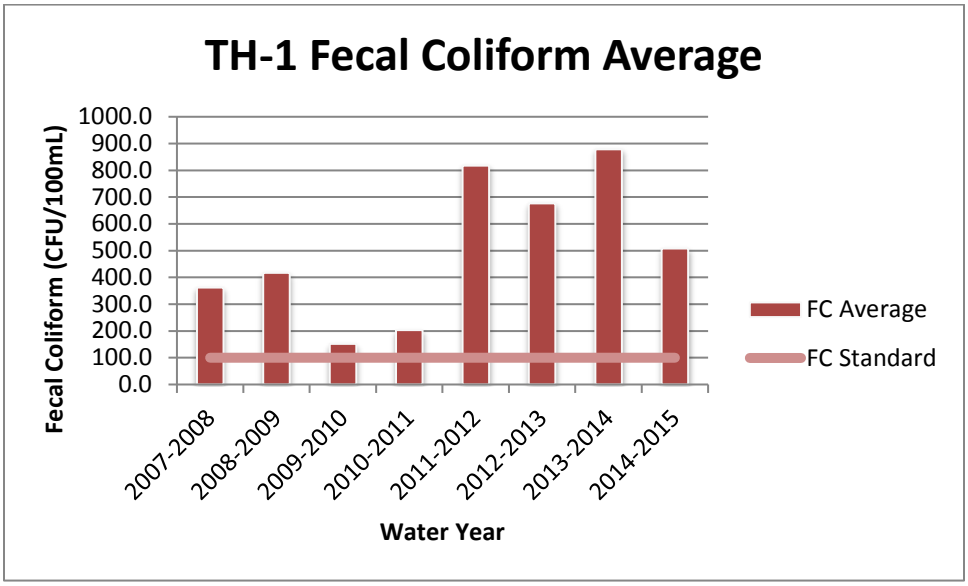
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	96.9%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	69.0%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	94.6%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.8%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	85.8%	Fair




TH-1 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

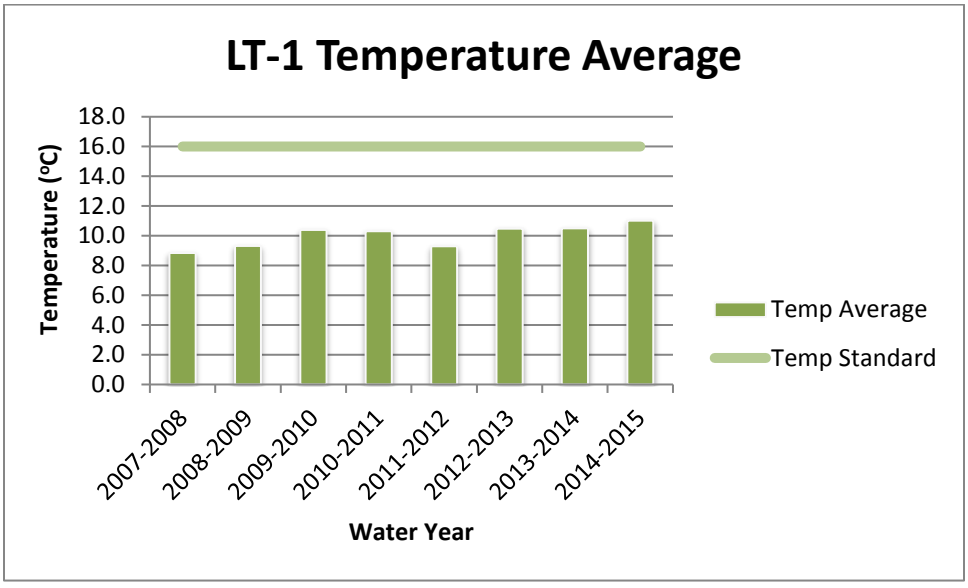

TH-1 pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High

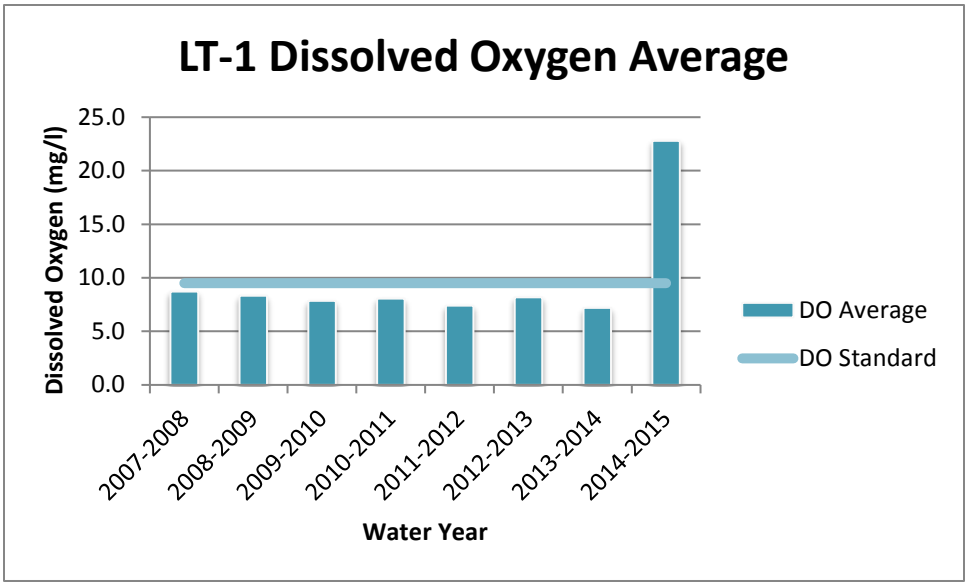

TH-1 Turbidity Average
Turbidity (NTU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

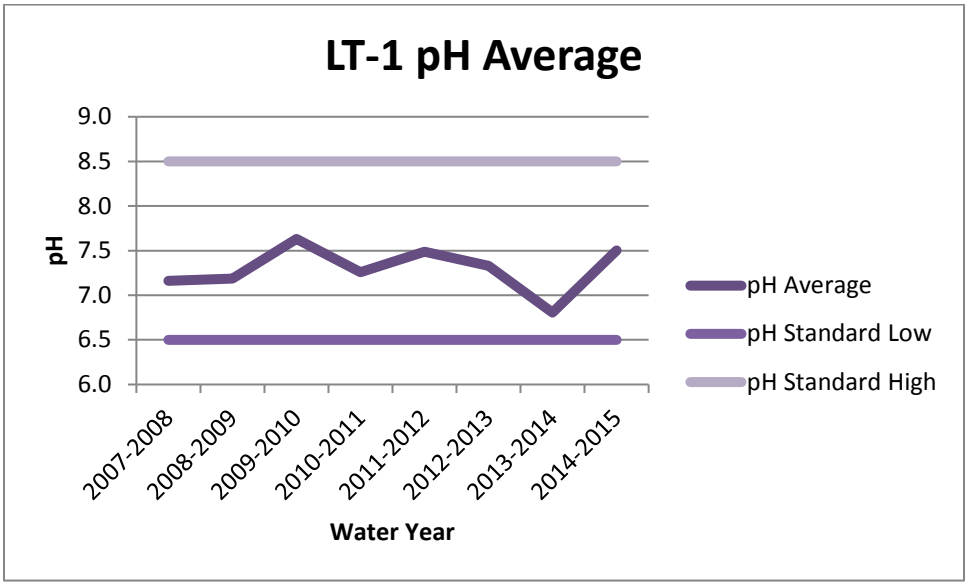

TH-1 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

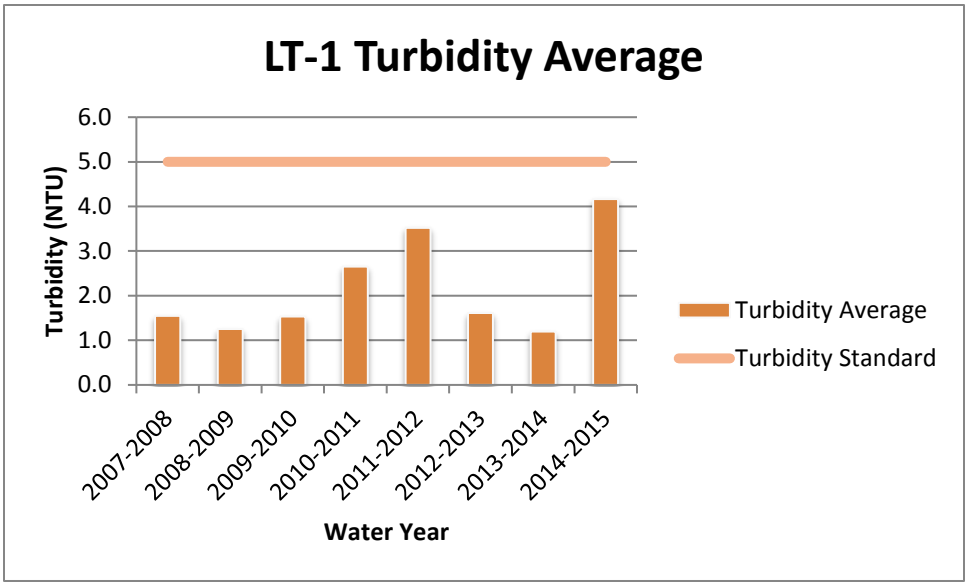
A.4 Littles Creek (LT-1)

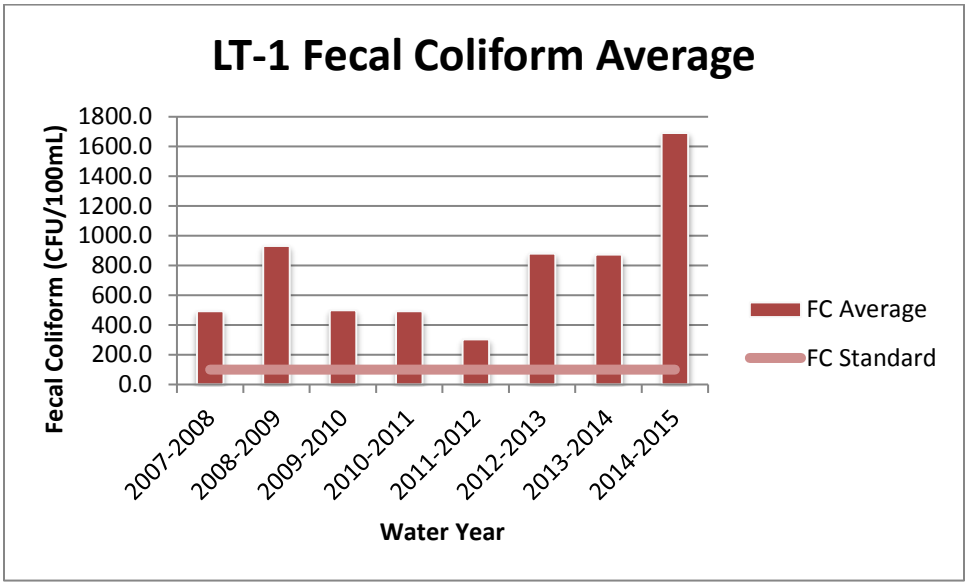
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	22.1%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	41.6%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.8%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	91.7%	Good




LT-1 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

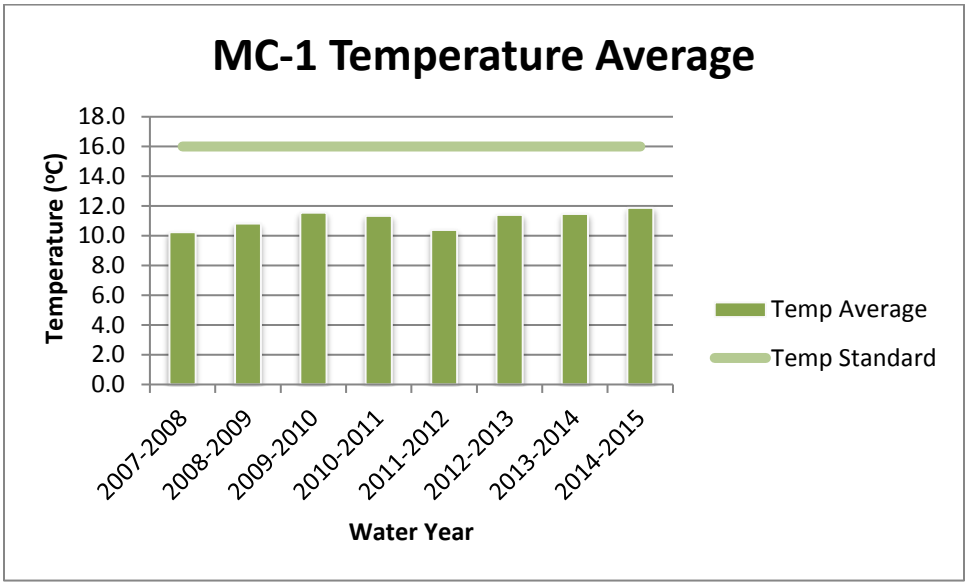

LT-1 pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High

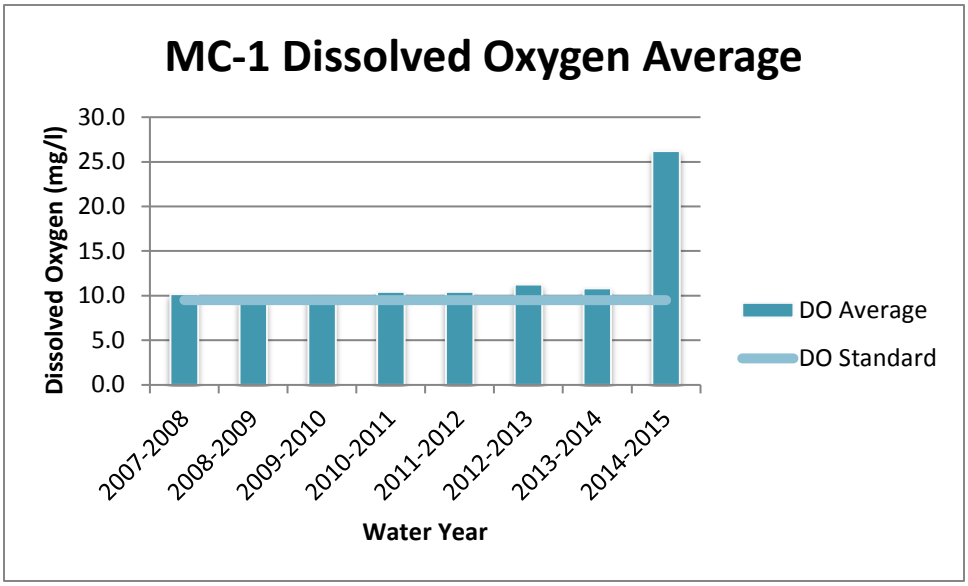

LT-1 Turbidity Average
Turbidity (NTU)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

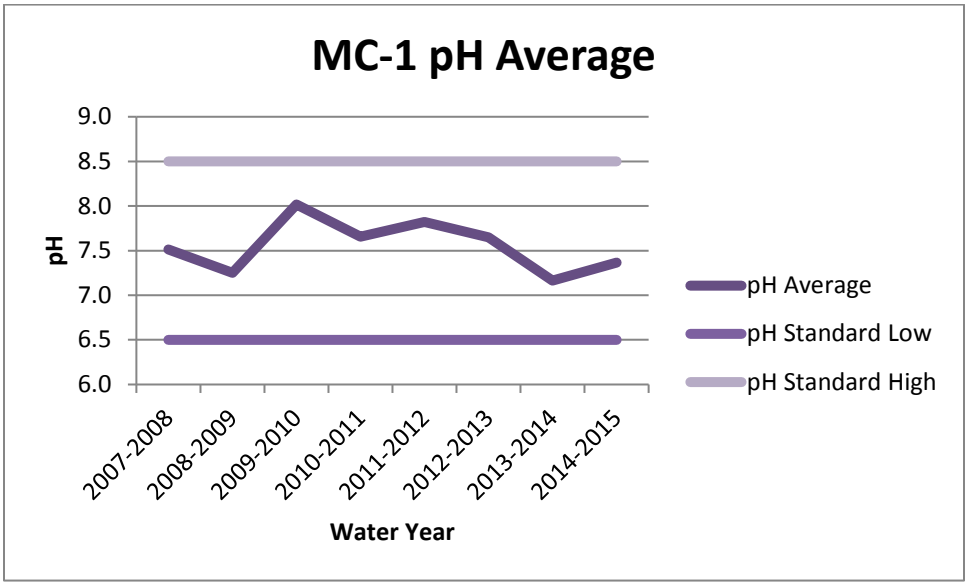

LT-1 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

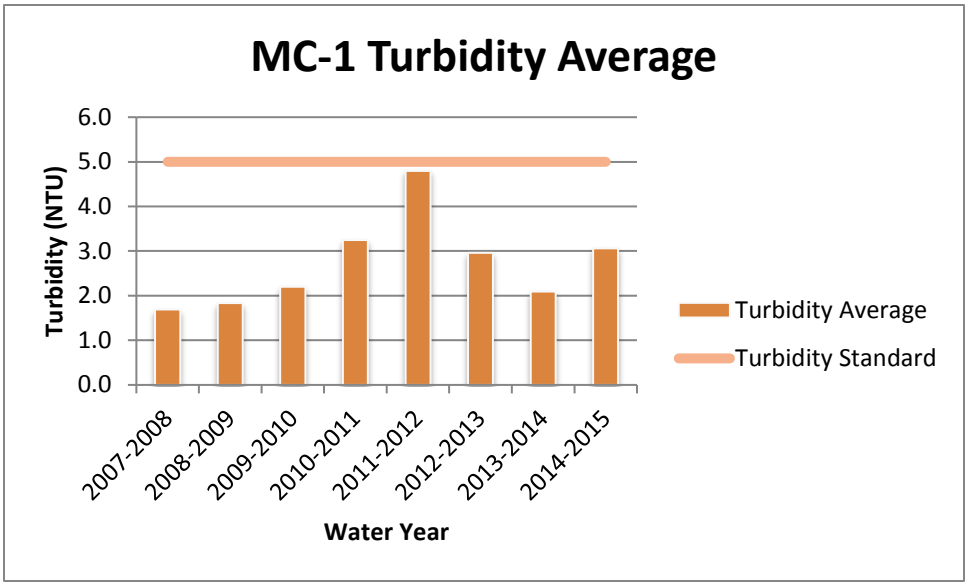
A.5 McAleer Creek (MC-1)

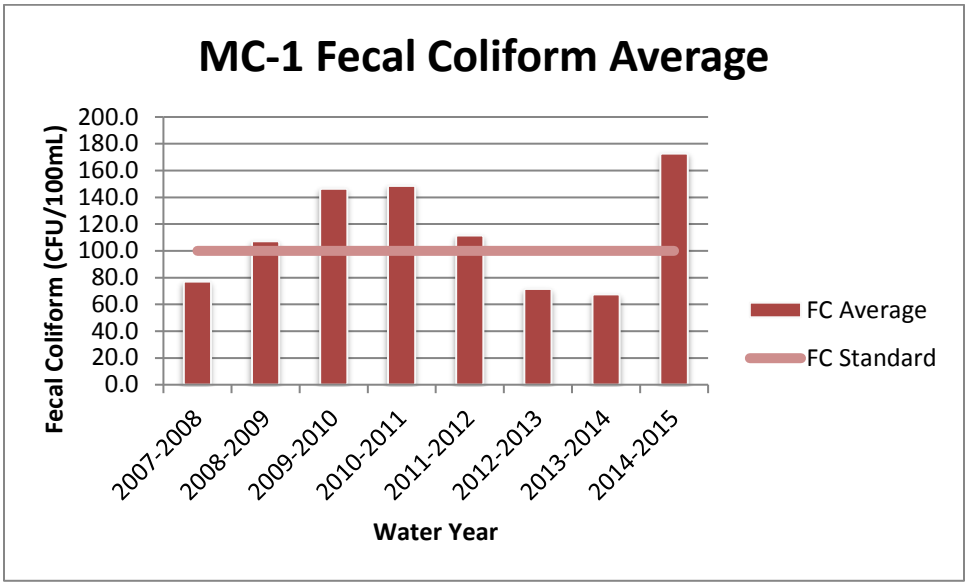
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	94.2%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	80.6%	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	97.5%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	98.6%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	91.7%	Good




MC-1 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

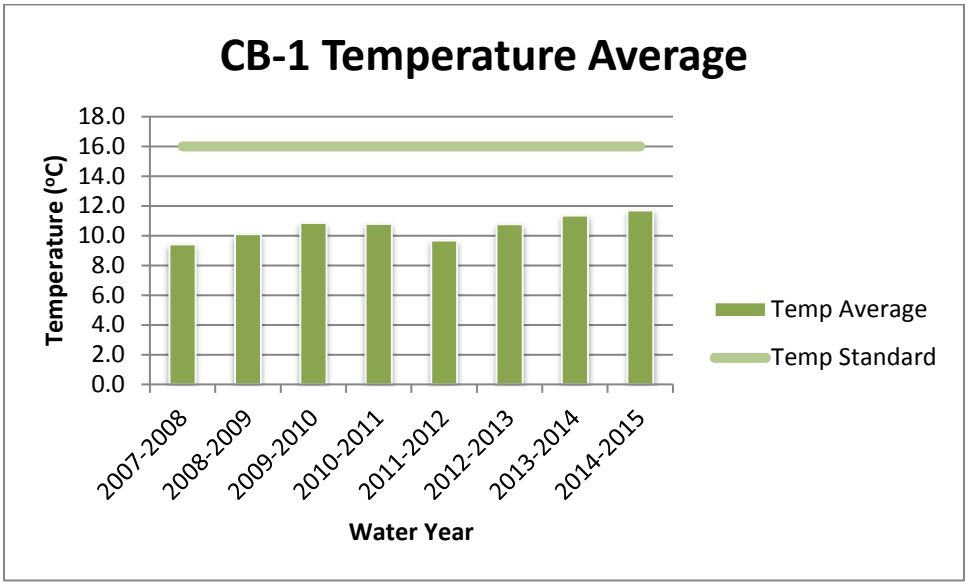

MC-1 pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High

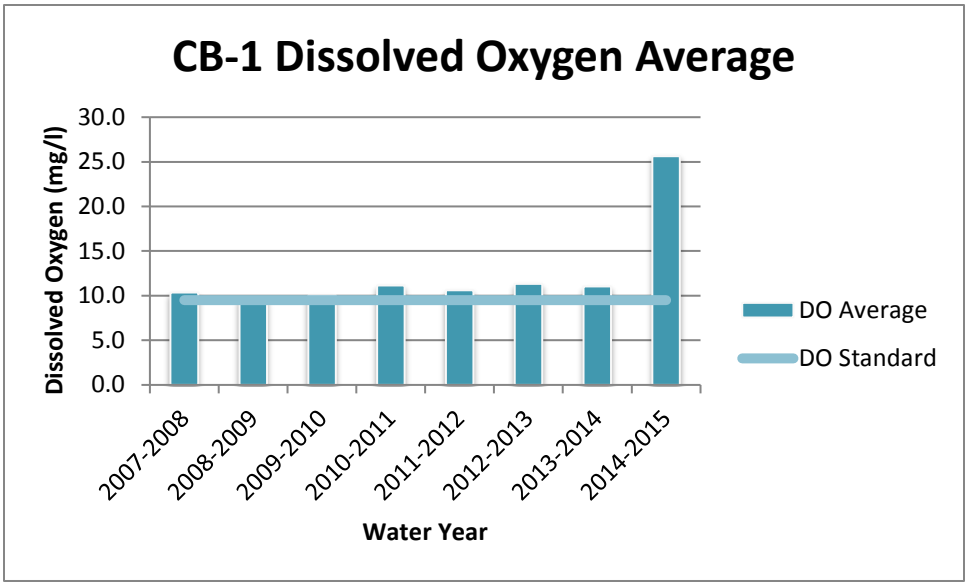

MC-1 Turbidity Average
Turbidity (NTU)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

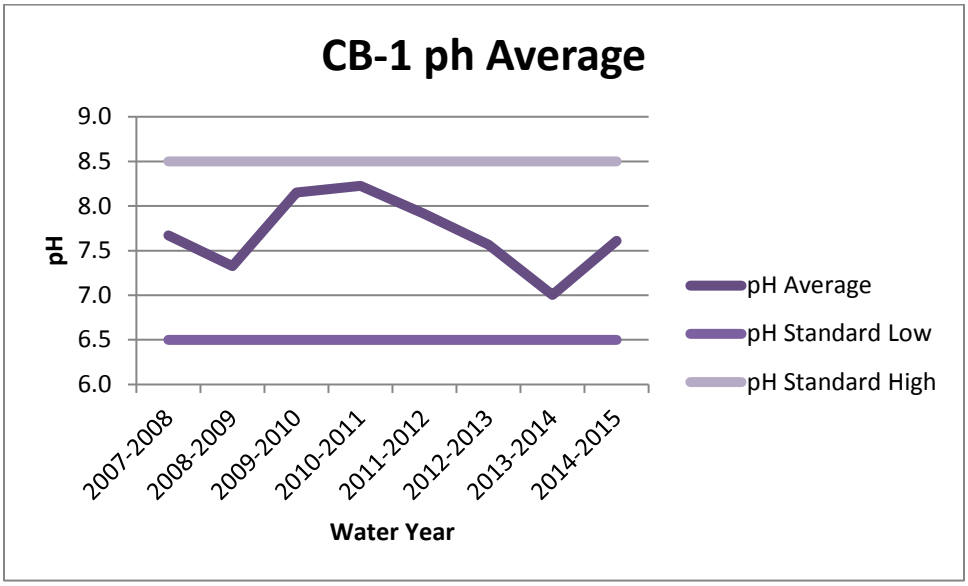

MC-1 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

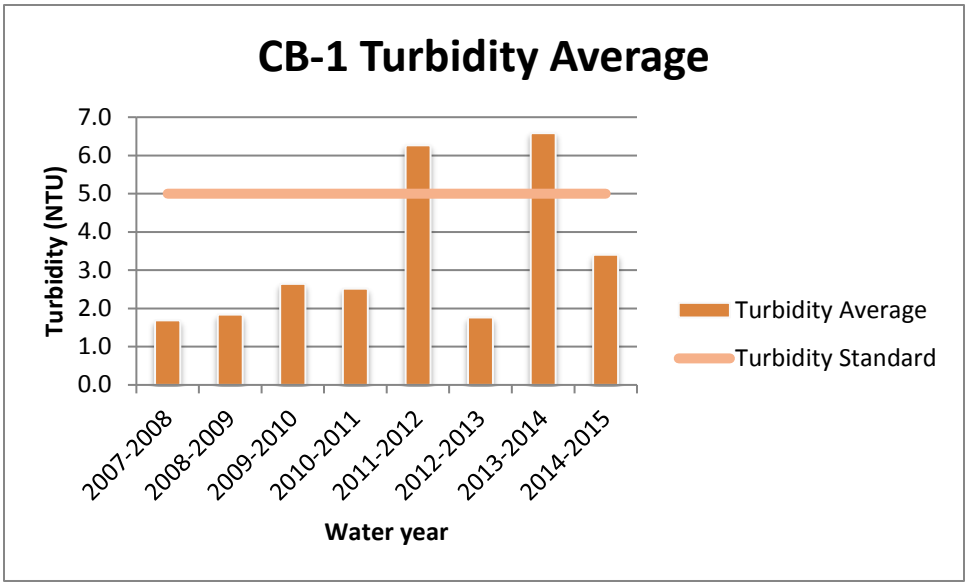
A.6 Cedarbrook Creek (CB-1)

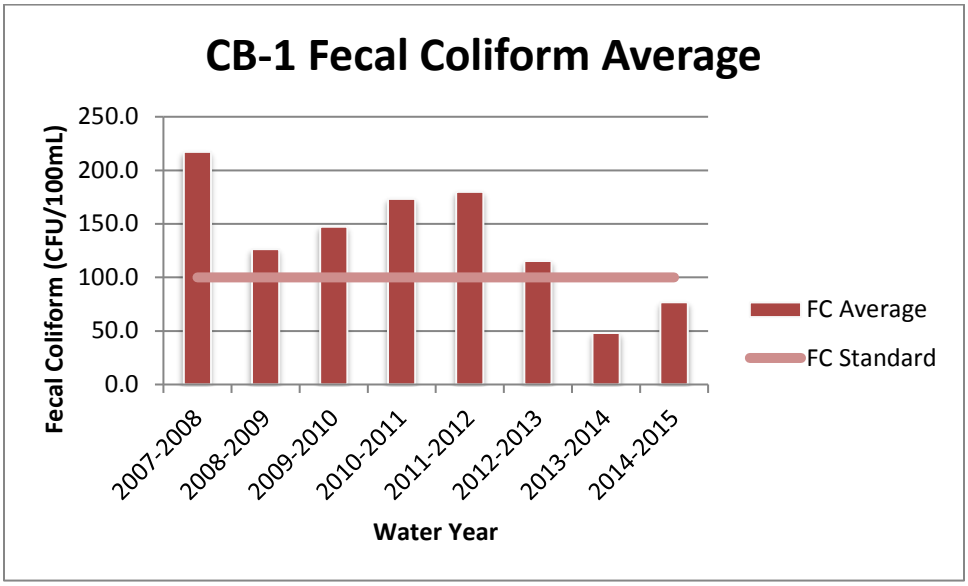
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	94.6%	Good
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	100%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	97.1%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.0%	Good




CB-1 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard

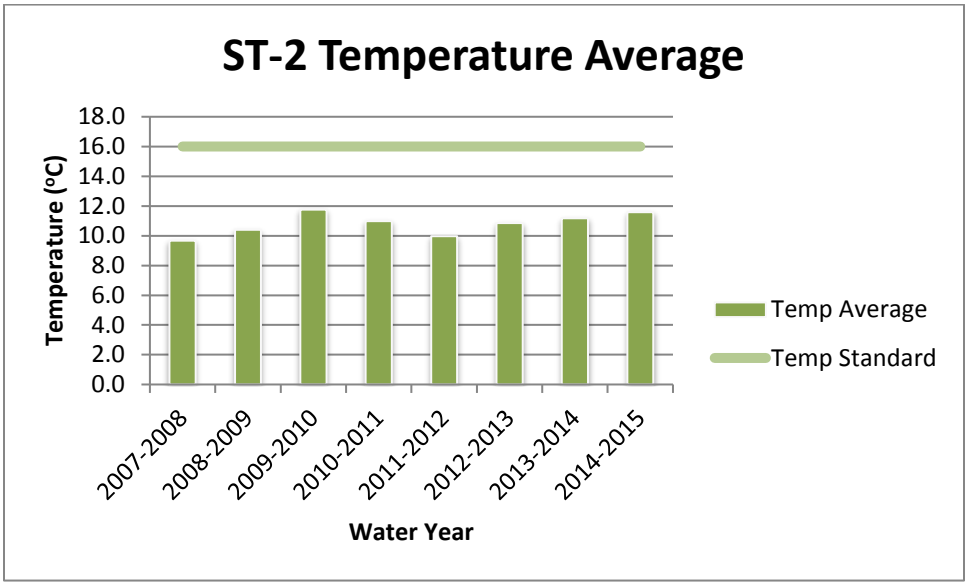

CB-1 ph Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High

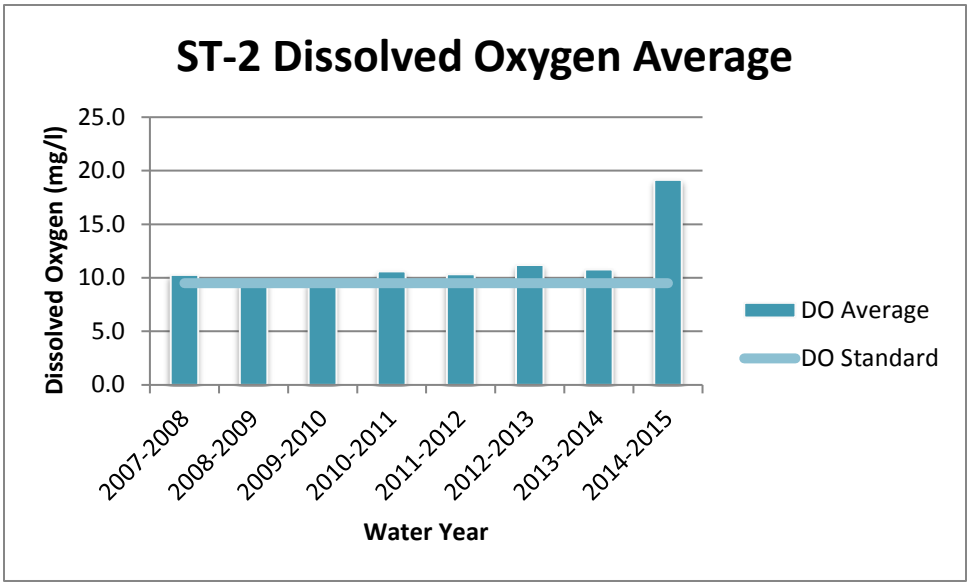

CB-1 Turbidity Average
Turbidity (NTU)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water year
Turbidity Average
Turbidity Standard

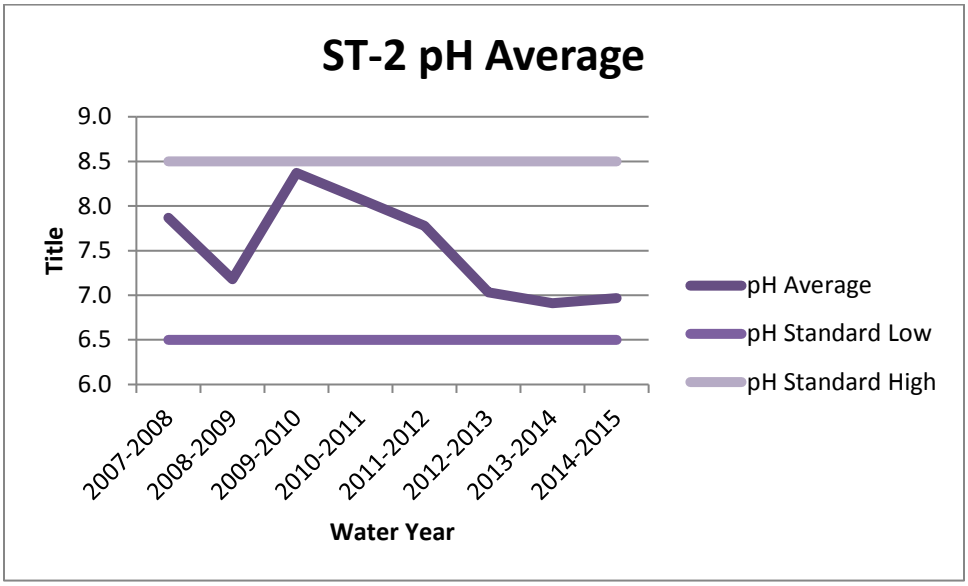

CB-1 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
250.0
200.0
150.0
100.0
50.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

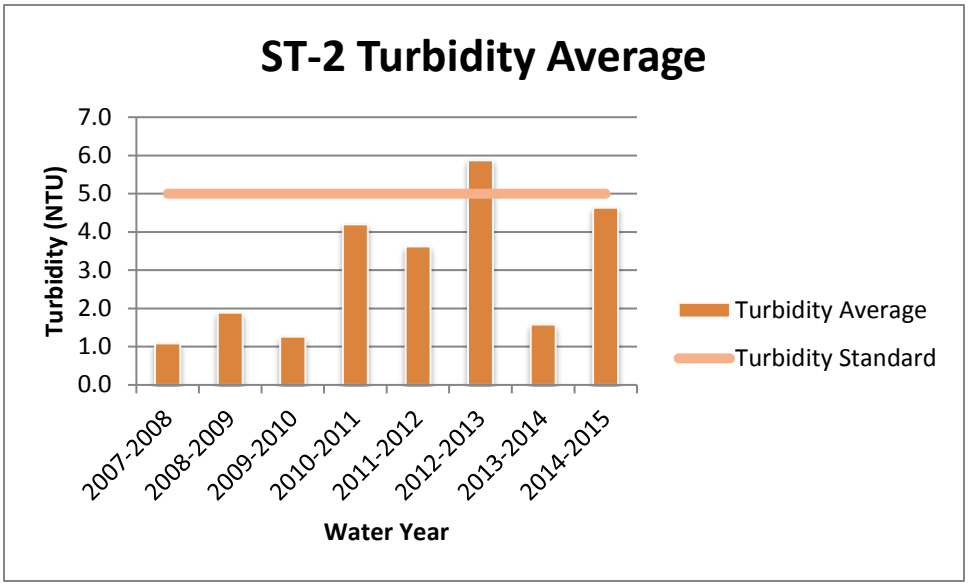
A.7 Storm Creek (ST-2)

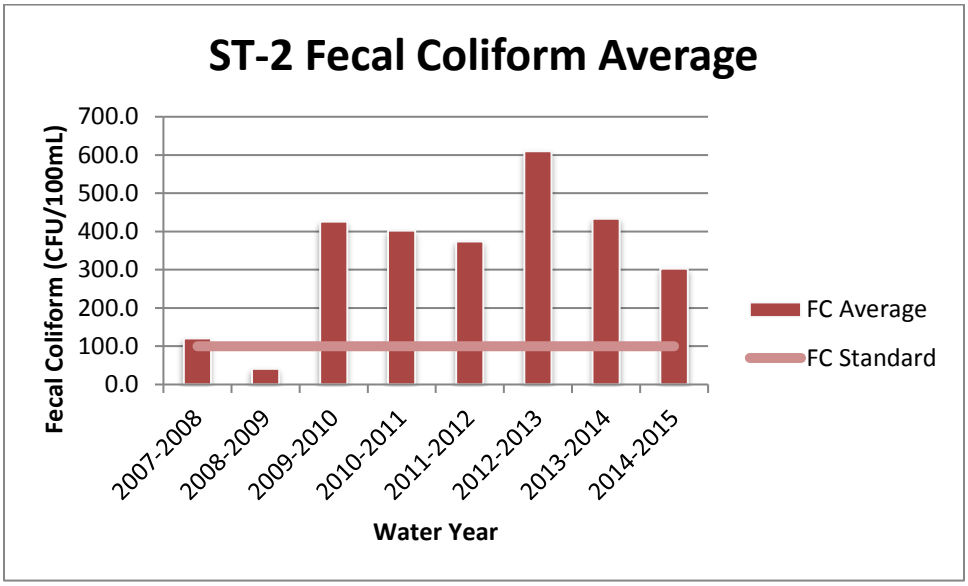
	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	85.0%	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	96.7%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	88.1%	Fair
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	87.5%	Fair




ST-2 Dissolved Oxygen Average
Dissolved Oxygen (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
DO Average
DO Standard


ST-2 pH Average
Title
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
pH Average
pH Standard Low
pH Standard High


ST-2 Turbidity Average
Turbidity (NTU)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
Turbidity Average
Turbidity Standard

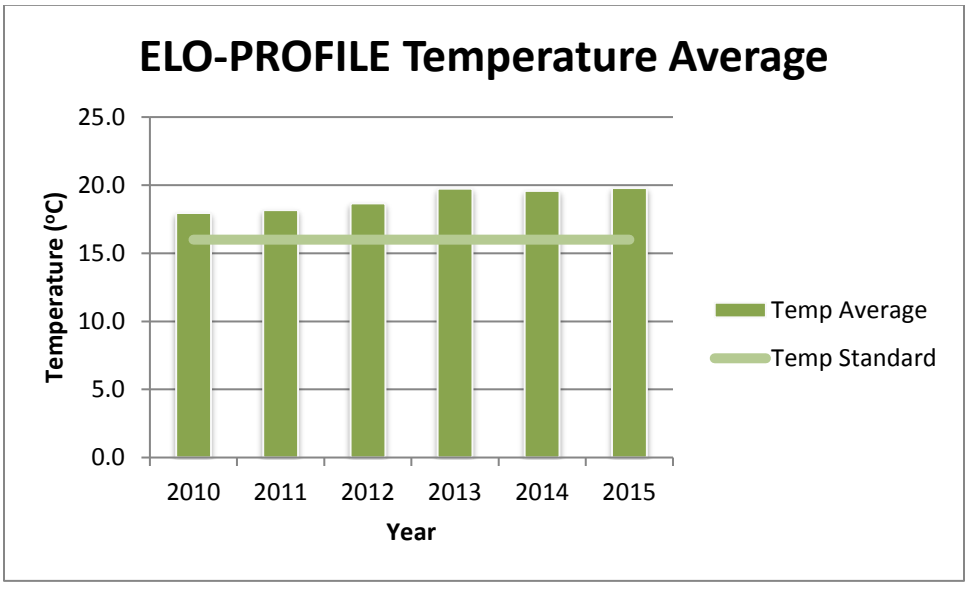

ST-2 Fecal Coliform Average
Fecal Coliform (CFU/100mL)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
Water Year
FC Average
FC Standard

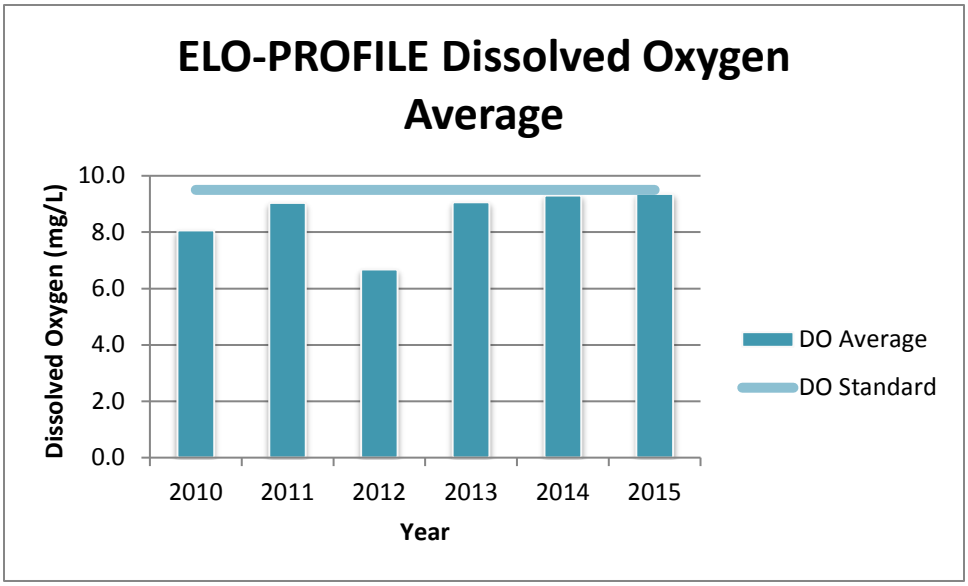
Appendix B. Lake Water Quality Data

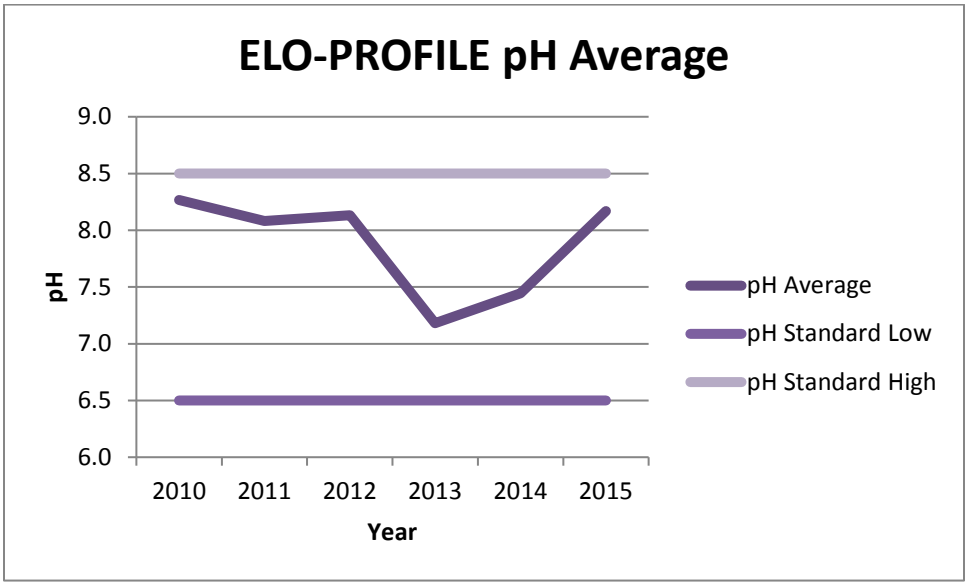
The following tables exhibit percent compliance of water quality standards for each sampling site. The graphs illustrate the annual data averages.

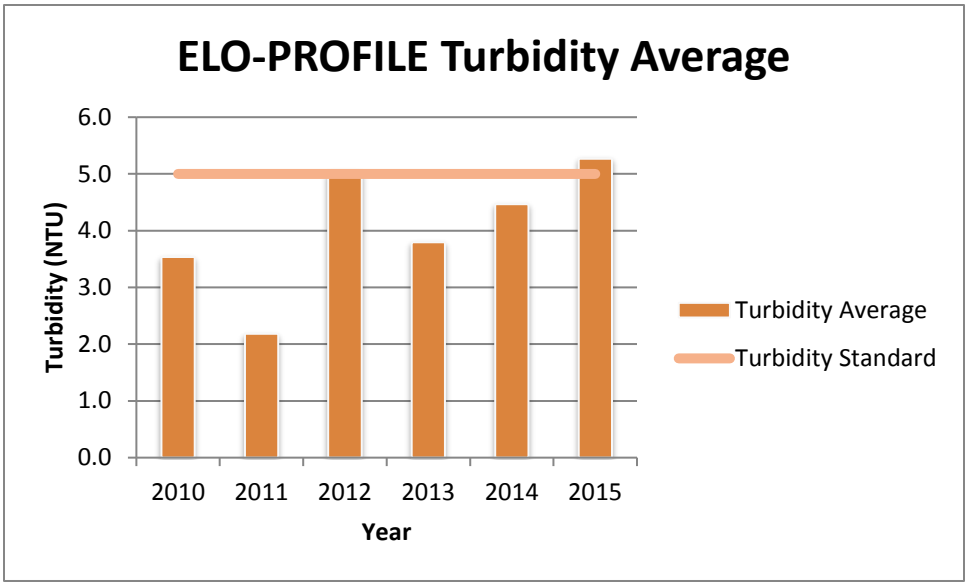
B.1 Echo Lake (ELO-PROFILE)

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	19.8%	Poor
Temperature; Salmonid Spawning, Rearing and Migration	33%	Poor
Dissolved Oxygen; Core Summer Salmonid Habitat	30.2%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	64.0%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	80.6%	Fair
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	74.7%	Poor

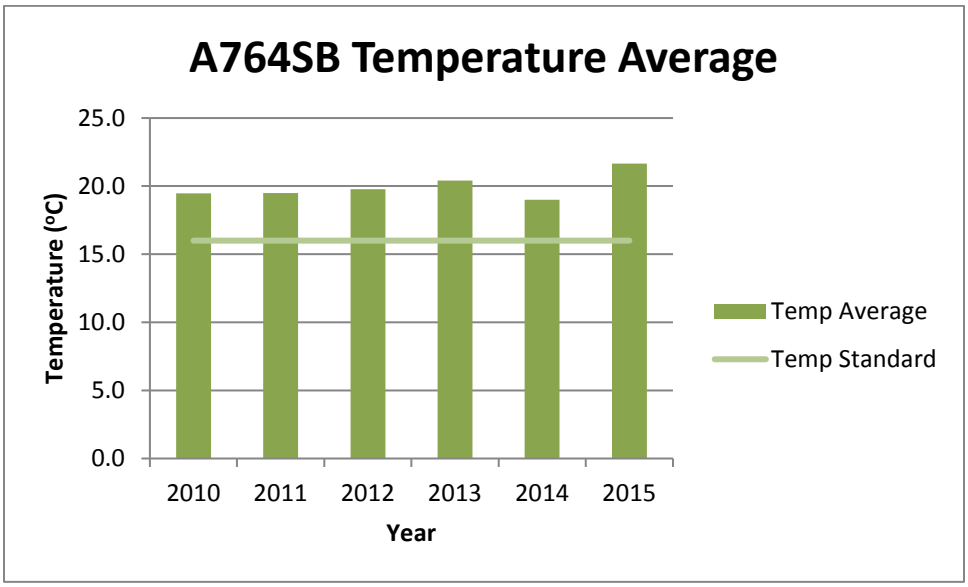


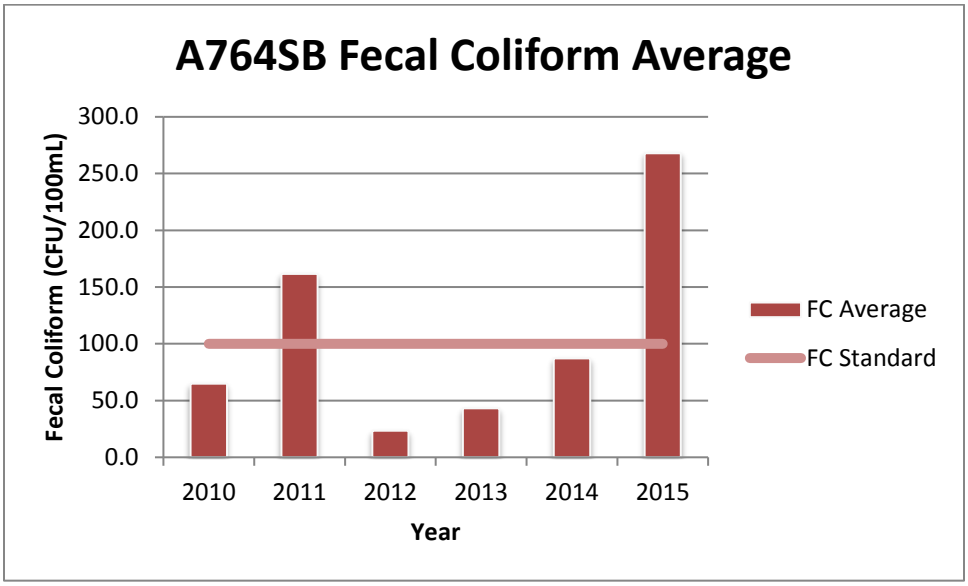

ELO-PROFILE Dissolved Oxygen Average
Dissolved Oxygen (mg/L)
10.0
8.0
6.0
4.0
2.0
0.0
2010
2011
2012
2013
2014
2015
Year
DO Average
DO Standard


ELO-PROFILE pH Average
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
2010
2011
2012
2013
2014
2015
Year
pH Average
pH Standard Low
pH Standard High

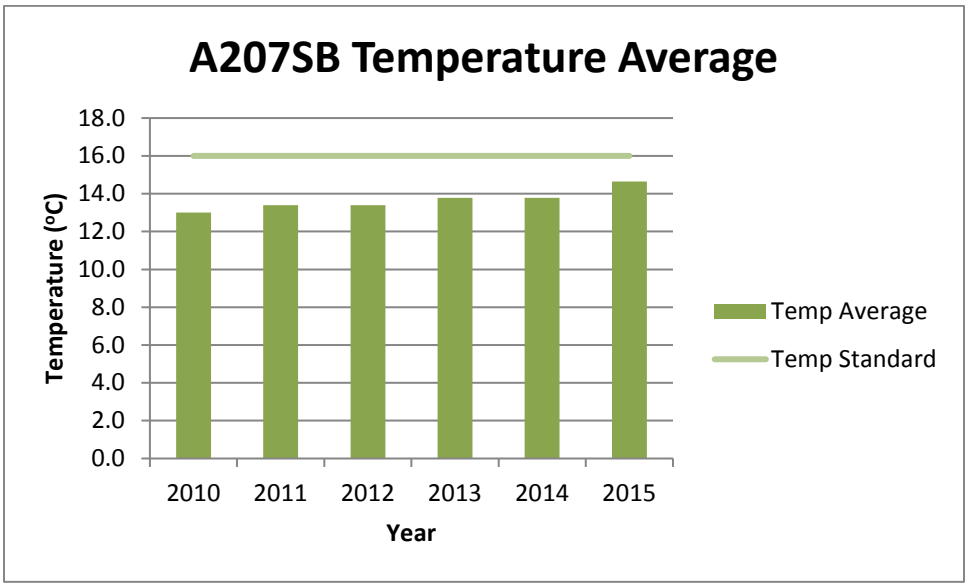

ELO-PROFILE Turbidity Average
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Turbidity (NTU)
2010
2011
2012
2013
2014
2015
Year
Turbidity Average
Turbidity Standard

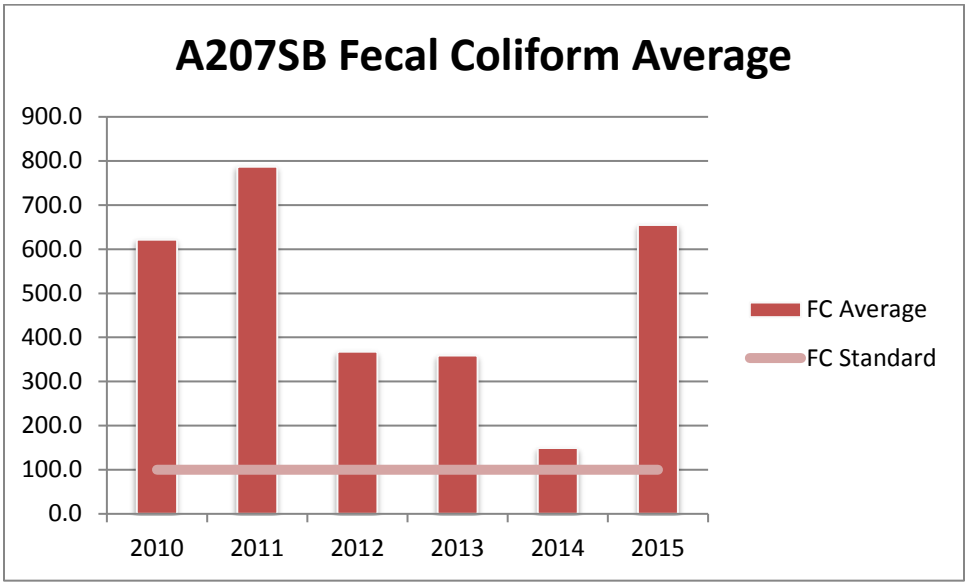
B.2 Echo Lake (A764SB)





B.3 Hidden Lake (A207SB)





Appendix C. King County Water Quality Index (WQI) Scores

Table 9 - Water Quality Index Score and Impairment Levels for Selected Streams

Sampling Station	Year	Numerical Score	WQI Impairment Level
Boeing Creek (BC-2)	2009-2010	83	Low Concern
	2010-2011	73	Moderate Concern
	2011-2012	72	Moderate Concern
	2012-2013	71	Moderate Concern
	2013-2014	83	Low Concern
	2014-2015	57	Moderate Concern
Boeing Creek (BC-3)	2009-2010	83	Low Concern
	2010-2011	80	Low Concern
	2011-2012	79	Moderate Concern
	2012-2013	75	Moderate Concern
	2013-2014	78	Moderate Concern
	2014-2015	54	Moderate Concern
Thornton Creek (TH-1)	2009-2010	38	High Concern
	2010-2011	52	Moderate Concern
	2011-2012	30	High Concern
	2012-2013	39	High Concern
	2013-2014	41	Moderate Concern
	2014-2015	32	High Concern
Littles Creek (LT-1)	2009-2010	35	High Concern
	2010-2011	29	High Concern
	2011-2012	42	Moderate Concern
	2012-2013	29	High Concern
	2013-2014	22	High Concern
	2014-2015	7	High Concern
McAleer Creek (MC-1)	2009-2010	63	Moderate Concern
	2010-2011	67	Moderate Concern
	2011-2012	71	Moderate Concern
	2012-2013	74	Moderate Concern
	2013-2014	54	Moderate Concern
	2014-2015	54	Moderate Concern
Cedarbrook Creek (CB-1)	2009-2010	68	Moderate Concern
	2010-2011	68	Moderate Concern
	2011-2012	70	Moderate Concern
	2012-2013	68	Moderate Concern
	2013-2014	66	Moderate Concern
	2014-2015	65	Moderate Concern
Storm Creek (ST-2)	2009-2010	15	High Concern
	2010-2011	24	High Concern
	2011-2012	24	High Concern
	2012-2013	36	High Concern
	2013-2014	42	Moderate Concern
	2014-2015	42	Moderate Concern

There are two reasons why the WQI score cannot be directly compared to the results of this report. First, the WQI score is an imperfect number designed to give decision makers, who are not water quality experts, general information on water quality conditions that can be a helpful guide when making water quality decisions. Second, the calculation used in the WQI matrix is based on state water quality standards, but the method for calculating the score is different than the one used in this report. However, the WQI scores can loosely be compared to the results of this report for relative water quality impairment levels. The WQI impairment levels in the selected streams indicate that these streams are moderately to severely impacted by urbanization, which is consistent with the findings of this report.

Appendix D. 2009 Stream Data

Table 10 - Aquatic Life Designated Use Support Ratings for Streams							
	Boeing Creek (BC-2)	**Boeing Creek (BC-3)**	**Thornton Creek (TH-1)**	**Littles Creek (LT-1)**	**McAleer Creek (MC-1)**	**Cedar Brook Creek (CB-1)**	**Storm Creek (ST-2)**
Temperature; Core Summer Salmonid Habitat	Good	Good	Good	Good	Good	Good	Good
Temperature; Salmonid Spawning, Rearing and Migration	Good	Good	Good	Good	Good	Good	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor	Fair	Poor	Poor	Poor	Fair	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Good	Good	Fair	Fair	Good	Good	Good
pH; Core Summer Salmonid Habitat **AND** Salmonid	Good	Good	Good	Good	Good	Good	Good
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Good	Good	Fair	Fair	Fair	Fair	Good

Table 11 - Primary Contact Recreation Designated Use Support Rating for Streams By Season		
Sampling Site	**Year**	**Designated Use Support Rating**
Boeing Creek (BC-2)	2007	Good
	2008	Good
	2009	Good
Boeing Creek (BC-3)	2007	Good
	2008	Good
	2009	Good
Thornton Creek (TH-1)	2007	Poor
	2008	Poor
	2009	Poor
Littles Creek (LT-1)	2007	Poor
	2008	Poor
	2009	Poor
McAleer Creek (MC-1)	2007	Poor
	2008	Good
	2009	Fair
Cedarbrook (CB-1)	2007	Fair
	2008	Poor
	2009	Fair
Storm Creek (ST-2)	2007	Poor
	2008	Fair
	2009	Fair

Table 12 - Primary Contact Recreation Designated Use Support Rating for Streams By Geometric Mean	
Sampling Site	**Designated Use Support Rating**
Boeing Creek (BC-2)	Good
Boeing Creek (BC-3)	Good
Thornton Creek (TH-1)	Poor
Littles Creek (LT-1)	Poor
McAleer Creek (MC-1)	Good
Cedarbrook (CB-1)	Poor
Storm Creek (ST-2)	Poor

Appendix E. 2009 Lake Data

Table 13 - Aquatic Life Designated Use Support Ratings for Lakes		
	Echo Lake (ELO-1)	**Hidden Lake (HLO-1)**
Temperature; Core Summer Salmonid Habitat	Poor	Good
Temperature; Salmonid Spawning, Rearing and Migration	Poor	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Poor	Good
pH; Core Summer Salmonid Habitat **AND** Salmonid	Fair	Good
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Fair	Fair

Table 14 - Primary Contact Recreation Designated Use Support Rating for Lakes By Season		
Sampling Site	**Year**	**Designated Use Support Rating**
Echo Lake (ELO-1)	2004	Fair
	2005	Good
	2006	Fair
	2007	Good
	2008	Good
	2009	Good
Hidden Lake (HLO-1)	2004	Poor
	2005	Good
	2006	Fair
	2007	Poor
	2008	Fair
	2009	Fair

Table 15 - Primary Contact Recreation Designated Use Support Rating for Lakes By Geometric Mean	
Sampling Site	**Designated Use Support Rating**
Echo Lake (ELO-1)	Good
Hidden Lake (HLO-1)	Poor