2020 FRESHWATER ASSESSMENT REPORT:

State of Water Quality in Shoreline Streams and Lakes

Prepared for: City of Shoreline

Project No. 200383 • May 3, 2024 FINAL

Aspect
A Geosyntec Company

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Aspect Consulting

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Executive Summary

The City of Shoreline's (City) Surface Water Utility within the Public Works Department routinely monitors the quality of stream systems and surface waters within the City (see Figure ES-1). This report summarizes the results of water quality data collected between the 2001 and 2020 water years[1] (no data gathered after September 30, 2020 was included in this report) and compares them to the results of the 2009 Freshwater Assessment Report, referred to as the 2009 report (Shoreline 2010) and the 2016 Freshwater Assessment Report, referred to as the 2016 report (Shoreline 2017).

This Report adheres to the Vision 2029 Plan[2] adopted in 2009 by the City, in particular the following "Framework Goal" (FG) in that plan:

- FG 2: Provide high quality public services, utilities, and infrastructure that accommodate anticipated levels of growth, protect public health and safety, and enhance the quality of life.
- FG 7: Conserve and protect our environment and natural resources, and encourage restoration, environmental education and stewardship.
- FG 8: Apply innovative and environmentally sensitive development practices.

Purpose

The City of Shoreline became the first city in Washington to achieve Salmon-Safe Certification in 2019.[3] This aligns with goals sated in the City's Vision 2029 that state that the City is committed to conserving and protecting environmental and natural resources and also encourages restoration, environmental education and stewardship.

The findings of this report will help to:

- Document the current conditions of the surface water streams and lakes within the City.
- Analyze water quality trends from 2001 (where available) through 2020 to determine if water quality is improving or degrading within the City's streams and lakes.
- Identify potential problem areas to prioritize restoration actions and inform future surface water planning.
- Foster a broader awareness within the community of the current conditions of the City's streams and lakes.

[1] Water years begin from October of the previous year to September of the current year.
[2] https://www.shorelinewa.gov/government/departments/planning-community-development/long-range-planning/vision-2029
[3] https://www.shorelinewa.gov/our-city/salmon-safe

City of Shoreline Water Quality Standards

This report compares the current conditions of water quality in the City relative to the water quality standards under the Surface Waters of the State of Washington (Chapter 173-201A WAC), as updated by the Washington State Department of Ecology (Ecology) on December 30, 2019, for fresh water supporting *Core Summer Salmonid Habitat, Salmonid Spawning, Rearing, and Migration, and Primary Contact Recreation.*

The five City water quality parameters identified in Ecology's water quality 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.
- **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.
- **Turbidity –** High turbidity indicates that there is a greater amount of solids in the water than normal. Suspended solids and fine 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.

Future water quality reports can be compared to the conditions documented in this report to assess policy or program effectiveness with regards to improving water quality.

City of Shoreline Water Resources

In general there are three categories of water resources in the City that are monitored for water quality: The City's major surface water features are designated for Primary Contact Recreation (the designated categories are defined in the 173-201A WAC as updated December 30, 2019). Shoreline's water quality monitoring program collects data from:

Creeks

There are six primary City creeks that have been monitored for water quality parameters.

- Boeing Creek

- Thornton Creek
- Littles Creek
- McAleer Creek
- Cedarbrook Creek
- Storm Creek

Lakes

The City and King County have monitored water quality in:

- Echo Lake
- Hidden Lake

Wetlands

There are several identified and unidentified wetlands within the City of Shoreline limits which vary significantly in size. Most of the data collected from these sites were collected prior to 2010. Wetlands where previous monitoring was located include:

- Meridian Park Wetland
- Ronald Bog
- Twin Ponds

2001-2020 Water Quality Results: Creeks

Streams within the City were rated "good" for temperature and turbidity for both *Core Summer Salmonid Habitat* and *Salmonid Spawning, Rearing and Migration Aquatic Life Designated Use* categories. Every creek but Storm Creek also rated "good" for pH. Several creeks rated "poor" for dissolved oxygen, particularly for *Core Summer Salmonid Habitat*. Overall, Aquatic Life ratings since the 2016 report (Shoreline 2017) remained steady with little improvement or decline.

For the Primary Contact Recreation Designated Use category, the Boeing Creek sites rated mostly "good" with some "fair" ratings as well. Thornton Creek, Littles Creek, and Storm Creek rated mostly "poor" since 2008. Cedarbrook Creek and McAleer Creek sampling sites both rated "poor" in roughly half the years since 2008 but also mix in "good" and "fair" ratings.

Data since 2008 show Ecology's water quality index rated Boeing Creek (both sites) as little to moderate concern. Cedarbrook Creek and McAleer Creek have consistently rated as moderate concern since data collection began. Storm Creek and Thornton Creek have both rated moderate to high concern and Littles Creek consistently rated as high concern. Overall, fecal coliform and dissolved oxygen were the main drivers for high concern, and temperature and nutrients also contributed to moderate concern ratings in multiple creeks.

The trend analysis showed very little change in in ratings for Shoreline's streams. Streams that were rated "poor" or "high concern" when data collection began have not improved and streams in "moderate" or "low concern" categories have not degraded

significantly nor improved. Fecal coliform and dissolved oxygen levels are the most widespread concerns within the City's streams.

2001-2020 Water Quality Results: Lakes

In most Aquatic Life water quality categories, Echo Lake rated as "poor" since 2016, particularly for temperature, pH, and dissolved oxygen levels. Turbidity was rated "fair". The findings since 2016 are generally in line with the ratings from prior reports and even dating back to 1931 where dissolved oxygen and temperature data would have warranted a "poor" rating although the overall compliance percentages were higher.

In the Primary Contact Recreation Designated Use category, Echo Lake rated "poor" or "fair" from 2014 through 2020 with a single "good" rating in 2017. More recently in 2014 and 2015, Echo Lake received "poor" ratings. Hidden Lake rated "poor" most years since the beginning of sampling with the exception of 2017 when it rated "good".

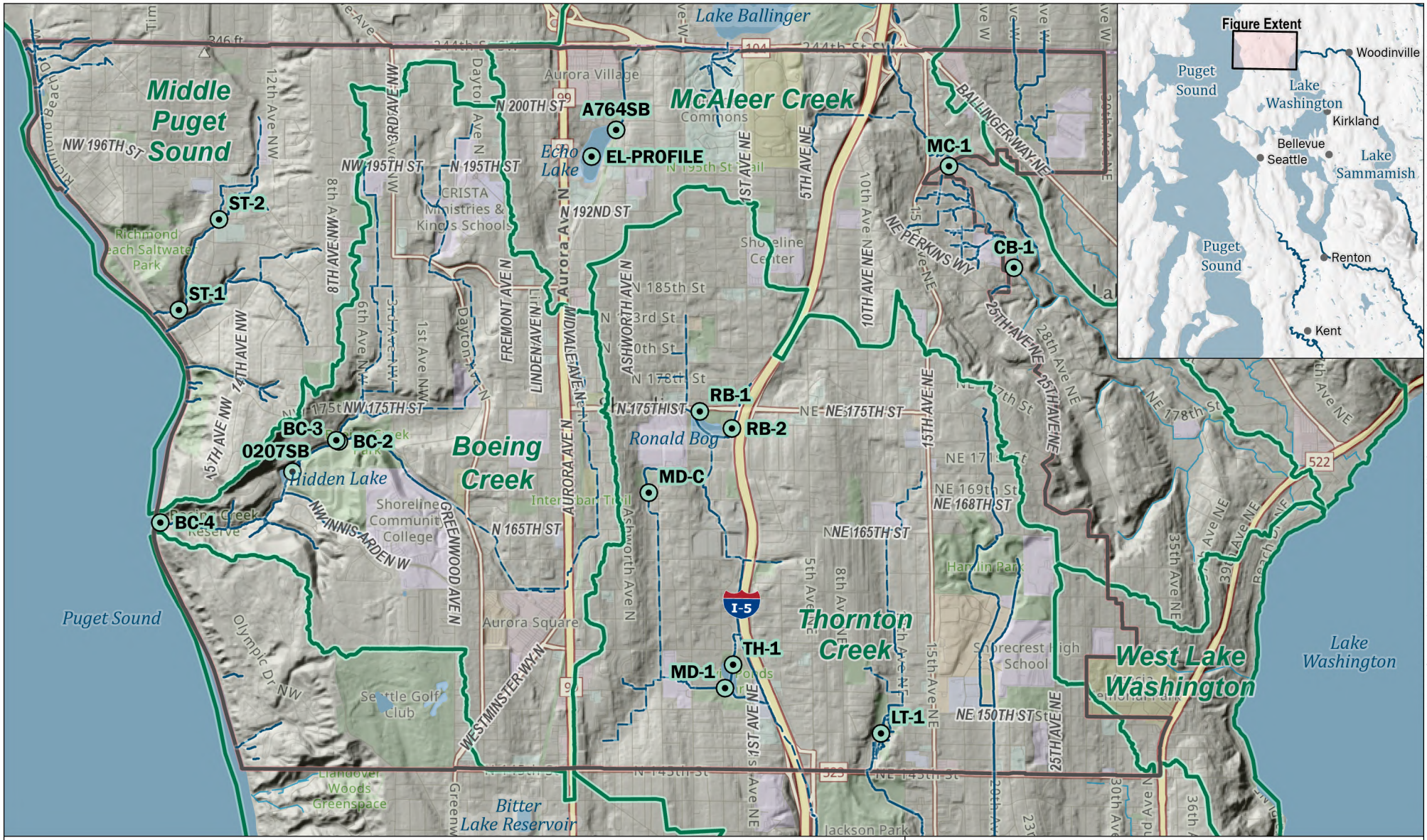
The monitoring results of the chemical and physical parameters in the lakes indicate that the lakes are moderately to severely impacted by stormwater.

2001-2020 Water Quality Results: Wetlands

The City has not monitored any wetlands since 2013, when monitoring ceased at Ronald Bog and Meridian Park wetlands. In general, the wetland stations rated poor for dissolved oxygen and temperature at sites that maintained water year-round. pH and turbidity were also rated "poor" to "fair".

Recommendations:

1. Increase water quality testing requirements to comply with Salmon Safe Condition 7. At minimum:
    a. Add heavy metals and dissolved metals to current WQI program,
    b. Increase sampling frequency to capture up to six wet weather events.
    c. Resume benthic invertebrate sampling and begin riparian vegetation sampling in selected City streams – at least in Boeing Creek to monitor restoration of channel post Hidden Lake dam removal.
    d. Prepare a Sampling and Analysis Plan (SAP) for water quality monitoring. The SAP should describe the water quality program study design, methods and analytes, and be developed for the 2024 Surface Water Master Plan update.



- Water Quality Sample Site
- Basin
- Open Water Course
- Piped Water Course
- Waterbody
- City Limit

N

0 3,000 6,000 Feet

1:36,000
(1 inch equals 3,000 feet)

Shoreline Drainage Basins and Monitoring Stations

2021 Shoreline Surface Water Quality Report
City of Shoreline, Washington

Aspect CONSULTING	MAY-2024	BY: BB / EAC	FIGURE NO. ES-1
	PROJECT NO. 200383-a-001-1A	REVISED BY: ---/---	

Data source credits: None || Basemap Service Layer Credits: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community, City of Shoreline, King County, WA State Parks GIS, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS, Esri, HERE, Garmin, USGS, EPA, NPS

1 Introduction

The City of Shoreline's (City) Surface Water Utility within the Public Works Department routinely monitors the quality of stream systems and surface waters within the City. This report summarizes the results of water quality data collected between the 2001 and 2020 water years[4] and compares them to the results of the 2009 Freshwater Assessment Report, referred to as the 2009 report (Shoreline 2010) and the 2016 Freshwater Assessment Report, referred to as the 2016 report (Shoreline 2017).

1.1 Purpose

The City of Shoreline became the first city in Washington to achieve Salmon-Safe Certification in 2019.[5] This aligns with goals sated in the City's Vision 2029 that state that the City is committed to conserving and protecting environmental and natural resources and also encourages restoration, environmental education and stewardship.

The findings of this report will help to:

- Document the current conditions of the surface water streams and lakes within the City.
- Analyze water quality trends from 2001 (where available) through 2020 to determine if water quality is improving or degrading within the City's streams and lakes.
- Identify potential problem areas to prioritize restoration actions and inform future surface water planning.
- Foster a broader awareness within the community of the current conditions of the City's streams and lakes.

1.2 City of Shoreline Water Quality Standards

This report compares the current conditions of water quality in the City relative to the water quality standards under the Surface Waters of the State of Washington (Chapter 173-201A WAC), as updated by the Washington State Department of Ecology (Ecology) on December 29, 2019, for fresh water supporting *Core Summer Salmonid Habitat, Salmonid Spawning, Rearing, and Migration, and Primary Contact Recreation.*

The five freshwater quality parameters identified in Ecology's water quality standards that the City has typically monitored historically are:

- **Temperature** - Fish and aquatic organisms must live in an environment that is within a certain temperature range. Specifically, temperatures that are above the

[4] Water years begin from October of the previous year to September of the current year.
[5] https://www.shorelinewa.gov/our-city/salmon-safe

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.

Future water quality reports can be compared to the conditions documented in this report to assess policy or program effectiveness with regards to improving water quality.

2 Geographic Area and History of Development

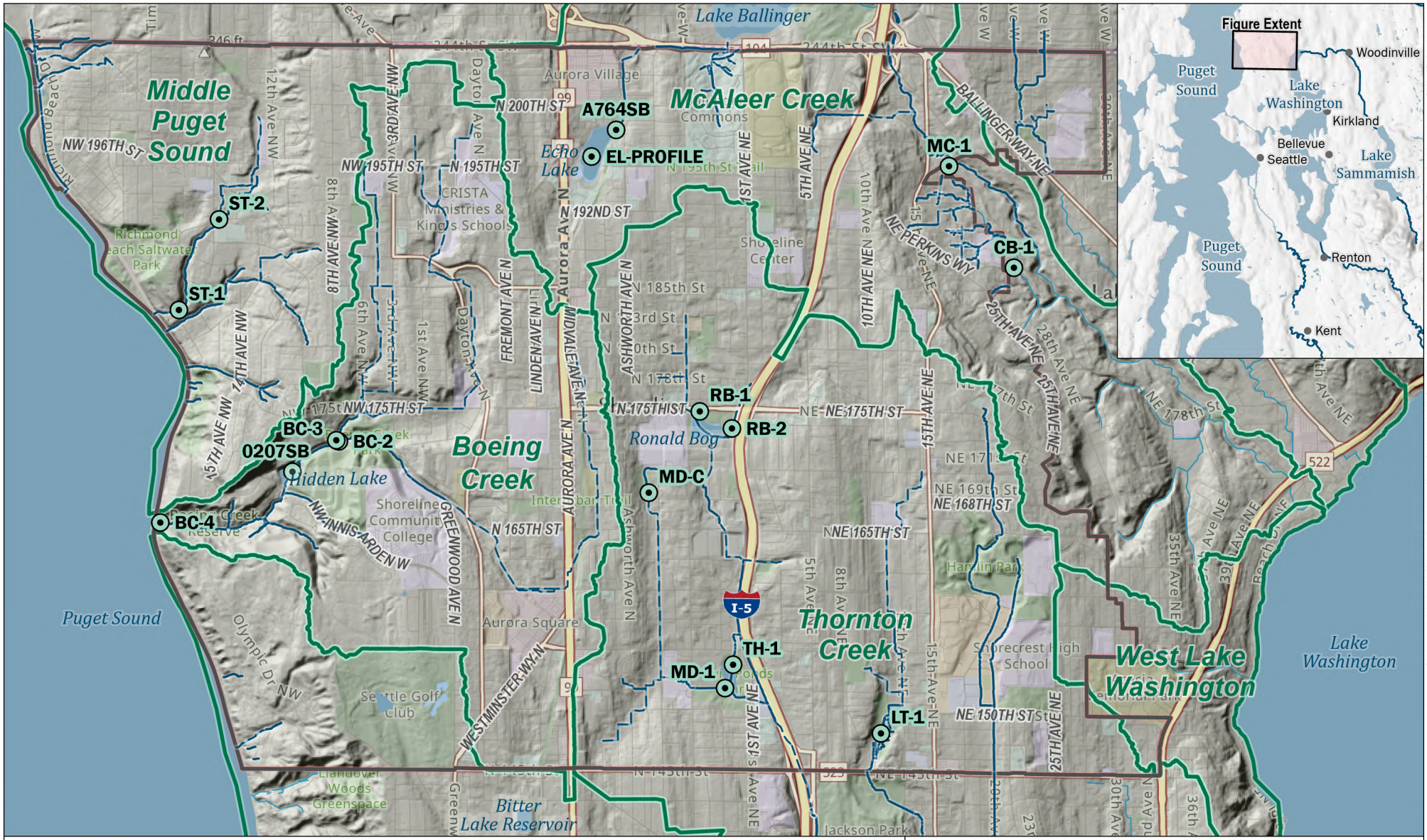
The City of Shoreline is located in the northwestern corner of King County. Shoreline is generally bounded by the City of Lake Forest Park to the east, the City of Seattle to the south, Puget Sound to the west, and Snohomish County to the north (including the cities of Mountlake Terrace, Edmonds, and 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 multiple small lakes and ponds including Echo Lake, Hidden Lake, Ronald Bog, and Twin Ponds[6]. 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, Thornton Creek, and McAleer Creek (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 very little undeveloped buildable land remaining.

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 certain primary arterials, such as N 175th Street at 15th Avenue NE, N 185th Street at 8th Avenue NW, and Ballinger Way NE at 15th Avenue NE. There is limited light industrial development within City limits.

Currently, development within the City is primarily higher-density residential or mixed use and focused near light rail stations under construction at two locations near Interstate 5 (at NE 148th Street and NE 185th Street). 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.

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



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Shoreline Drainage Basins and Monitoring Stations

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Aspect CONSULTING	MAY-2024	BY: BB / EAC	FIGURE NO. 1
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3 Description of City of Shoreline Water Resources

This section summarizes the City's major surface water resources, which consist of creeks, two small lakes, and a few of the larger wetlands on City properties. The City leads water quality monitoring programs for these water resources and partners with King County for laboratory analysis and other programmatic support, including ongoing water quality programs at the two lakes.

3.1 Basins

There are several drainage basins within the City limits of varying size. The four largest drainage basins, listed from west to east, are the Middle Puget Sound (including Storm Creek), Boeing Creek, Thornton Creek, and McAleer Creek basins (Figure 1). Smaller portions of other basins, such as the Lyon Creek and West Lake Washington drainage basins, are also within the City limits; but are not well represented in any recent monitoring data, and 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, Lyon Creek, and the West Lake Washington basins flow east into Lake Washington. All 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 designated categories are defined in the 173-201A WAC as updated December 30, 2019).

Table 1. City of Shoreline Basin Characteristics

	Basin Characteristics				
Basin	**Basin Size within City (acres)**	**Impervious (%)**	**Roads (mi/mi^2)**	**Lakes/Ponds (acres)**	**Wetland (%)**
Thornton Creek	**2,375**	**41**	**27.3**	**14.3[a]**	**41.7 acres (1.7%)**
McAleer Creek	1,373	39	18.6	15.2[b]	31.8 acres (2.4%)
Boeing Creek	1,772	39	20.2	1.7[c]	2.6 acres (0.15 %)
Middle Puget Sound [d]	1,628	29	19	0	3.7 acres (1.2%)

Notes:
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
d. Includes Storm Creek

3.2 Creeks

There are six creeks that are sampled by the City for water quality. Detailed water quality results for City creeks are in Appendix A.

3.2.1 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). A very small portion of the basin extends south into Seattle. Boeing Creek is the second largest basin within the City. Some of the City's largest and best-preserved natural riparian areas are protected by public parklands and private reserve lands within the Boeing Creek ravine along the perennially flowing groundwater-fed portion of the stream that starts at Boeing Creek Park.

Current land use in the upper Boeing Creek basin is dominated by urban development, including dense older commercial development along the Aurora Avenue N corridor. The downstream natural channel has been highly impacted by erosive downcutting and other damage due to increased stormwater flows from upper basin development. In upper basin areas, much of the contributing area is drained by ditches and pipes of formal stormwater conveyance systems. Such piped systems include some headwater tributary systems currently characterized as piped streams, although many of such systems lack the unambiguous presence of pre-development natural stream channels and may have been erroneously characterized as streams. Other prominent impacts from the built environment affecting Boeing Creek include four dams of varying proportions, functionality, and design along the lower reach. The lowermost dam, over 100 years old and located within a private reserve, limits anadromous fish use to only the first 2,300 feet of the lowest reach. A detailed description of the basin can be found in the Boeing Creek Basin Plan (Windward 2013a).

3.2.2 Thornton Creek Basin: Thornton and Littles Creek

The headwaters of the Thornton Creek basin are located in the central portion of the City (Figure 1). Approximately 32 percent of the total basin is located within Shoreline's city limits. The Thornton Creek basin drains nearly 2,400 acres in the south-central and -eastern areas of Shoreline before entering Seattle city limits and ultimately flowing into Lake Washington. All Thornton Creek drainages within Shoreline flow to the North Fork branch of the creek as identified in Seattle.

The City monitors the main branch of Thornton Creek in Shoreline. The headwaters of Littles Creek also originate in this basin and the creek eventually merges with Thornton Creek south of the City boundary, in Seattle. Littles Creek is also monitored within Shoreline, as a separate creek from the Thornton Creek main branch.

Urban development and automobile transportation infrastructure (including Interstate 5 between roughly 180th Street and 145th Street) 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 in the City are highly impacted and fragmented, with a general 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 with open water areas exist within the Thornton Creek basin, with a combined area of 41.7 acres. These wetlands, Ronald Bog and Twin Ponds, both originated as peat bogs, 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).

3.2.3 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 NE 196th Street (Figure 1).

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. The McAleer Creek main branch flows east out of Lake Ballinger through the Nile Golf course, under Interstate 5, and briefly (2,700 linear feet) through Shoreline, and then is joined by the Cedarbrook Creek and Whisper Creek tributaries while flowing through the City of Lake Forest Park on the way to Lake Washington.

Urban development dominates McAleer Creek's watershed within the City. Impervious surfaces make up 46 percent of the watershed in Shoreline (Table 1). The northern part of Aurora Avenue N, Ballinger Way NE, 205th Street, and part of Interstate 5 represent major urban modifications within the watershed. While high quality forested habitat exists within 50 feet along some short reaches of McAleer Creek, the overall quality diminishes with distance from the stream and in some areas single-family homes, apartments, and lawns are located in close proximity to the creek.

The entire main stem of McAleer Creek within the City, up to Interstate 5 is used by anadromous fish. Anadromous use of the various tributaries is unknown. Other notable water features include Echo Lake (13.5 acres) within Shoreline and Lake Ballinger (101.4 acres) just north of Shoreline's northern boundary.

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

3.2.4 Middle Puget Sound Basin: Multiple Drainages including Storm Creek

The Middle Puget Sound basin in the City drains into Puget Sound through multiple hydrologically separate small creeks and storm drainage systems (Figure 1). These Puget Sound drainages encompass approximately 1,628 acres in the westernmost areas of the City, both north and south of the Boeing Creek basin.

There is record of only one small stream in the southern portion of the basin within The Highlands neighborhood. Three relatively significant streams, Blue Heron Creek, Storm Creek, and Barnacle Creek (listed from south to north), are located within the north portion of the basin (Figure 1); of these three streams, Storm Creek is the largest. There are multiple other smaller streams in the northern portion of basin. The overall Middle Puget Sound basin extends both north and south past the City boundary into Edmonds and Seattle, respectively.

More information is provided below about Storm Creek, as the largest and most-studied of the Middle Puget Sound Drainages. Conditions within the Storm Creek basin can be considered relatively representative of conditions throughout the larger Middle Puget Sound basin within the City.

According to the 2013 Storm Creek Basin Plan, the watershed is 47 percent impervious, and current land use in the basin mostly single-family residential, followed by roads, with small areas developed as multifamily, schools, commercial, and parks and open space (Windward 2013b). Commercial areas are primarily along the Richmond Beach Road corridor.

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

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

3.3 Lakes

The City partners with King County to monitor water quality in Echo Lake and Hidden Lake. The lakes are described below. Detailed water quality results for City lakes are in Appendix B.

3.3.1 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 Avenue 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. Roughly one block west of the lake is Aurora Avenue N and associated commercial developments. Echo Lake receives significant runoff contribution from this heavily developed area. Roughly one block 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).

3.3.2 Hidden Lake

Hidden Lake is a small, man-made lake located in the southwest portion of the City within the Boeing Creek drainage basin, along NW Innis Arden Way north of the roadway. The lake occupies approximately 1.7 acres. To help mitigate stormwater impacts to Boeing Creek, many projects were constructed starting in the 1970s, including reconstructing Hidden Lake in 1995 after the original version had previously filled in with sediment. However, the Hidden Lake design did not anticipate the large volume of sediment deposited after reconstruction. In order to maintain the Hidden Lake as an open water feature, the City removed large volumes of sediment on a recurring basis from 2002 to 2013. In 2014, City Council approved ceasing sediment removal and starting a project to remove the dam and re-establish Boeing Creek within the lakebed.

The north end of the lake is accessible from Shoreview Park and is visited frequently by dog owners who bring their dogs to swim in the water. Hidden Lake shore consists of City park land on the east side and single-family residential properties on the west side. The lake is fed by Boeing Creek and there are two dams on separate tributaries that add some flood control or flow control which are each located approximately a quarter mile upstream of the lake. Stormwater contributions to that pond include a large amount of runoff from the Aurora Avenue N commercial zone to the east. The north “forebay” of the lake was designed to function as a settling basin to capture sediment. The forebay was periodically dredged until the City ceased doing so after 2013, and is now completely full of sandy sediment. A stormwater structure at the south end of the lake acts as the outlet and conveys all significant streamflow to the lower reach of Boeing Creek that drains to Puget Sound.

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

The City is currently planning a project to remove the dam, drain Hidden Lake, and restore this reach of Boeing Creek to a more natural state. Dam removal and stream restoration are scheduled to be completed by the fall of 2022, followed by replacing the aging Boeing Creek culvert under NW Innis Arden Way in 2024.

3.4 Wetlands

There are many wetlands within the City of Shoreline limits, both identified and unidentified, which vary significantly in size. Three of the largest and best-known wetlands on City properties, with a history of monitoring, are listed below – but this is by no means an exhaustive listing of known wetlands or larger wetlands within the City. Most of the data collected from these sites were collected prior to 2010.

3.4.1 Meridian Park Wetland

Meridian Park wetland is located in the Thornton Creek drainage basin. This wetland covers the majority of the Meridian Park property and is at the headwaters of Meridian Creek, a west-branch tributary to Thornton Creek. Meridian Park Wetland is approximately 1.1 acres in size. It is classified as Palustrine Forested and Palustrine Scrub-Shrub (Tetra Tech/KCM 2004). It is the only known true wetland of significant size within City limits that retains standing water for at least 6-months out of the year.

The dominant land use surrounding the Meridian Park wetland is single family residential. There is a school located immediately north of the wetland. A trail constructed of earthen fill material once mostly separated two portions of the wetland, but the City constructed a boardwalk trail to allow for better hydraulic connection between the two portions.

A more detailed description of the wetland can be found in the Thornton Creek basin characterization study (Tetra Tech/KCM 2004).

3.4.2 Ronald Bog and Twin Ponds

Ronald Bog and Twin Ponds are two unique resources in the City that are considered wetlands but resemble open water small lakes or ponds on the surface. These two resources are located within the Thornton Creek basin and originated as pre-development peat bogs. They were commercially mined beginning around the 1940s and then allowed to go fallow. Each is now within a City Park (respectively named for the water features) and function as shadow bogs.

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 dominant the wetland soils. Because of these characteristics, Ronald Bog and Twin Ponds do not fit neatly into the lake or wetland categories. For the purpose of this report, these features were categorized as wetlands.

Ronald Bog is a single open water area occupying approximately 7.7 acres located at the upper most headwaters of Thornton Creek. The wetland portion around the edge of the waterbody until recent years occupied approximately 1 acre (Otak 2001). Single family residential developments, residential roads and a major arterial street are located north of the bog. Residential developments are located to the east and south. Single family residential developments, residential roads, a major arterial street and a school are located west of the bog. In 2020, Sound Transit construction floodplain restoration and wetland enhancements along the eastern areas of Ronald Bog, as mitigation for wetlands impacted by light rail construction on the east side of Interstate 5 within the Thornton basin.

Twin Ponds are two small ponds separated by a raised earthen berm between and hydraulically connected by a short section of stream flowing through a gap in berm. Twin Ponds occupy approximately 5.4 acres and include the location where the Meridian Creek Tributary flows into Thornton Creek (along the west side of the southern pond). Of those 5.4 acres in total area, approximately 2.4 acres are wetlands classified as either forested or emergent. (TetraTech/KCM 2004). Land use surrounding Twin Ponds is primarily City park land with single family residential around the park property boundaries to the south and west. On the east side of the pond is a synthetic-turf soccer playfield, with

arterial streets located east and north of the ponds and park, and Interstate 5 located a short distance to the east.

A more detailed description of these resources can be found in the Thornton Creek basin characterization study (Tetra Tech/KCM 2004).

4 City of Shoreline Monitoring Locations

The City has been monitoring creeks, lakes and wetlands since 2001. The monitoring locations and methods for the monitoring program are described below.

4.1 Sampling Stations

Ten sampling stations were monitored for this report (Figure 1). 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 where the stream leaves the City.

Each of these sample locations is representative of water quality throughout the basin since they are downstream of the contributing areas within the City's portion of each basin. For lakes, the sampling locations are primarily accessed from the 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.

4.1.1 Creeks

Water quality samples were collected for monthly chemical, physical (ambient), and bacteriological monitoring. In addition, bioassessments were completed at several sites in the early 2000s. The sampling occurred at the following stations:

Boeing Creek Sample Locations

Two sites (BC-2 and BC-3) are located within Boeing Creek Park near the confluence of the northern and southern tributary systems for Boeing Creek (Figure 1). The site BC-2 is located on the south branch of Boeing Creek. The site BC-3 is located on the north branch of Boeing Creek. The two branches merge approximately 250 feet downstream of the sampling sites.

In addition to the routine monitoring, bioassessments were conducted in 2003 and 2007 at BC-2 and BC-4 which is located near the mouth of Boeing Creek just upstream of where the railroad line crosses Boeing Creek (The Watershed Company 2009).

Thornton Creek Sample Locations

One site (TH-1) is located about 30 feet upstream of where Thornton Creek enters Twin Ponds (Figure 1). Bioassessments were conducted at TH-1 in 2003 and 2007 (The Watershed Company 2009). A second monitoring site (RB-2) was located in the inlet channel of Ronald bog adjacent to the southbound onramp to Interstate 5. RB-2 was sampled from 2001 through 2013.

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 exits Shoreline and enters Seattle (Figure 1). A bioassessment was conducted at LT-1 in 2003 but was not repeated in 2007 (The Watershed Company 2009).

Meridian Creek Sample Location

The Meridian Creek inlet to Twin Ponds was monitored for chemical and physical (ambient) parameters at one site (MD-1) roughly 50 feet upstream of the confluence with Twin Ponds. MD-1 was monitored from 2001 through 2013.

McAleer Creek Sample Location

One site (MC-1) is located upstream of the NE 196th Street crossing and the dam-like flow control structure across the roadway culvert inlet (Figure 1). The sampling location is located just upstream of where McAleer Creek exits Shoreline and enters Lake Forest Park. Bioassessments were conducted at MC-1 in 2003 and 2007 (The Watershed Company 2009).

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 downstream of where McAleer Creek exits Shoreline and enters Lake Forest Park (Figure 1).

Storm Creek Sample Locations

One site (ST-2) is located immediately downstream of the intersection of 15th Avenue NW and NW 190th Street. This location is approximately halfway between the headwaters and the mouth of Storm Creek (Figure 1). Downstream of this sampling station, Storm Creek flows through a primarily natural, riparian area.

Bioassessments were conducted in 2003 and 2007 at ST-1 which is located about 100 feet upstream of 17th Place NW (The Watershed Company 2009).

4.1.2 Lakes

Echo Lake Sample Locations

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 ("lake stewardship" monitoring from late spring to early fall) and is located in the near center of the lake (Figure 1) and accessible only by boat. The second site (A764SB[7]) was monitored for monthly chemical and physical (ambient) monitoring and for seasonal, weekly bacteriological monitoring ("swimming beach" monitoring from late spring to early fall).

The specific location is adjacent to the Echo Lake park beach on the north end of the lake (Figure 1). Echo Lake is located along Ashworth Ave N, southwest of the intersection of Ashworth Ave N and N 200th Street. The specific location is adjacent to the Echo Lake park beach on the north end of the lake (Figure 1).

[7] Sampling site A764SB was referred to as ELO-1 in the 2009 report

Hidden Lake Sample Location

One site (0207SB[8]) was chosen for seasonal, weekly bacteriological monitoring and monthly chemical and physical (ambient) monitoring ("swimming beach" monitoring from late spring to early fall). 0207SB is near the outlet on the south end of the lake (Figure 1). The 2009 report (Shoreline 2010) references a second sampling location for bacteriological monitoring located near the northeast end of the lake but the data were combined under 0207SB in that report and all the monitoring results remain combined in this report. The nearest residence to the 0207SB sampling site, which is located at the lake outlet point at the south end of the lake, is 944 NW Innis Arden Way.

4.1.3 Wetlands

Meridian Park Wetland Sample Location

One site (MD-C) was selected for monthly chemical and physical (ambient) monitoring from 2001 to 2013. The sampling site is located at the outlet of the bog along the southern-most boundary of the wetland. The sampling location is immediately north of the property located at 1632 N 167th Street (Figure 1).

Ronald Bog Inlet Sample Location

One site in Ronald bog was selected for monthly chemical and physical (ambient) monitoring from 2001 to 2013. Ronald Bog is located southeast of the intersection of N 175th Street and Meridian Ave N. Sampling station RB-1 is located south of the bus shelter east of the intersection along N 175th Street, adjacent to the shoreline (Figure 1) within Ronald Bog.

Twin Ponds Sample Location

King County collected a single sample at an unreported location within Twin Ponds on September 6, 2018 for algal toxins.

[8] Sampling site 0207SB was referred to as HLO-1 in the 2009 report.

5 Water Quality Parameters and Monitoring Methods

Creeks, lakes, and wetlands in Shoreline have been monitored for chemical, physical, and biological parameters, The methods and equipment used to collect the data are described below.

5.1 Chemical and Physical Parameters

Temperature

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

Dissolved Oxygen

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

pH

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

Turbidity

An Extech TB400 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).

5.2 Biological Parameters

Bacteria (Fecal Coliform) Monitoring

Fecal coliform samples were collected using grab-sample techniques. Grab samples are water samples that are collected at one discrete moment in time from one discrete 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.

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

Benthic Index of Biological Integrity (B-IBI)

Macroinvertebrate sampling was conducted in Thornton Creek (TH-1), McAleer Creek (MC-1), Boeing Creek (BC-2 and BC-4), Littles Creek (LT-1) and Storm Creek (ST-1).

B-IBI assessments were performed at all sites in 2003 and again in 2007 with the exception of LT-1, which was only sampled in 2003. Sampling methods are discussed in detail in the *2007 Bioassessment Report: Condition of City of Shoreline's Surface Waters* (The Watershed Company 2009).

Quality Assurance and Quality Control of Collected Data

The collection of water quality parameters was performed by the City's Senior Surface Water Program Specialist (known as the Water Quality Specialist prior to 2020) and/or other Surface Water staff. 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 logbook 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.

5.3 Sampling Frequency

Creek sampling: Almost all creek monitoring sites were sampled on a monthly basis throughout the year. Some sampling stations were dry during summers months and were only sampled when water was present. Bioassessments were completed in 2002 and 2007.

Lake sampling: From May to October, samples were collected every two weeks at the EL-PROFILE sampling location at Echo Lake. Swimming beach samplings were collected weekly during the same late spring to early fall timeframe.

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

The waterbodies described in this report support aquatic and water contact recreation designated uses at the monitored locations. 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 2. Collected water quality data was compared to these standards.

Table 2. 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 3, 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 3).

Table 3. 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**

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 discrete temperature value taken once per month at each location. Therefore, a direct comparison to water quality standards is not possible.

Throughout the City's water quality monitoring program, the City has lacked resources to collect continuous temperature data (to derive 7-DADmax values), and has instead gathered discrete data points for temperature during recurring weekly, biweekly, or monthly programmatic sampling intervals. City staff have determined that in the absence of collecting 7-DADmax data, comparing discrete temperature data points to the water quality standard for maximum temperature can 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.

Dissolved Oxygen (DO)

The water quality limit for DO is a discrete value and is expressed as a 1-DAD Max, which means the daily average of DO readings are directly compared to the standard. Similar to temperature data, the City has lacked resources to collect continuous DO data (to derive 1-DADmax values), and has instead gathered discrete data points for DO during recurring programmatic sampling intervals, typically monthly. City staff have determined that in the absence of collecting 1-DADmax data, comparing discrete DO data points to the water quality standard for maximum temperature can 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 DO 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.

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.

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 a turbidity limit of 6 NTUs were considered to be out of compliance for all creeks.

Fecal Coliform

Fecal coliform measured values were compared to the Primary Contact Recreation Bacteria Criteria. It should be noted that the Fecal coliform standards expired on December 21, 2020. All water quality data in this report were collected prior to this expiration and the Fecal coliform standard will be used in this assessment. 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. The values that were above the value of 100 colonies/100 mL were considered to be out of compliance.

5.4.3 Other Water Quality Indicators

Toxic Algae

The City collected algae samples for King County lab testing from multiple locations in Echo Lake from 2009 through 2020 and also from Twin Ponds in 2018.The Washington State Department of Health (DOH) has set a provisional guidance for toxic algae levels and direct contact (swimming) use. A bloom event or exceedance could trigger several consecutive weeks of sampling if levels were exceeded and sampling would continue until the sample levels dropped below the guidance level. The guidance levels are shown below in Table 4 and results were compared to these values.

Table 4. Provisional Recreation Guidance Levels for Algal Toxins

Toxin	Provisional Guidance Level
Microcystin	≥ 8 µg/L
Anatoxin-a	≥ 1 µg/L
Cylindrospermopsin	≥ 15 µg/L
Saxitoxin	≥ 75 µg/L

Water Quality Index

Ecology developed a water quality index (WQI) for Washington streams (Ecology 2002). For Shoreline, the index compares pH, temperature, dissolved oxygen, and fecal coliform to the water quality standards and other parameters such as nutrients (total nitrogen and phosphorus) and sediment are compared relative to their expected levels in the Puget Lowland Ecoregion. Ecology developed a spreadsheet to calculate the WQI and data collected in the City's streams from 2008 through 2020 were input into the spreadsheet to calculate annual WQI scores for individual parameters and the station as a whole. A score of 80 or above indicates that the station meets expectations and is considered "low concern. A score between 40 and 80 indicates some impairment a rating of "moderate concern". A WQI score below 40 indicates the station does not meet expectation and is considered to be "high concern". Results of the WQI analysis are presented below.

Benthic Index of Biological Integrity (B-IBI)

The Benthic Index of Biological Integrity metrics generate a score (Fore 1999) for each site based on the level of impairment. The lower the B-IBI score, the greater the impairment of the stream and the levels of impairment are categorized in Table 5. It should be noted that the scores presented come directly from the 2009 report (The

Watershed Company 2009) and have not been recalibrated to match King County's 2014 update to the scoring methods. The City has not conducted any B-IBI assessments since 2007.

Table 5. Benthic Index of Biotic Integrity Scores

B-IBI$_{10\text{-}50}$ Score	Level of Biological Impairment
≥10 to ≤19	Extreme
≥20 to ≤27	Severe
≥28 to ≤34	Moderate
≥35 to ≤42	Slight
≥43 to ≤50	None

5.4.4 Trend Analysis

This report includes a trend analysis of creek water quality data that have been collected between 2008 and 2020 water years. A Mann-Kendall non-parametric trend test (Mann 1945, Kendall 1975) was performed on the data to determine if any statistically significant increasing or decreasing trends exist in the data. The median value of each water quality parameter was calculated for each water year and the annual medians were then analyzed using a two-tailed Mann-Kendall trend test at a 95 percent confidence. The overall WQI for each station was also tested for any trends using the same test parameters.

6 Shoreline Water Quality Results 2001-2020

This section summarizes the results of water quality testing for the City's water resources. The results cover the time period between 2001 through 2020.

6.1 Creek Results

6.1.1 Boeing Creek (BC-2)

The Aquatic Life Designated Use Support Ratings at Boeing Creek monitoring station BC-2 (south tributary) are primarily "good" for the entire data record (Table 6). Temperature did not exceed the standard prior through the 2016 water quality report (2016 Report) (Shoreline 2017) and only exceeded the temperature standard 2 percent of the time in the 2016 through 2020 data period. Dissolved oxygen (DO) exceeded the standard for *Core Summer Salmonid Habitat* 26 percent of the time leading up to the 2016 report earning a "poor" rating but the data from 2016 through 2020 show that DO has improved to a rating of "good" with no exceedances since.

The pH rating was "good" in the 2016 report but the data from 2016 through 2020 show that it has dropped to a rating of "fair" with multiple measurements falling below the lower threshold of 6.5. Turbidity exceeded the standard 7 percent of the time prior to the 2016 Report and improved to 5 percent exceedance since then with a rating of "good" for both periods.

Table 6. Aquatic Life Designated Support Use Rating for Boeing Creek at Station BC-2

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (100%)	GOOD (100%)	POOR (74%)	GOOD (98%)	GOOD (98%)	GOOD (93%)
2016-2020	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (100%)	FAIR (86%)	GOOD (95%)

Notes:
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

Boeing Creek station BC-2 received a rating of "good" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform (Table 7) in 9 of the past 13 years.

Table 7. Primary Contact Recreation Designated Use Support Rating for Boeing Creek at BC-2

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	91.7%	No	GOOD
2009	100.0%	No	GOOD
2010	90.0%	No	GOOD
2011	75.0%	Yes	FAIR
2012	87.5%	Yes	FAIR
2013	91.7%	No	GOOD
2014	91.7%	No	GOOD
2015	75.0%	Yes	FAIR
2016	91.7%	No	GOOD
2017	100.0%	No	GOOD
2018	90.0%	No	GOOD
2019	90.9%	No	GOOD
2020	80.0%	Yes	FAIR

Notes:
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

According to the Ecology WQI score, this site's impairment level has most consistently been "moderate concern" (Table 8). In 2010, 2014, and 2017 the impairment level was considered a "low concern". Key constituents that were of moderate concern included fecal coliform and total phosphorous.

Table 8. Ecology Water Quality Index Scores for Boeing Creek at BC-2

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	74	52	93	77	96	89	94	91	68
2009	88	60	86	80	100	88	99	100	76
2010	78	74	85	83	100	88	99	100	80
2011	49	76	90	72	91	88	99	82	65
2012	71	73	90	76	92	90	93	85	68
2013	57	80	83	72	82	73	98	83	64
2014	74	87	79	82	99	88	97	99	80
2015	38	88	76	78	80	87	98	81	48
2016	71	85	67	76	100	88	95	100	75
2017	81	85	84	77	93	89	97	99	86
2018	65	89	66	71	92	88	97	97	72
2019	70	87	78	77	99	88	90	97	73
2020	62	85	70	73	95	87	100	92	69

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A trend analysis of the individual parameters and overall WQI scores showed no significant trends in the data from 2008 through 2020.

The B-IBI results from 2003 and 2007 for BC-2 and BC-4 indicated that Boeing Creek was rated at an "extreme" level of impairment (Table 9). This does not necessarily align with the WQI scores or the Aquatic Life Designated Use Support ratings. Per the report, the species composition at both BC-2 and BC-4 could indicate that nutrient or other organic pollutants might be impacting Boeing Creek (The Watershed Company 2009). While the WQI scores indicate that nitrogen concerns are "low" it does show "moderate concern" for phosphorous although the data WQI data were collected after the last round of B-IBI samples were completed.

Table 9. B-IBI scores for Boeing Creek at BC-2 and BC-4

Sampling Site	Year	Score	Level of Impairment
Boeing Creek (BC-2)	2003	14	Extreme
	2007	14	Extreme
Boeing Creek (BC-4)	2003	12	Extreme
	2007	14	Extreme

6.1.2 Boeing Creek (BC-3)

Boeing Creek station BC-3 (north tributary) 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 2016 report's results. This stem of the creek now meets all standards of the Aquatic Life Designated Use category. Dissolved oxygen and temperature standards in the *Salmonid Spawning, Rearing, and Migration* aquatic life category met the standards 100% of the time. The exceedances for pH did increase in data collected since the 2016 Report but overall pH rating was still "good".

Table 10. Aquatic Life Designated Use Support Ratings for Boeing Creek at Station BC-3

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (100%)	GOOD (100%)	FAIR (88%)	GOOD (99%)	GOOD (97%)	GOOD (93%)
2016-2020	GOOD (100%)	GOOD (100%)	GOOD (98%)	GOOD (100%)	GOOD (93%)	GOOD (98%)

Notes:
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

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 2009, 2010, 2013, 2014, 2016, and 2017 the ratings were "good". In 2008, 2011, 2012, and 2020 the

rating was “fair”. In 2015, the site received a rating of “poor” due to a series of high fecal coliform measurements in the fall and winter months.

Table 11. Primary Contact Recreation Designated Use Support Rating for Boeing Creek at BC-3

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	83.3%	Yes	FAIR
2009	100.0%	No	GOOD
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
2016	91.7%	No	GOOD
2017	100.0%	No	GOOD
2018	81.8%	Yes	FAIR
2019	80.0%	Yes	FAIR
2020	90.0%	No	GOOD

Notes:
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

In 2009, 2016, and 2017, BC-3’s WQI impairment level was rated as a “low concern”. In all other years, it was rated as “moderate concern” (Table 12). A Mann-Kendall analysis of the individual parameters and overall WQI scores showed no significant trends in the data from 2008 through 2020. Similar to BC-2, main constituents of “moderate concern” are fecal coliform and total phosphorous with the addition of total nitrogen.

Table 12. Ecology Water Quality Index Scores for Boeing Creek at BC-3

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp	Total Nitrogen	Turbidity	Overall
2008	61	59	91	74	94	86	70	91	73
2009	87	72	92	75	100	84	70	100	80
2010	76	65	80	79	100	85	73	100	79
2011	61	85	86	74	95	85	70	87	73
2012	66	78	86	78	97	87	68	91	73
2013	52	87	93	70	97	71	66	93	66
2014	68	90	77	77	99	85	64	99	74
2015	41	93	30	77	91	85	63	88	52
2016	76	91	88	75	96	85	66	100	80
2017	93	89	89	76	94	87	74	98	88
2018	57	89	75	74	99	86	77	97	68
2019	64	84	92	76	94	85	74	95	77
2020	65	78	70	73	97	85	76	95	68

Notes:
Low Concern = WQI score above 80

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp	Total Nitrogen	Turbidity	Overall

Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A Mann-Kendall trend analysis of the individual parameters and overall WQI scores showed no significant trends in the data from 2008 through 2020.

6.1.3 Thornton Creek (TH-1)

Prior to the 2016 Report, the Aquatic Life Designated Use Support Ratings at the Thornton Creek monitoring station TH-1 were rated "good" for all parameters with the exceptions of turbidity which was rated "fair", and dissolved oxygen which was rated "poor" (Table 13). Overall, the percentage of samples meeting the standards increased across all parameters compared to the 2016 Report and turbidity improved with a rating of "good.

Table 13. Aquatic Life Designated Use Support Ratings for Thornton Creek at Station TH-1

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (96%)	GOOD (99%)	POOR (57%)	GOOD (92%)	GOOD (93%)	FAIR (89%)
2016-2020	GOOD (100%)	GOOD (100%)	POOR (60%)	GOOD (98%)	GOOD (95%)	GOOD (95%)

Notes:
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

Thornton Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform for all years except 2018 and 2019 (Table 1**Table** 4). The more recent results are consistent with the older results from the 2016 report, also indicating no notable improvement in this category.

Table 14. Primary Contact Recreation Designated Use Support Rating for Thornton Creek at TH-1

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	33.3%	Yes	POOR
2009	27.3%	Yes	POOR
2010	50.0%	Yes	POOR
2011	58.3%	Yes	POOR
2012	37.5%	Yes	POOR

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2013	41.7%	Yes	POOR
2014	16.7%	Yes	POOR
2015	50.0%	Yes	POOR
2016	41.7%	Yes	POOR
2017	83.3%	Yes	FAIR
2018	75.0%	Yes	FAIR
2019	58.3%	Yes	POOR
2020	60.0%	Yes	POOR

Notes:
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

Ecology's WQI rated the impairment level of this site as mostly "high concern" (years 2009, 2010, 2012 to 2015, and 2020) (Table 15). In 2008, 2011, and from 2016 to 2019, the site received "moderate concern" ratings. TSS, turbidity and pH were generally rated as "low concern". Dissolved oxygen, temperature, and total phosphorus were generally rated as moderate concern. The key parameters that pulled the overall rating down are fecal coliform which mostly was rated as a "high concern" and total nitrogen (mix of "high concern" and "moderate concern" ratings).

Table 15. Ecology Water Quality Index Scores for Thornton Creek at TH-1

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	35	61	91	75	88	76	20	91	42
2009	35	45	31	74	95	70	16	92	37
2010	53	56	84	59	90	63	50	84	35
2011	48	66	86	76	88	75	70	83	51
2012	26	55	90	59	85	74	78	78	25
2013	23	68	69	79	95	64	60	89	34
2014	19	71	75	63	94	75	35	96	37
2015	31	78	90	37	63	78	29	78	33
2016	34	66	95	73	89	74	42	95	49
2017	55	73	89	74	96	76	49	94	64
2018	61	70	68	66	87	67	51	85	54
2019	38	65	87	73	95	67	63	93	50
2020	37	60	67	52	86	72	39	91	36

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A trend analysis of the individual parameters and overall WQI scores showed no significant trends in the data from 2008 through 2020.

The B-IBI results from 2003 and 2007 for TH-1 show that Thornton Creek was rated at an "extreme" level of impairment (Table 16). Per the report, the species composition could indicate that nutrient or other organic pollutants as well as sediment, elevated temperatures and low dissolved oxygen might be impacting Thornton Creek (The Watershed Company 2009). This aligns with many of the "moderate" or "high" concerns identified in the WQI scores for Thornton Creek at TH-1 (Table 15).

Table 16. B-IBI scores for Thornton Creek at TH-1

Sampling Site	Year	Score	Level of Impairment
Thornton Creek (TH-1)	2003	14	Extreme
	2007	18	Extreme

6.1.4 Thornton Creek (RB-2)

The City performed water quality monitoring in Thornton Creek at the inlet to Ronald Bog from 2002 through 2013. The Aquatic Life Designated Use Support ratings in the inlet channel (RB-2) were generally rated "poor" (Table 17). The inlet channel was rated "good" for both temperature ratings but it should be noted that the channel was dry during 30 of the 45 attempts to sample during the warmest months (June-September) and the majority of the samples come from the cooler months where temperature is not a concern.

Table 17. Aquatic Life Designated Use Support Ratings for the inlet to Ronald Bog Wetland at RB-2

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Thonrton Creek (RB-2)	2001-2013	GOOD (94%)	GOOD (97%)	POOR (29%)	POOR (45%)	FAIR (76%)	POOR (57%)

Notes:
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

The City did not monitor RB-2 for fecal coliform or the broader suite of Ecology's water quality index.

6.1.5 Littles Creek (LT-1)

The Aquatic Life Designated Use Support Ratings at the Littles Creek monitoring station LT-1 was rated "good" for all parameters except for dissolved oxygen which was rated "poor" (Table 18). There have been no improvements or further impairments in this creek since the 2016 report.

Table 18. Aquatic Life Designated Use Support Ratings for Littles Creek at Station LT-1

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (100%)	GOOD (100%)	POOR (22%)	POOR (50%)	GOOD (97%)	GOOD (94%)
2016-2020	GOOD (100%)	GOOD (100%)	POOR (15%)	POOR (33%)	GOOD (95%)	GOOD (93%)

Notes:
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

Littles Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform for all years from 2008-2020 with the exception of 2017 which was rated "fair" but at the lowest possible percent compliance with standards (Table 19**Table**). Fecal coliform levels remain a consistent concern at this station with no indications of improvement. Bacteroidales data collected in water year 2020 indicate that both human and dog markers are present in Littles Creek and contributing to the bacteria concerns.

Table 19. Primary Contact Recreation Designated Use Support Rating for Littles Creek at LT-1

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	16.7%	Yes	POOR
2009	40.0%	Yes	POOR
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
2016	25.0%	Yes	POOR
2017	75.0%	Yes	FAIR
2018	33.3%	Yes	POOR
2019	41.7%	Yes	POOR
2020	20.0%	Yes	POOR

Notes:
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

Little Creek at LT-1 was rated "high concern" for Ecology's WQI impairment level for every year except 2017 (Table 20). In 2017, this site was rated "moderate concern" with a

score (43) barely surpassing the minimum numerical score (40). Turbidity, TSS and pH were generally rated as "low concern" since 2008. Temperature ratings were generally a "low concern" through 2015 but have been consistently rated a "moderate concern" since then. Total phosphorous and total nitrogen have been a "moderate concern" since 2008. Dissolved oxygen and fecal coliform have been consistently rated a "high concern" and are the key drivers for the overall rating of "high concern" at this station. Littles Creek at LT-1 has the lowest WQI ratings of all the water quality monitoring sites in the City of Shoreline.

Table 20. Ecology Water Quality Index Scores for Littles Creek at LT-1

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	35	41	87	65	92	82	41	94	27
2009	14	53	83	78	100	82	41	99	32
2010	35	1	91	77	98	74	59	97	21
2011	35	26	90	65	92	81	41	91	23
2012	42	23	93	75	94	81	63	87	33
2013	21	22	91	75	85	69	59	94	16
2014	24	1	73	81	99	76	63	99	13
2015	7	16	87	67	79	80	75	79	12
2016	29	1	89	78	98	78	73	98	14
2017	58	6	90	73	94	79	66	92	43
2018	22	25	42	68	87	79	72	83	3
2019	40	4	92	75	100	74	74	94	15
2020	40	1	82	72	85	75	70	88	20

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A Mann-Kendall trend analysis of the individual parameters showed a statistically significant increasing trend in temperature and a significant decreasing trend in total nitrogen concentration. There was no significant trend in the overall WQI scores from 2008 through 2020.

Littles Creek at LT-1 was assessed in 2003 but not in 2007. The B-IBI results from 2003 for TH-1 show that Littles Creek was rated at an "extreme" level of impairment (Table 21). The results from Littles Creek were not discussed in the report (The Watershed Company 2009) but the rating of "high concern" for dissolved oxygen and overall WQI scores (Table) for Littles Creek align with low B-IBI scores.

Table 21. B-IBI score for Littles Creek at LT-1

Sampling Site	Year	Score	Level of Impairment
Littles Creek (LT-1)	2003	16	Extreme

6.1.6 Meridian Creek (MD-1)

Data was collected in Meridian Creek just upstream of the inlet to Twin Ponds from 2001 through 2013. The Aquatic Life Designated Use Support Ratings at this station was rated "good" for both temperature categories but "fair" to "poor" for all other parameters (Table 22). However, it should be noted that Meridian Creek at MD-1 was only sampled seven times in June, four in July, four in August, and four times in September with a note that the September 2012 sample was collected even though there was no flow into the ponds. This is because the monitoring site was dry during those visits and could not be sampled. The notes of the sites being dry indicate that although the site meets temperature standards when there is flow, it is often dry during the *Core Summer Salmonid Habitat* period and would not sustain salmonids in that period.

Table 22. Aquatic Life Designated Use Support Ratings for Meridian Creek at MD-1

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Meridian Creek (MD-1)	2001-2013	GOOD (99%)	GOOD (100%)	POOR (3%)	POOR (12%)	FAIR (78%)	FAIR (76%)

Notes:
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

6.1.7 McAleer Creek (MC-1)

The Aquatic Life Designated Use Support Ratings at the McAleer Creek monitoring station MC-1 ranged from "good" to "fair" (Table 23). This station rated "good" in the pH, and turbidity *Core Summer Salmonid Habitat* and good for temperature, pH, and turbidity *Salmonid Spawning, Rearing, and Migration* categories. The rating for *Core Summer Salmonid Habitat* for temperature and dissolved oxygen was "fair". The dissolved oxygen rating for *Core Summer Salmonid Habitat* has have improved since the 2016 Report, from "poor" to "fair". The temperature for *Core Summer Salmonid Habitat* decreased slightly from "good" to "fair".

Table 23. Aquatic Life Designated Use Support Ratings for McAleer Creek at Station MC-1

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (92%)	GOOD (99%)	POOR (74%)	GOOD (98%)	GOOD (98%)	GOOD (96%)
2016-2020	FAIR (90%)	GOOD (100%)	FAIR (87%)	GOOD (98%)	GOOD (95%)	GOOD (97%)

Notes:
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

The Primary Contact Recreation Designated Use Support criteria ratings for fecal coliform for McAleer Creek ranged from "good" to "poor" (Table 24). The ratings are inconsistent since data collection began and range from only 50 percent of samples meeting the standard in 2015 to 100 percent of the samples meeting the standard in 2019. Since the 2016 Report there have been two years with "good" ratings, two years with "poor" ratings and one year with a "fair" rating.

Table 24. Primary Contact Recreation Designated Use Rating for McAleer Creek (MC-1)

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	83.3%	Yes	FAIR
2009	81.8%	Yes	FAIR
2010	60.0%	Yes	POOR
2011	66.7%	Yes	POOR
2012	75.0%	Yes	FAIR
2013	91.7%	Yes	GOOD
2014	81.8%	Yes	FAIR
2015	50.0%	Yes	POOR
2016	91.7%	Yes	GOOD
2017	66.7%	Yes	POOR
2018	75.0%	Yes	FAIR
2019	100.0%	No	GOOD
2020	60.0%	Yes	POOR

Notes:
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

This site has consistently received an impairment level of "moderate concern" for Ecology's WQI scoring (Table 25). Turbidity, TSS, and pH were all generally "low

concern" while fecal coliform, dissolved oxygen, total phosphorous, temperature and total nitrogen were generally rated "moderate concern".

Table 25. Ecology Water Quality Index Scores for McAleer Creek at MC-1

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	63	4	95	78	92	73	63	96	51
2009	61	69	68	78	94	67	41	96	59
2010	52	65	85	85	96	61	67	95	52
2011	51	73	92	81	88	65	81	91	58
2012	61	56	92	81	91	65	88	89	58
2013	67	77	94	75	89	65	65	89	62
2014	65	79	82	54	95	69	35	93	61
2015	51	86	93	76	69	67	45	84	57
2016	71	43	92	79	91	63	68	91	68
2017	51	78	84	76	96	58	62	97	58
2018	60	84	65	76	87	69	59	84	60
2019	74	80	92	67	85	64	60	88	68
2020	56	72	81	72	86	63	65	88	62

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A Mann-Kendall trend analysis of the individual parameters showed a statistically significant increasing trend in temperature and also a significant increasing trend in the overall WQI scores from 2008 through 2020.

The B-IBI results from 2003 and 2007 for TH-1 show that McAleer Creek at MC-2 was rated at a "severe" level of impairment in 2003 and an "extreme" level of impairment in 2007 (Table 26). Per the report, the species composition at MC-2 could indicate that nutrient or other organic pollutants might be impacting Boeing Creek (The Watershed Company 2009).

Table 26. B-IBI scores for McAleer Creek at MC-2

Sampling Site	Year	Score	Level of Impairment
McAleer Creek (MC-2)	2003	24	Severe
	2007	18	Extreme

6.1.8 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 (Table 27), which is an improvement on the 2016 Report's results. Previously, this site received "fair" ratings for the turbidity standards and the dissolved oxygen *Core Summer Salmonid Habitat* standard. This creek currently meets all Aquatic Life Designated Use categories.

Table 27. Aquatic Life Designated Use Support Ratings for Cedarbrook Creek at Station CB-1

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (100%)	GOOD (100%)	FAIR (90%)	GOOD (99%)	GOOD (98%)	GOOD (97%)
2016-2020	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (97%)	GOOD (93%)

Notes:
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

The Primary Contact Recreation Designated Use Support criteria rating for fecal coliform for Cedarbrook Creek ranged from "good" to "poor" (**Table**Table 28). This site was rated either "fair" or "good" from 2012 to 2017 including 100 percent compliance in 2014 and 2017 but the ratings since 2017 have been "poor" including failing to meet the standard 50 percent of the time in 2020.

Table 28. Primary Contact Recreation Designated Use Support Rating for Cedarbrook Creek at CB-1

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	50.0%	Yes	POOR
2009	72.7%	Yes	POOR
2010	40.0%	Yes	POOR
2011	58.3%	Yes	POOR
2012	75.0%	Yes	FAIR
2013	83.3%	Yes	FAIR
2014	100.0%	No	GOOD
2015	83.3%	Yes	FAIR
2016	91.7%	Yes	GOOD
2017	100.0%	No	GOOD
2018	66.7%	Yes	POOR
2019	66.7%	Yes	POOR
2020	50.0%	Yes	POOR

Notes:
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

This site has consistently received an impairment level of "moderate concern" for Ecology's WQI scoring (Table 29). Turbidity, TSS, and pH were all generally "low

concern" while fecal coliform, dissolved oxygen, total phosphorous, and total nitrogen were generally rated "moderate concern". Temperature ratings varied from "moderate concern" to "low concern".

Table 29. Ecology Water Quality Index Scores for Cedarbrook Creek at CB-1

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	48	26	93	77	96	85	43	96	55
2009	55	75	87	80	93	82	41	95	69
2010	47	79	82	76	96	74	47	93	58
2011	49	82	76	73	93	81	43	93	60
2012	56	71	83	77	89	83	54	86	64
2013	57	84	92	58	95	76	46	95	60
2014	74	88	73	68	78	75	37	77	58
2015	63	87	89	58	80	76	46	82	68
2016	63	85	88	67	91	76	50	87	73
2017	74	81	92	71	91	77	47	93	79
2018	54	86	62	70	88	80	45	88	59
2019	53	85	95	74	96	76	52	97	67
2020	43	83	72	73	93	76	56	96	57

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A trend analysis of the individual parameters showed a statistically significant increasing trend in temperature and a significant decreasing trend in total nitrogen concentration. There was no significant trend in the overall WQI scores from 2008 through 2020.

6.1.9 Storm Creek (ST-2)

The Aquatic Life Designated Use Support Ratings at the Storm Creek monitoring station were rated "good" for all categories except pH which was rated "poor" (Table 30). Dissolved oxygen for *Core Summer Salmonid Habitat* improved from "fair" for the 2016 Report to "good" while pH dropped from "fair" to "poor" in the same period.

Table 30. Aquatic Life Designated Use Support Ratings for Storm Creek at Station ST-2

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
2007-2015	GOOD (100%)	GOOD (100%)	FAIR (80%)	GOOD (98%)	FAIR (85%)	GOOD (92%)
2016-2020	GOOD (100%)	GOOD (100%)	GOOD (95%)	GOOD (100%)	POOR (71%)	GOOD (93%)

Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration

Notes:
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

Storm Creek received ratings of "poor" in the Primary Contact Recreation Designated Use Support criteria category for fecal coliform in all years except 2009 (**Table**Table 31) and several years with less than half of the samples meeting the standard.

Table 31 Primary Contact Recreation Designated Use Support Rating for Storm Creek at ST-2

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2008	50.0%	Yes	POOR
2009	100.0%	Yes	GOOD
2010	60.0%	Yes	POOR
2011	50.0%	Yes	POOR
2012	62.5%	Yes	POOR
2013	66.7%	Yes	POOR
2014	41.7%	Yes	POOR
2015	50.0%	Yes	POOR
2016	66.7%	Yes	POOR
2017	58.3%	Yes	POOR
2018	16.7%	Yes	POOR
2019	41.7%	Yes	POOR
2020	50.0%	Yes	POOR

Notes:
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

This site is rated "moderate concern" to "high concern" from Ecology's WQI scoring (Table 32**Table**). In 2010, 2013, and 2018 this site's WQI impairment level was "high concern" and in 2011, 2013, and 2014 this site was only a couple of points from being "high concern". Turbidity and TSS were generally scored as "low concern" and temperature and dissolved oxygen and total nitrogen were a mix of "low concern" and "moderate concern". Temperature, total phosphorous, and pH were generally rated as "moderate concern" and fecal coliform was a mix of "moderate concern" and "high concern".

Table 32. Ecology Water Quality Index Scores for Storm Creek at ST-2

Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temp.	Total Nitrogen	Turbidity	Overall
2008	42	72	90	65	96	82	87	92	48
2009	77	75	1	65	100	82	71	95	55
2010	34	48	78	67	100	70	86	97	34
2011	34	77	80	67	100	78	55	86	42
2012	42	69	89	66	91	80	82	87	45
2013	35	75	70	45	79	68	76	80	36
2014	31	80	76	65	99	74	78	96	41
2015	40	86	74	49	84	79	84	81	41
2016	49	72	73	53	89	76	72	86	48
2017	32	83	54	69	96	77	80	98	46
2018	28	81	43	59	94	79	80	88	19
2019	36	80	52	67	100	75	61	94	46
2020	52	78	60	59	90	74	95	88	50

Notes:
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

A Mann-Kendall trend analysis of the individual parameters and overall WQI scores showed no significant trends in the data from 2008 through 2020.

The B-IBI results from 2003 and 2007 for ST-1 (located downstream of ST-2) show that Storm Creek was rated at an "extreme" level of impairment (Table 33). Per the report, the species composition could indicate that nutrient or other organic pollutants might be impacting Storm Creek (The Watershed Company 2009).

Table 33. B-IBI scores for Storm Creek at ST-1

Sampling Site	Year	Score	Level of Impairment
Storm Creek (ST-1)	2003	14	Extreme
	2007	18	Extreme

6.2 Lake Results

6.2.1 Echo Lake (EL-Profile and A746B)

The full suite of Aquatic Life Designated Use Support data was only collected at the EL-Profile station while the station at A746B only collected temperature data (Table 34). Temperature was "poor" at both sites for the entire data period with much less than half of the samples meeting standard. Dissolved oxygen *for Salmonid Spawning, Rearing, and Migration* was rated "fair" prior to the 2016 report but "poor" since 2016 and dissolved oxygen for *Core Summer Salmonid Habitat* was rated "poor" since 2012. Turbidity in

Echo Lake was rated as "fair" since 2012 and pH improved slightly since the 2016 report shifting from a rating of "poor" to "fair".

As a point of comparison, a study on Echo Lake was conducted in 1930-1931 (Scheffer, 1933) and monthly temperature, dissolved oxygen, and pH were estimated from graphs in the report. In water year 1931 Echo Lake was estimated to rate as "poor" for *Core Salmonid Habitat* for temperature and dissolved oxygen and also rate "poor" for *Salmonid Spawning Rearing, and Migration* for temperature but it was rated "good" for pH and *Salmonid Spawning, Rearing and Migration* for dissolved oxygen.

Table 34. Aquatic Life Designated Use Support Ratings for Echo Lake at A746B and EL-Profile

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Echo Lake surface	1931	POOR (64%)	POOR (71%)	POOR (38%)	GOOD (100%)	GOOD (100%)	
Echo Lake A746B	2004-2015	POOR (4%)	POOR (6%)				
	2016-2020	POOR (1%)	POOR (2%)				
Echo Lake EL-Profile	2012-2015	POOR (13%)	POOR (28%)	POOR (36%)	FAIR (82%)	POOR (73%)	FAIR (76%)
	2016-2020	POOR (21%)	POOR (32%)	POOR (27%)	POOR (58%)	FAIR (77%)	FAIR (79%)

Notes:
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

Echo Lake at A746B received ratings ranging from "poor" to "good" in the Primary Contact Recreation Designated Use Support category for fecal coliform (Table 35). The most recent rating was "fair" in 2020. Bacteria data from Scheffer's 1933 report are not directly comparable but he does note that water near a swimming beach was closed due to bacterial levels in July 1931 and was subsequently chlorinated three times in August 1931 to reduce the bacteria levels.

Table 35. Primary Contact Recreation Designated Use Support Rating for Echo Lake at A746B

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2004	78.9%	Yes	FAIR
2005	78.9%	Yes	FAIR
2006	78.9%	Yes	FAIR
2007	100.0%	No	GOOD
2008	100.0%	No	GOOD
2009	85.0%	Yes	FAIR
2010	83.3%	Yes	FAIR
2011	94.7%	No	GOOD
2012	100.0%	No	GOOD
2013	94.7%	No	GOOD
2014	71.4%	Yes	POOR
2015	43.5%	Yes	POOR
2016	47.6%	Yes	POOR
2017	95.0%	No	GOOD
2018	89.5%	Yes	FAIR
2019	45.0%	Yes	POOR
2020	76.2%	Yes	FAIR

Notes:
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

King County collected 156 samples from Echo Lake for algal toxins from 2009-2020 (Table 36). The Microcystin levels exceeded DOH guidance 9 times during what appears to be 6 different bloom events. All other toxin levels were below guidance levels for all samples.

Microcystin was detected below recreational guidelines at Echo Lake all years between 2009 - 2020, except in 2016 when no Microcystin were detected in the 2 samples that were collected and no Microcystin were detected. The recreational threshold was exceeded in 2009 (n=3), 2012 (n=2), 2013(n=1), 2015 (n=3). All of those events likely resulted in beach/lake closure.

Anatoxin-a was detected at a concentration below the recreational guideline levels in 2012, 2013, and 2014, but none of those events resulted in lake closures.

Sampling frequency decreased in 2019 and 2020 with only one sample collected each year.

Table 36. Algal Toxin Sampling Results for Echo Lake

Toxin	Number of Samples	Exceedances
Microcystin	83	9
Anatoxin-a	66	0
Cylindrospermopsin	3	0
Saxitoxin	4	0

6.2.2 Hidden Lake (0207SB)

Temperature data from Holden Lake has earned a rating of "poor" relative to the *Core Summer Salmonid Habitat* and *Salmonid Spawning, Rearing and Migration* designated use standards throughout the data collection period (Table 37).

Table 37. Aquatic Life Designated Use Support Ratings for Hidden Lake at 0207SB

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration
Hidden Lake 0207SB	2004-2015	POOR (50%)	POOR (50%)
	2016-2020	POOR (49%)	POOR (49%)

Notes:
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

Hidden Lake at 0207SB was rated "poor" in most years for Primary Contact Recreation Designated Use Support for fecal coliform (Table 38).

Table 38. Primary Contact Recreation Designated Use Support Rating for Hidden Lake at 0207SB

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2004	72.2%	Yes	POOR
2005	83.3%	Yes	FAIR
2006	65.0%	Yes	POOR
2007	60.0%	Yes	POOR
2008	63.2%	Yes	POOR
2009	78.9%	Yes	FAIR
2010	26.3%	Yes	POOR
2011	52.6%	Yes	POOR
2012	61.1%	Yes	POOR
2013	61.1%	Yes	POOR

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2014	57.9%	Yes	POOR
2015	39.1%	Yes	POOR
2016	36.4%	Yes	POOR
2017	90.0%	Yes	GOOD
2018	52.4%	Yes	POOR
2019	25.0%	Yes	POOR
2020	42.1%	Yes	POOR

Notes:
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

King County has not sampled Hidden Lake for toxins.

It should be noted that the Hidden Lake dam is scheduled for removal in the summer of 2022. In addition, a culvert replacement for Boeing Creek under Innis Arden Way is scheduled for 2024. The 2022 dam removal will effectively drain Hidden Lake and return this area to a flowing stream channel for Boeing Creek.

6.3 Wetland Results

6.3.1 Ronald Bog and Twin Ponds

The City performed water quality monitoring in Ronald Bog from 2001 through 2013. The Aquatic Life Designated Use Support ratings in Ronald Bog (RB-1) were generally rated “poor”, except for pH which was rated “fair” (Table 39).

Table 39. Aquatic Life Designated Use Support Ratings for Ronald Bog Wetland at RB-1

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Ronald Bog (RB-1)	2001-2013	POOR (57%)	POOR (62%)	POOR (27%)	POOR (52%)	FAIR (88%)	POOR (57%)

Notes:
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

King County collected a single sample in Twin Ponds on September 6, 2018, and analyzed it for Anatoxin-a and Microcystin. The concentrations for both toxins were well below guidance levels.

6.3.2 Meridian Park

Data was collected at the Meridian Park wetland from 2001 through 2013. The Aquatic Life Designated Use Support Ratings at this station was rated "good" for both temperature categories but "fair" to "poor" for all other parameters (Table 40). However, it should be noted that the Meridian Park wetland at MD-C was only sampled three times in June and once in August. It was never sampled in July or September between 2001 and 2013. This is because the monitoring site was dry during those visits and could not be sampled. The notes of the site being dry indicate that although the site meets temperature standards when there is flow, it is often dry during the *Core Summer Salmonid Habitat* period and would not sustain salmonids in that period.

Table 40. Aquatic Life Designated Use Support Ratings for Meridian Park Wetland at MD-C and Twin Ponds at MD-1

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Meridian Park Wetland (MD-C)	2001-2013	GOOD (99%)	GOOD (100%)	POOR (1%)	POOR (1%)	POOR (44%)	POOR (70%)

Notes:
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

7 Monitoring Program Recommendations

7.1 Salmon-Safe Monitoring Recommendations

The City's Salmon-Safe Report (Salmon Safe 2018) contains several recommendations for changes or additions to the current ambient water quality monitoring program. These recommendations are described under Condition 7 (C7) of the Salmon-Safe Report and summarized in the list below along with recommendations for implementing these conditions. See Appendix C for more details of Salmon-Safe Program approach.

- **Add metals analysis (zinc, copper, and lead) to water quality monitoring program.**

  Adding metals to the existing monthly water quality sampling would be relatively easy. The field crew would need to obtain sample bottles for metals analysis from their water quality lab and fill them at the same time they are collecting other samples.

  Recommendations to City: Although it is not specified in C7, it is recommended that the City sample for both total and dissolved metals as they affect different aspects of aquatic life within the stream. In addition, it is recommended that the City analyze for hardness as it affects bioavailability of dissolved metals for aquatic species.

- **Restart B-IBI sampling**

  The City sampled Boeing Creek (BC-2 and BC-4) Thornton Creek (TH-1), Littles Creek (LT-1) McAleer Creek (MC-2), and Storm Creek (ST-1) in 2003 and 2007. C7 does not specify how many stations should be sampled, nor does it specify a frequency.

  Recommendations to City: It is recommended that at a minimum, the City consider sampling Thornton Creek and Boeing Creek as they receive the largest volumes of stormwater inputs and will likely be the focus of other increased monitoring under C7. Benthic monitoring could be restarted at other stations as well but other larger basins like McAleer Creek and Lyon Creek are largely outside of the City's jurisdiction and B-IBI monitoring may not provide an accurate representation of conditions within the City. It is recommended that the City conduct B-IBI sampling every 5 years at the selected stations to monitor overall trends within each creek.

- **Find sample locations that receive significant stormwater**

  Every creek within the City receives stormwater inputs but the cost of intensive monitoring in every creek could be prohibitive.

  Recommendations to City: It is recommended that the City monitor Thornton Creek and Boeing Creek under C7. These two creeks drain relatively large portions of the City and represent a range of both commercial and residential land uses. In addition, the headwaters of Boeing Creek and Thornton Creek are almost entirely withing Shoreline city limits with little to no impact from adjacent

municipalities. These two creeks provide a good representation of the land use, geology, and the impacts of stormwater management programs within the City.

- **Increase frequency of sampling and include storm and non-storm samples. Add in automated sampling systems as feasible.**

  The City currently collects monthly water quality samples based on a regular schedule but it does not target specific weather or stream flow conditions. Condition 7 does not define what "more frequent sampling" means but does specify sampling during storm and non-storm conditions and prioritizes automated sampling rather than manual grab sampling if feasible.

  Recommendations to City: If the City decides to pursue automated sampling, it is recommended that the City only pursue this more intensive monitoring in Thornton Creek and Boeing Creek per the C7-related recommendations for B-IBI and significant stormwater inputs described above. This report proposes two different monitoring approaches for the City to consider to meet Salmon-Safe's desire for increased sampling and automated sampling.

  Both approaches would monitor Thornton Creek at or near TH-1 and Boeing Creek at BC-2 and BC-3. Both approaches also use B-IBI sampling, flow monitoring, continuous water quality sonde deployments and flow-weighted composite sampling. The approaches are described below and briefly summarized in Table 41. A detailed breakdown of the costs associated with each approach is in Appendix C.

  1) Establish current baseline water quality over three years then reassess every 5th year. This approach would target 5 automated sample events each year for the first 3 years. In addition, continuous flow monitoring would be established at each station for the purpose of pacing the autosampler to collect flow-weighted composites and to estimate loading for metals and nutrients at each station.

     Sondes would be deployed at each station and continuously collect temperature, dissolved oxygen, pH and conductivity. In addition, B-IBI samples would be collected during the first year of the monitoring. The initial three years of data collection would serve as a baseline for water quality in each basin.

     In year 5 of the study, an additional round of 5 samples will be collected at each site along with the B-IBI sampling and continuous sonde and flow monitoring and this will be repeated in year 10 of the study and so on. This will allow the City to track water quality and overall stream health at each station and document improvements over time within each watershed. In between monitoring years the equipment will be removed and stored in a protected environment.

  2) Establish baseline in one year then reassess every 5th year. This approach would target 12 automated sample events in the first year of the study. In addition, continuous flow monitoring would be established at each station for

the purpose of pacing the autosampler to collect flow-weighted composites and to estimate loading for metals and nutrients at each station. Sondes would be deployed at each station and continuously collect temperature, dissolved oxygen, pH and conductivity. In addition, B-IBI samples would be collected during the first year of the monitoring. The initial year of data collection would serve as a baseline for water quality in each basin.

In year 5 of the study, an additional round of 12 samples will be collected at each site along with the B-IBI sampling and continuous sonde and flow monitoring and this will be repeated in year 10 of the study and so on. This will allow the City to track water quality and overall stream health at each station and document improvements over time within each watershed. In between monitoring years, the equipment will be removed and stored in a protected environment.

Table 41. Summary of Proposed Monitoring Approaches

Approach	Monitoring Year	Flow Monitoring	Automated Sampling	Sonde Monitoring	B-IBI	Notes
3-year baseline	1	Up to 8 discharge measurement at each site	3 wet season and 1 dry season storm, 1 baseflow	Continuous	Samples at all three sites,	Purchase and install all equipment
	2	Up to 5 discharge measurement at each site	3 wet season and 1 dry season storm, 1 baseflow	Continuous	None	
	3	Up to 5 discharge measurement at each site	3 wet season and 1 dry season storm, 1 baseflow	Continuous	None	Station de-commissioning and equipment storage
	5, 10, etc.	Up to 8 discharge measurement at each site	3 wet season and 1 dry season storm, 1 baseflow	Continuous	Samples at all three sites,	Station rebuild, likely equipment reconditioning, removing and storing equipment at end of each year.
1 year baseline	1	Up to 8 discharge measurement at each site	8-9 wet season and 1-2 dry season storm, 1-2 baseflow	Continuous	Samples at all three sites,	Purchase and install all equipment, station de-commissioning and equipment storage
	5, 10 etc.	Up to 8 discharge measurement at each site	8-9 wet season and 1-2 dry season storm, 1-2 baseflow	Continuous	Samples at all three sites,	Station rebuild, likely equipment reconditioning, removing and storing equipment at end of year.

The water quality monitoring in other creeks could be continued on a monthly basis if desired along with the Boeing Creek and Thornton Creek sites during non-monitoring years.

If automated sampling is determined to be infeasible (i.e., cost prohibitive) it is recommended that the City confirm with Salmon-Safe that the current monitoring locations satisfy the condition of "receiving significant stormwater". If the current locations are deemed suitable, it is recommended that the City add metals analysis to its current monthly sample collection, target up to 6 additional sample events per water year to be collected during active storm runoff conditions, and perform B-IBI sampling in program years 1/5/10. If the current locations do not receive enough stormwater to satisfy Salmon-Safe, it is recommended that the City either add in additional locations or move monitoring locations within a basin to meet the requirement. The City can then resume the monthly sampling with the addition of metals and up to 6 additional samples per year as described above.

- **Prepare Sampling and Analysis Plan (SAP) for next Surface Water Master Plan**

  The overall purpose of the monitoring program outlined under C7 is to track long term trends and improvements in water quality within the City's creeks. The SAP will specify the sites and methods (based on the recommendations above or other City program needs) that will be used to monitor these trends. Salmon-Safe has requested to review the SAP and the results of the monitoring program.

7.2 Options for shared implementation: Shoreline CC, Shoreline public schools, citizen volunteer?

Water quality monitoring can be expensive and under certain circumstances there might be opportunities to both involve and engage the community and reduce costs through volunteer or educational monitoring. However, coordinating a volunteer program that is reliable and robust enough to meet the requirements of C7 and accurately assess water quality within the City will require significant coordination and oversight by City staff. It is recommended that the City use City staff or experienced professionals for any monitoring that could affect compliance with Salmon-Safe, NPDES permits, or other state water quality standards as mistakes or missed samples due to inexperienced or unreliable volunteers could be costly.

7.3 Evaluate monitor or pay in-cost benefit analysis

Under Section S8.A.2 and S8.B.2 of the current Western Washington Phase II Municipal Stormwater (a.k.a. NPDES) Permit (Permit), the City has the option to either make an annual payment into collective funds for status and trends monitoring (S8.A.2) and/or stormwater program management effectiveness studies (S8.B.2) or pursue its own monitoring of status and trends and/or effectiveness as laid out in Section S8.C and Appendix 9 of the Permit. The City could opt to pay into either Part A or Part B or both. If the City chose to pursue its own monitoring program it would be required to monitor 3 sites under Part A or 3 sites under Part B or 6 sites if it monitored both.

Table 42. Comparison of regional permit fees vs permit monitoring costs

Permit Section	Options	Benefits	Costs
S8.A.2 Status and Trends	Pay into collective fund	• Simple • Requires no additional staff or oversight • Cost effective	$9,107 per year[1] $36,428 per permit cycle (Aug 2020-Aug 2024)
	Stormwater discharge monitoring at 3 sites within City Requires developing QAPP, 1 year of flow monitoring, 3 years of water quality and flow monitoring	• Generate local data for City planning or improve water quality • City funds pay for work within City rather than fund regional study which may or may not be useful for Shoreline	Develop QAPP: $25K-$40K Equipment purchase, site installation and monitoring: $350K-$500K (Potential cost efficiencies if combining with S8.B.2. QAPP: $40K-$50K Monitoring: $600K-$700K)
S8.B.2 SWMP Effectiveness	Pay into collective fund	• Simple • Requires no additional staff or oversight • Cost effective	$16,644 per year[1] $66,576 per permit cycle (Aug 2020-Aug 2024)
	Stormwater discharge monitoring at 3 sites within City Requires developing QAPP, 1 year of flow monitoring, 3 years of water quality and flow monitoring	• Generate local data for City planning or improve water quality • City funds pay for work within City rather than fund regional study which may or may not be useful for Shoreline	Develop QAPP: $25K-$40K Equipment purchase, site installation and monitoring: $350K-$500K (Potential cost efficiencies if combining with S8.B.2. QAPP: $40K-$50K Monitoring: $600K-$700K)

Notes:
1. Western Washington Phase II Municipal Stormwater Permit (2019-2024) Appendix 11

Aspect also evaluated the potential for combining the monitoring under Salmon-Safe C7 and the permit. If the two programs could be combined the City could then satisfy both needs under one program but it was determined that the programs were not compatible unless either Salmon-Safe or Ecology changed their requirements. Salmon-Safe requirements under C7 are focused on water quality within the streams but stormwater discharge monitoring under the Permit is limited to storm drain outfalls and cannot be done in the stream.

The City could decide to install a stream site and outfall site adjacent to each other but would need to purchase monitoring equipment for both and operate and maintain them per the unique requirements of each program. There could also be labor efficiencies if the sites could be sampled during the same events. However, the combined effort would likely cost significantly more than sampling for C7 and continuing to pay into the annual permit funds.

7.4 Fecal Source Tracing

Bacteria monitoring can be difficult due to the transient nature of contamination and the extreme variability in levels from sample to sample even within a few minutes of each other. This can make source tracing difficult unless the levels are so high as to indicate a point source, such as a direct cross connection with sanitary sewer within a drainage system. More often, the levels can be variable as single events such as a spill or dumping could overlap with legacy sources such as abandoned drainfields. The high variability can make source tracing expensive and labor intensive and can involve years of monitoring.

The data collected by the city suggest that fecal coliform have been a long-standing problem within Littles Creek, Thornton Creek, and Storm Creek as well as an intermittent concern in McAleer Creek and Cedarbrook Creek. In the fall of 2020, the City began collecting bacteroides data in Littles Creek and Thornton Creek. The preliminary results suggest that potential sources could be from humans and dogs. These results can help the City screen for potential sources within these drainage basins, such as encampments, illicit connections, and dog-walking areas.

Ecology recently funded a guidance manual for source tracing (Ecology 2020) and the brief methods below are based on field screening methods outlined in the guidance. For pet related waste the likely sources are parks or paths where the public has direct access to a water body. It is recommended that a screening level monitoring program collect several samples upstream and downstream of these public areas to determine if the elevated levels are coming from these public areas. Unfortunately, drainage basins with open ditch networks can spread the publicly accessible areas across the entire basin but even in these basins the likeliest concentration of pet waste is in parks or paths along the stream or lake where the public tends to congregate.

For human related waste it is recommended that each basin be split into key drainage areas that can be screened through a series of sample events. Both wet weather and dry weather samples collected in each portion of the drainage basin can be compared and then drainages with higher levels can be targeted for more in-depth tracing. The City can also review drainage data looking for concentrations of current or abandoned septic systems as another screening method, such as canine scent tracking to identify specific source areas.

Ultimately, the variability in bacteria data can make tracing difficult without multiple samples to identify overall trends. The methods above could help the City identify some of the larger potential sources and provide cost-effective results. Further details and approaches are outlined in the Ecology guidance if more detailed studies are needed.

8 City of Shoreline Water Quality Summary

8.1 Creeks

Creeks within the City were rated "good" for Aquatic Life Designated Use categories in the state Water Quality Standards, including temperature and turbidity for both *Core Summer Salmonid Habitat* and *Salmonid Spawning, Rearing and Migration*. Every creek but Storm Creek also rated good for pH. Several creeks rated "poor" for dissolved oxygen, particularly for *Core Summer Salmonid Habitat*. Overall, Aquatic Life ratings since the 2016 report (Shoreline 2017) remained steady with little improvement or decline.

For the Primary Contact Recreation Designated Use category of the state Water Quality Standards, the Boeing Creek BC-2 sampling site rated mostly "good" while BC-3 was a mix of "fair" and "good". Thornton Creek, Littles Creek, and Storm Creek rated mostly "poor" since 2008. Cedarbrook Creek and McAleer Creek sampling sites both rated "poor" in roughly half the years since 2008 but also mix in "good" and "fair" ratings.

For Ecology's water quality index, data since 2008 show Boeing Creek (both sites) as little to moderate concern. Cedarbrook Creek and McAleer Creek have consistently rates as moderate concern since data collection began. Storm Creek and Thornton Creek have both rated moderate to high concern and Littles Creek consistently rated as high concern. These WQI ratings align with the Aquatic Life and the Primary Contact Recreation Designated use ratings. Overall, fecal coliform, dissolved oxygen were the main drivers for high concern and temperature and nutrients contributed to moderate concern ratings in many creeks.

The trend analysis performed on the data showed very little change in ratings for Shoreline's streams over the general period for which data were available: 2001 through 2020. Streams that were rated "poor" or "high concern" when data collection began have not improved and streams in "moderate" or "low concern" categories have not degraded significantly nor improved. Fecal coliform and dissolved oxygen levels are the most widespread concerns within the City's streams.

8.2 Lakes

In most Aquatic Life Designated Use categories, Echo Lake rated as "poor" since 2016, particularly for temperature, pH, and dissolved oxygen levels. Turbidity was rated "fair". The findings since 2016 are generally in line with the ratings from prior reports and even dating back to 1931 where dissolved oxygen and temperature data would have warranted a "poor" rating although the overall compliance percentages were higher.

In the Primary Contact Recreation Designated Use category, Echo Lake rated "poor" or "fair" from 2014 through 2020 with a single "good" rating in 2017. More recently in 2014 and 2015, Echo Lake received "poor" ratings. Hidden Lake rated "poor" most years since the beginning of sampling with the exception of 2017 when it rated "good".

As noted above, the Hidden Lake dam is scheduled for removal in 2022 and Hidden Lake will be drained and Boeing Creek will flow freely though this area once the dam is removed.

The monitoring results of the Echo Lake chemical and physical parameters indicate that the lake is moderately to severely impacted by stormwater.

In 2005, the City began monitoring Echo Lake as part of the King County Lake Stewardship Program. King County has now taken over this monitoring and it has continued through 2020. Samples collected are analyzed for total phosphorous, total nitrogen, chlorophyll-*a*, and pheophytin. Temperature is measured at the time of sample collection. Echo Lake is high in primary productivity (eutrophic) with fair water quality. Due to eutrophic conditions Echo Lake is susceptible to algal blooms. Cyanobacteria blooms could produce toxins harmful to humans and animals. When algae blooms are present in Echo Lake they are tested for toxins under the Department of Ecology Freshwater Algae Program. 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.

8.3 Wetlands

The wetlands at Ronald Bog and Twin Ponds have not been monitored by the City since 2013. In general, the wetland stations rated "poor" for dissolved oxygen and temperature at sites that maintained water year-round. pH and turbidity were also rated "poor" to "fair".

Most of the wetlands within Shoreline have been altered via peat mining or other development and receive water inputs from stormwater runoff, streams, and groundwater. The following passage from the 2009 Report (Shoreline 2010) summarizes the conditions well:

> *Wetlands, like lakes, are considered a "window" into the groundwater water table and the water tends to flow much more slowly through them than in streams. This means that the water in wetlands is not getting the chance to mix with oxygen on the surface, as it does in many streams. In addition, the slow moving water has more residence time in a wetland and can be more affected by the process of decaying organic material.*
>
> *Decaying organic material tends to consume oxygen in the process of decomposition. Turbidity can also be affected by the decaying matter and detritus that is present in a wetland. These detritus particles can be suspended in the water column on a frequent basis and are easily stirred up into the water column during sampling activities. Although low dissolved oxygen levels and high turbidity levels are present in most stormwater runoff, the inherent quality of wetlands can make it hard for the water to recover from those variances once it reaches the wetland.*

9 Conclusion

The findings of this report indicate the water quality in the City's waterbodies is moderately to severely impacted by stormwater runoff. Analysis of the longer term trends indicate that these impacts have largely remained steady since data collection began in the early 2000's.

The water quality parameters analyzed in this report can be affected by both natural and artificial inputs. For example, temperature levels in most Puget lowland streams and lakes naturally warms to levels exceeding the Aquatic Life Use standards for salmonids in the summer due to higher air temperatures. 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 a significant water pollution problem within urban areas. 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. Projects like the removal of Hidden Lake dam in Boeing Creek and other CIP projects can have meaningful impacts in the streams and lakes in Shoreline. In addition, the conditional Salmon Safe certification obtained by the City in 2019 helps provide prioritization and guidance for salmon habitat. By continuing to increase the program and capital project efforts and targeting the improvements towards stream specific impairments such as bacteria or dissolved oxygen, the City may improve surface water quality conditions.

10 References

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Limitations

Work for this project was performed for the City of Shoreline (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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APPENDIX A

Creek Water Quality Results

A.1 Boeing Creek (BC-2)

Table A.1-1. Aquatic Life Designated Support Use Rating for Boeing Creek at BC-2

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Boeing Creek (BC-2)	2007-2015	GOOD (100%)	GOOD (100%)	POOR (74%)	GOOD (98%)	GOOD (98%)	GOOD (93%)
	2016-2020	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (100%)	FAIR (86%)	GOOD (95%)

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 A.1-2. Primary Contact Recreation Designated Use Support Rating for Boeing Creek at BC-2

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Boeing Creek (BC-2)	2008	91.7%	No	GOOD
	2009	100.0%	No	GOOD
	2010	90.0%	No	GOOD
	2011	75.0%	Yes	FAIR
	2012	87.5%	Yes	FAIR
	2013	91.7%	No	GOOD
	2014	91.7%	No	GOOD
	2015	75.0%	Yes	FAIR
	2016	91.7%	No	GOOD
	2017	100.0%	No	GOOD
	2018	90.0%	No	GOOD
	2019	90.9%	No	GOOD
	2020	80.0%	Yes	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 A.1-3. Ecology Water Quality Index Scores for Boeing Creek at BC-2

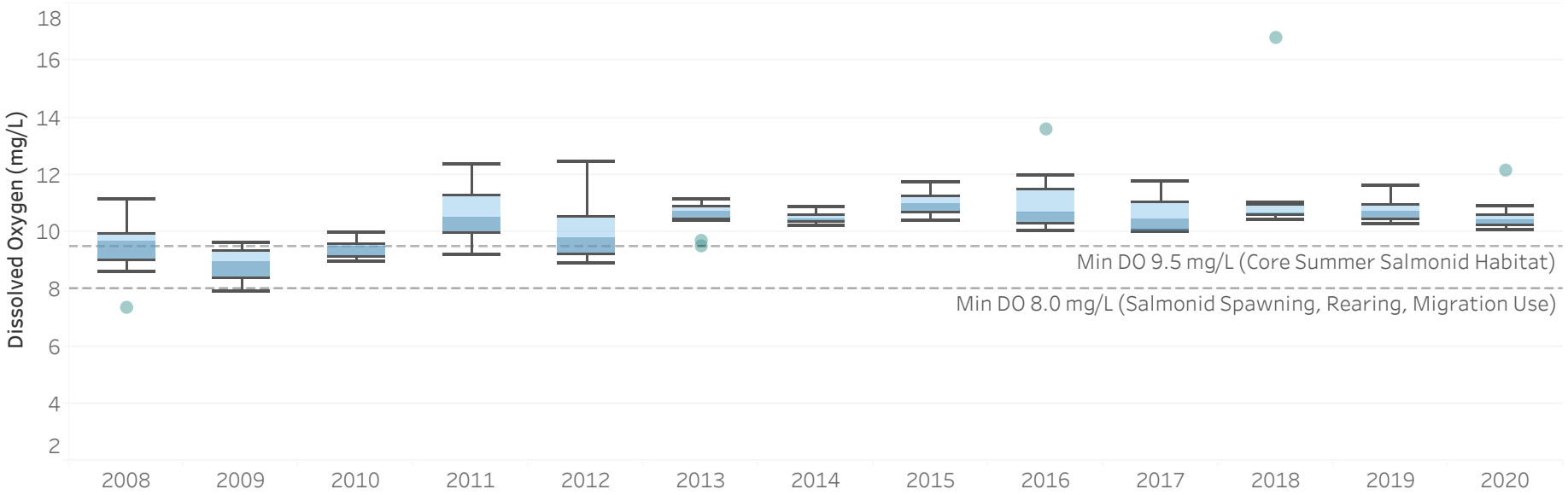
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	74	52	93	77	96	89	94	91	68
2009	88	60	86	80	100	88	99	100	76
2010	78	74	85	83	100	88	99	100	80
2011	49	76	90	72	91	88	99	82	65
2012	71	73	90	76	92	90	93	85	68
2013	57	80	83	72	82	73	98	83	64
2014	74	87	79	82	99	88	97	99	80
2015	38	88	76	78	80	87	98	81	48
2016	71	85	67	76	100	88	95	100	75
2017	81	85	84	77	93	89	97	99	86
2018	65	89	66	71	92	88	97	97	72
2019	70	87	78	77	99	88	90	97	73
2020	62	85	70	73	95	87	100	92	69

Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

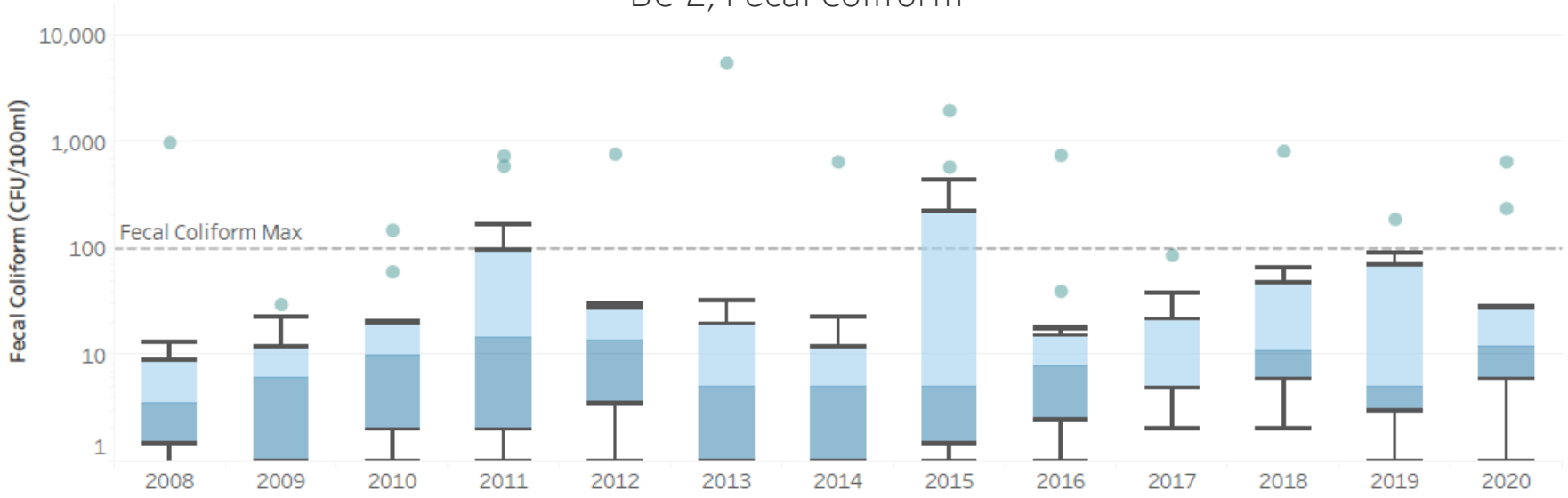
Table A.1-4. B-IBI scores for Boeing Creek at BC-2 and BC-4

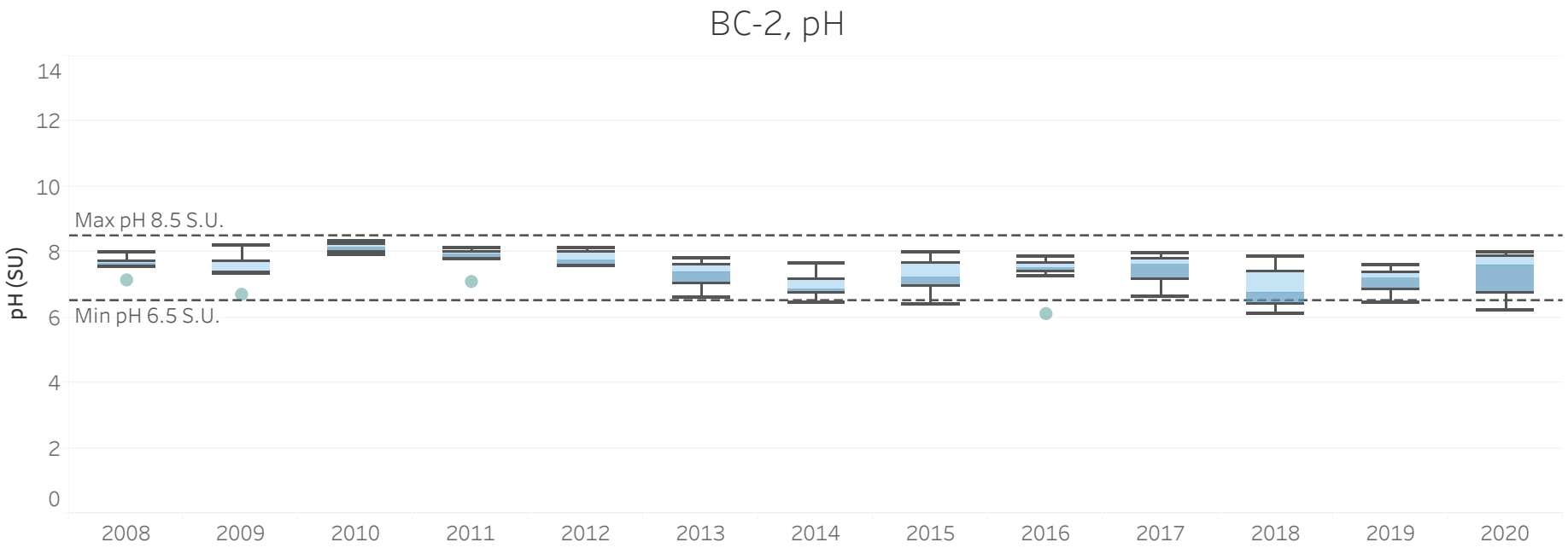
Sampling Site	Year	Score	Level of Impairment
Boeing Creek (BC-2)	2003	14	Extreme
	2007	14	Extreme
Boeing Creek (BC-4)	2003	12	Extreme
	2007	14	Extreme

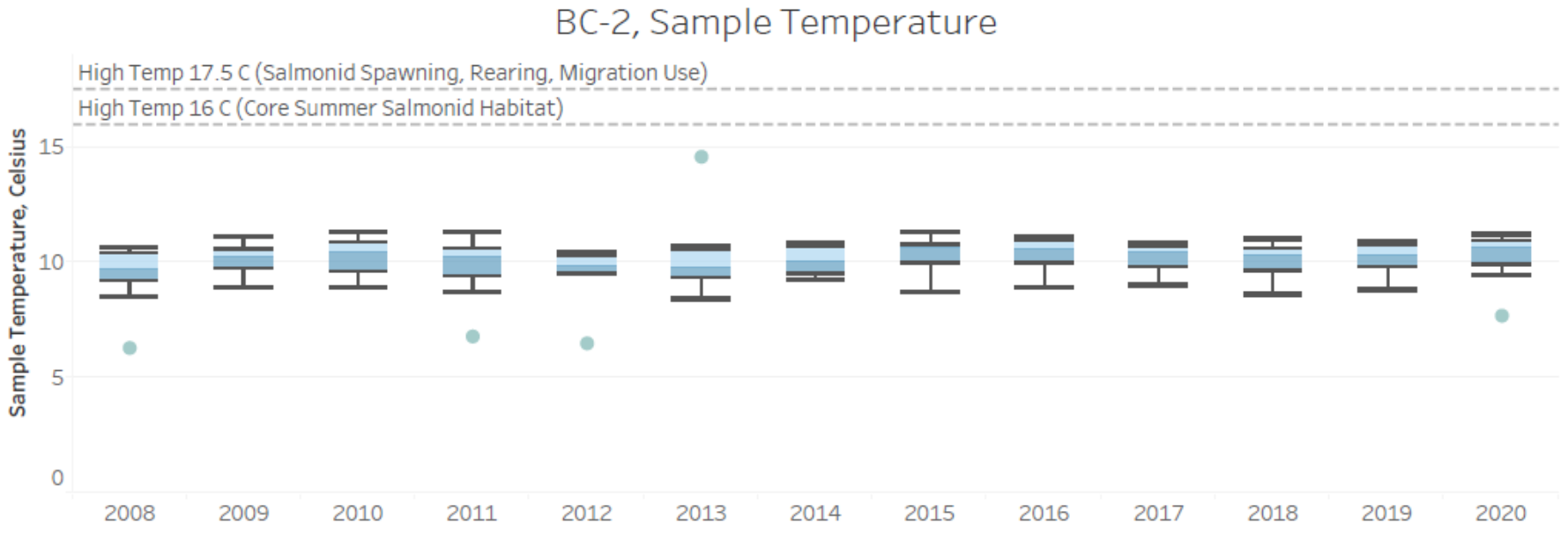
BC-2, Dissolved Oxygen



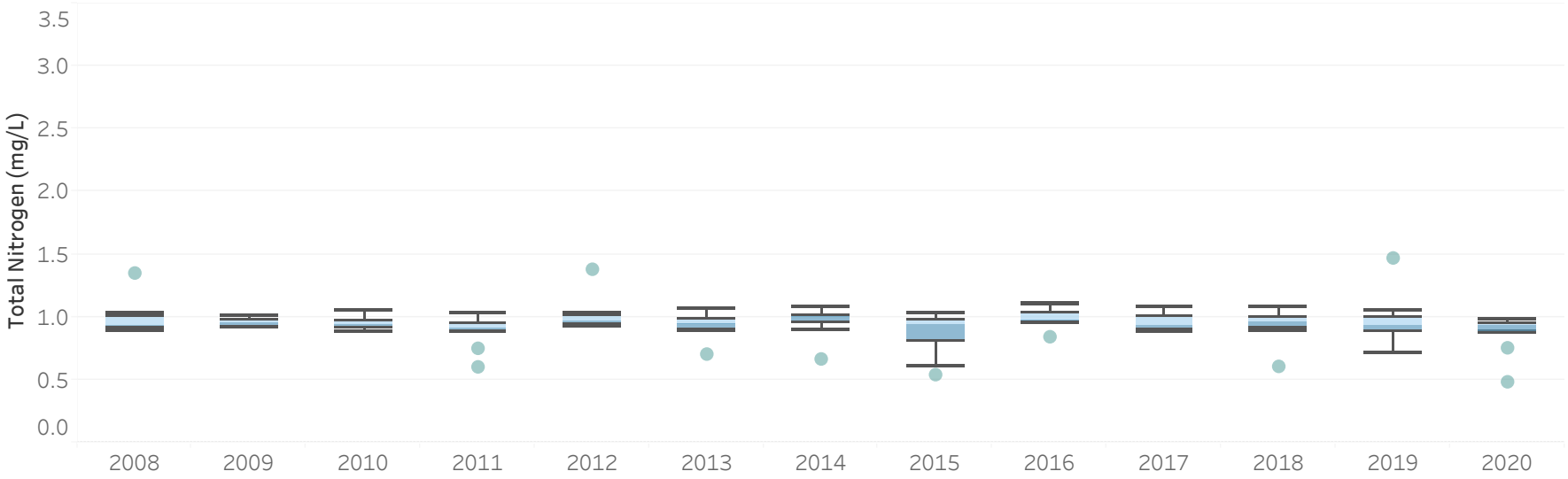
BC-2, Fecal Coliform



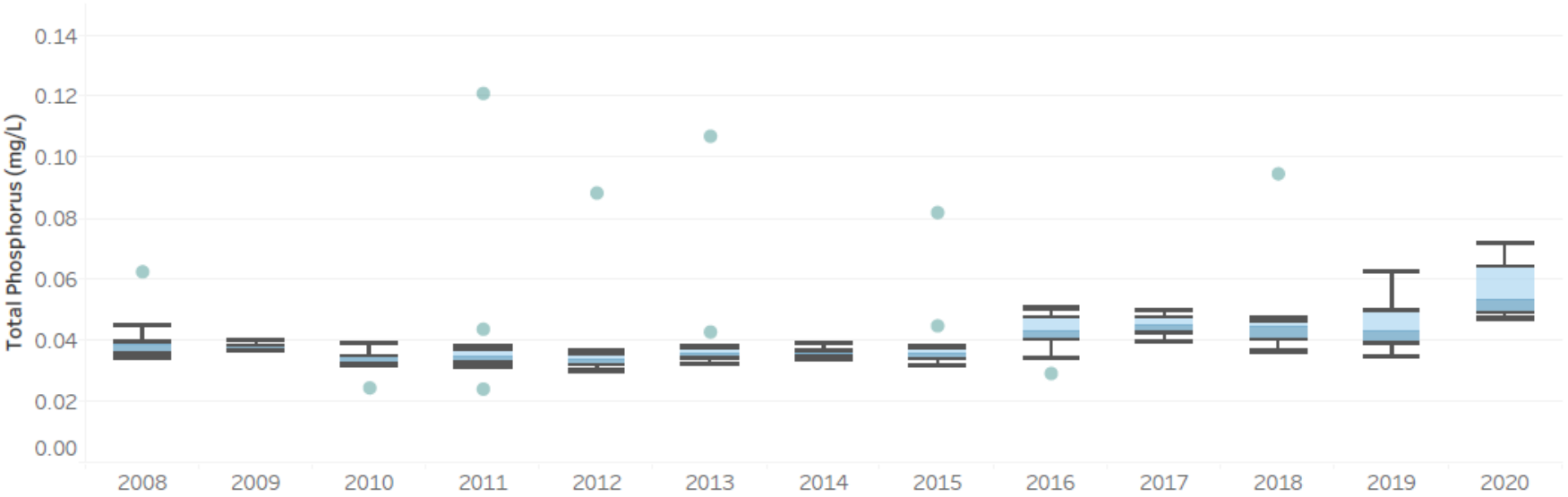

BC-2, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


BC-2, Sample Temperature
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
Sample Temperature, Celsius
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

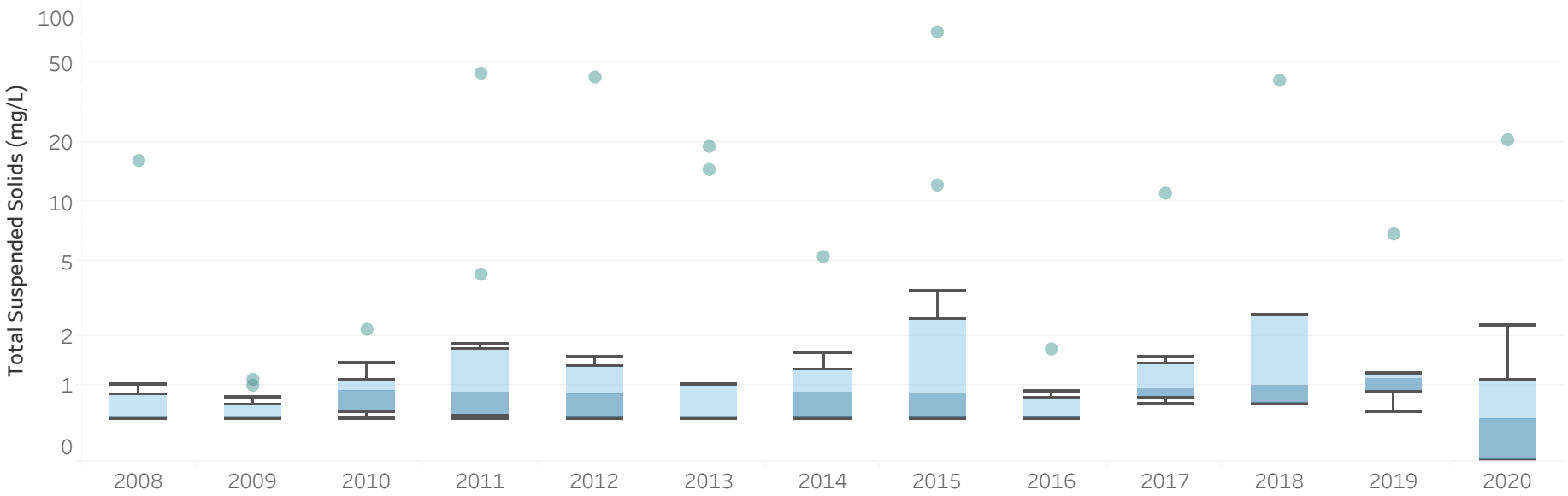
BC-2, Total Nitrogen



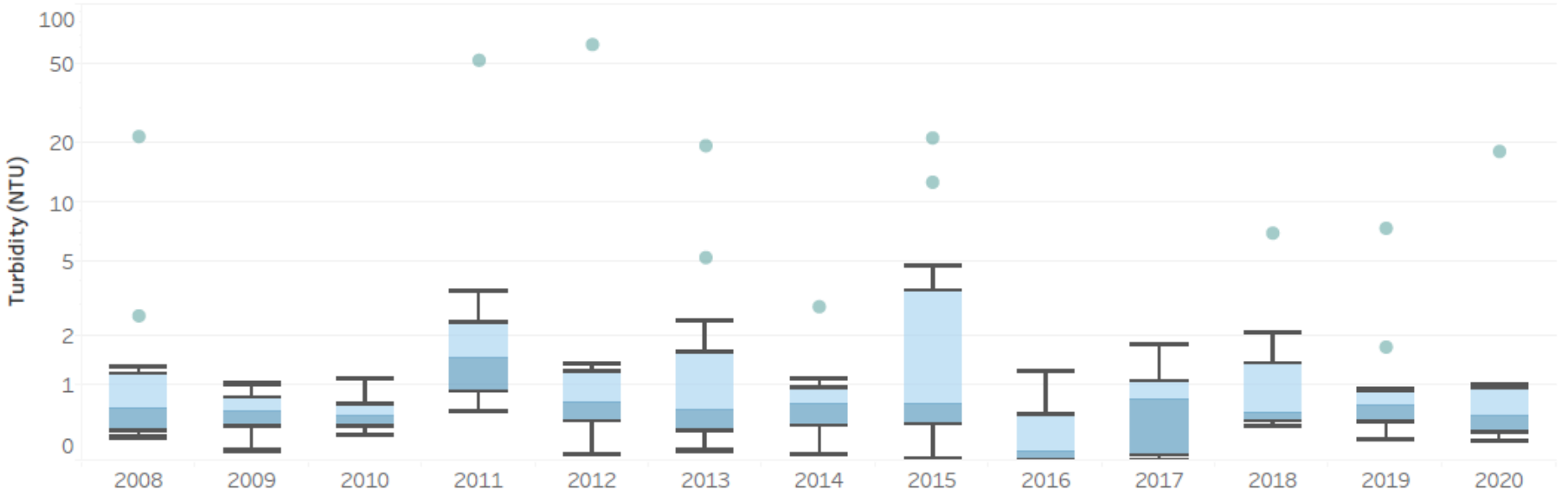
BC-2, Total Phosphorus



BC-2, Total Suspended Solids



BC-2, Turbidity



A.2 Boeing Creek (BC-3)

Table A.2-1. Aquatic Life Designated Use Support Ratings for Boeing Creek at BC-3

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Boeing Creek (BC-3)	2007-2015	GOOD (100%)	GOOD (100%)	FAIR (88%)	GOOD (99%)	GOOD (97%)	GOOD (93%)
	2016-2020	GOOD (100%)	GOOD (100%)	GOOD (98%)	GOOD (100%)	GOOD (93%)	GOOD (98%)

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 A.2-2. Primary Contact Recreation Designated Use Support Rating for Boeing Creek at BC-3

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Boeing Creek (BC-3)	2008	83.3%	Yes	FAIR
	2009	100.0%	No	GOOD
	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
	2016	91.7%	No	GOOD
	2017	100.0%	No	GOOD
	2018	81.8%	Yes	FAIR
	2019	80.0%	Yes	FAIR
	2020	90.0%	No	GOOD

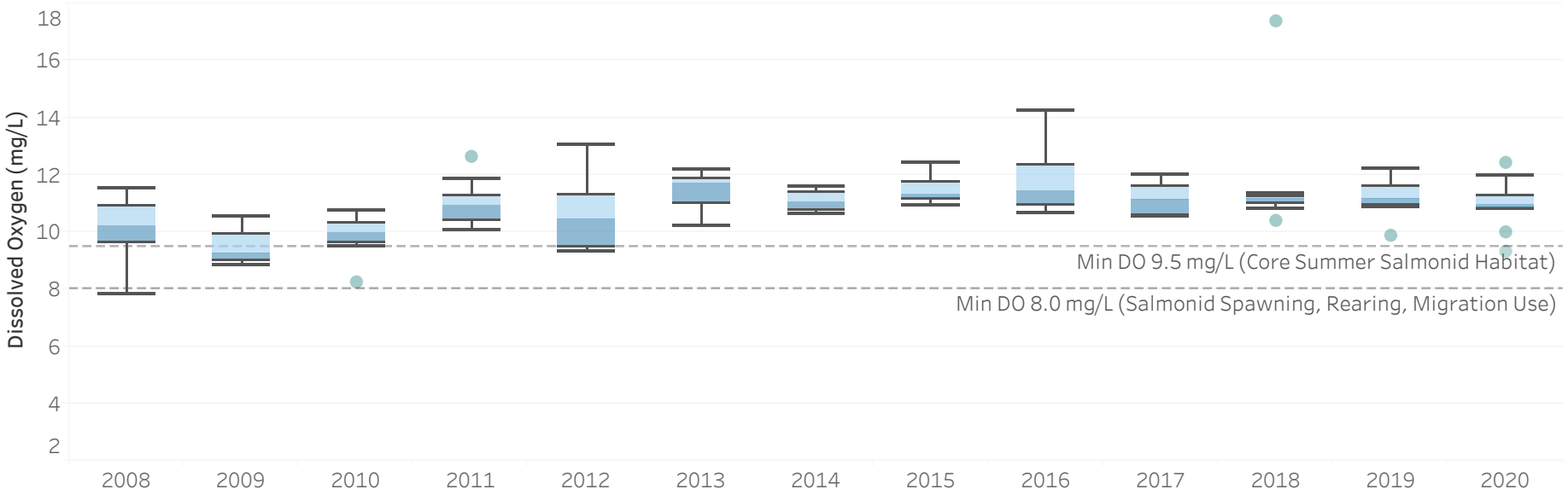
Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

Table A.2-3. Ecology Water Quality Index Scores for Boeing Creek at BC-3

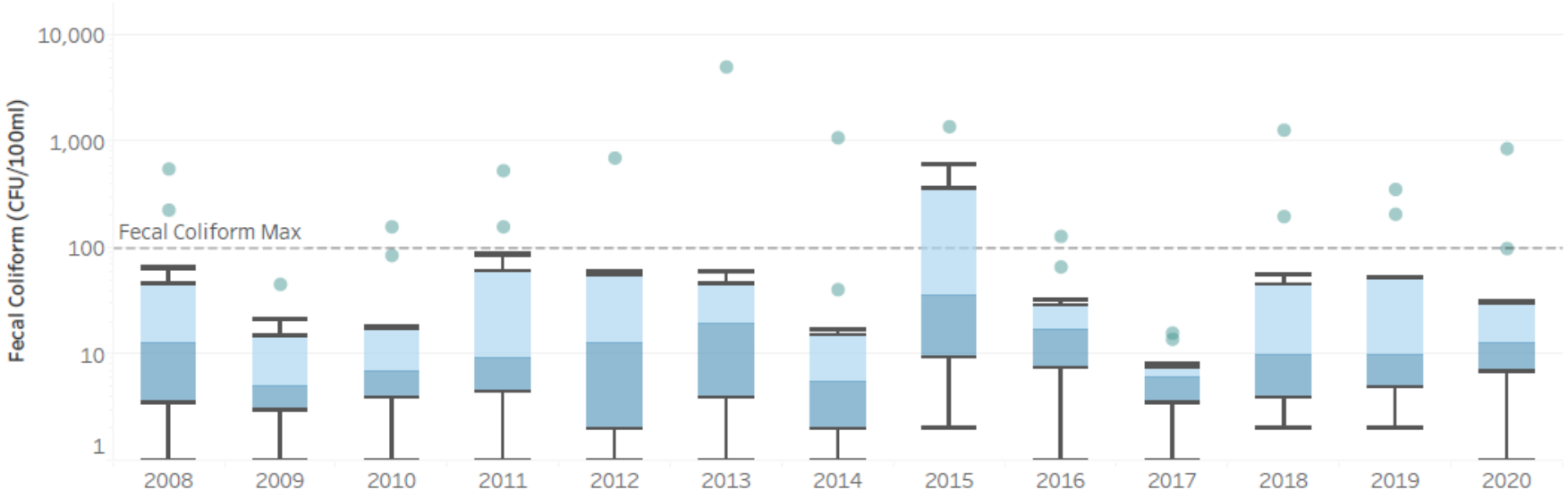
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	61	59	91	74	94	86	70	91	73
2009	87	72	92	75	100	84	70	100	80
2010	76	65	80	79	100	85	73	100	79
2011	61	85	86	74	95	85	70	87	73
2012	66	78	86	78	97	87	68	91	73
2013	52	87	93	70	97	71	66	93	66
2014	68	90	77	77	99	85	64	99	74
2015	41	93	30	77	91	85	63	88	52
2016	76	91	88	75	96	85	66	100	80
2017	93	89	89	76	94	87	74	98	88
2018	57	89	75	74	99	86	77	97	68
2019	64	84	92	76	94	85	74	95	77
2020	65	78	70	73	97	85	76	95	68

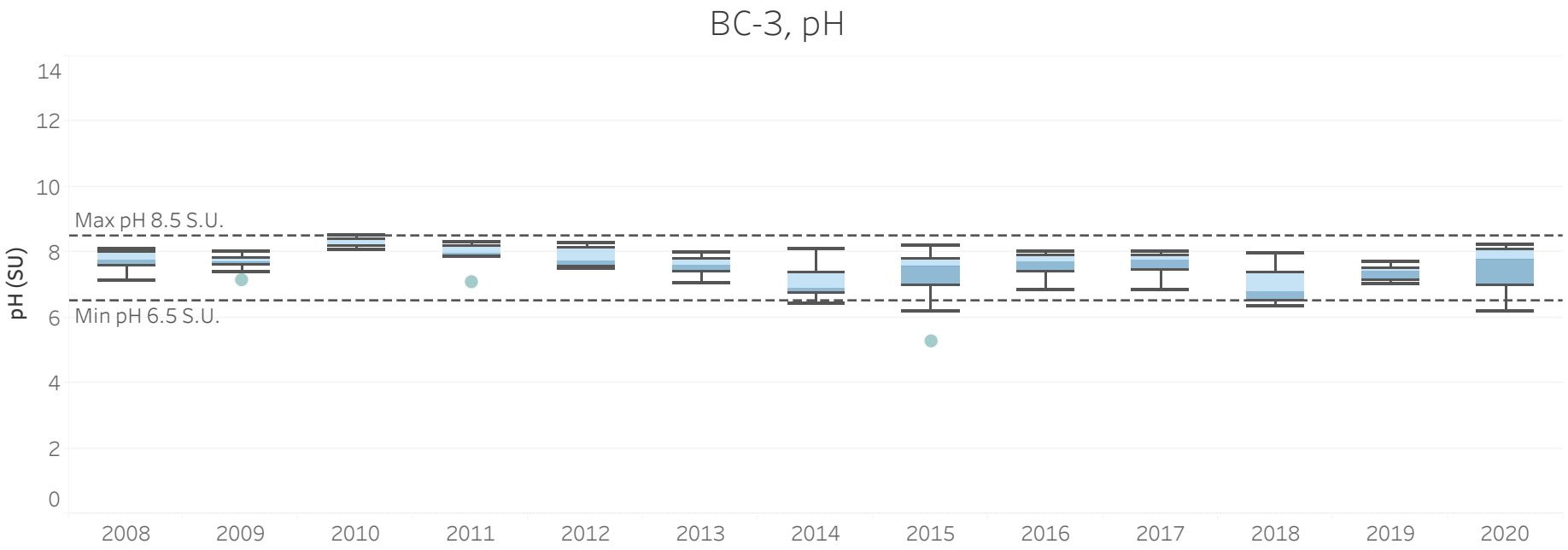
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

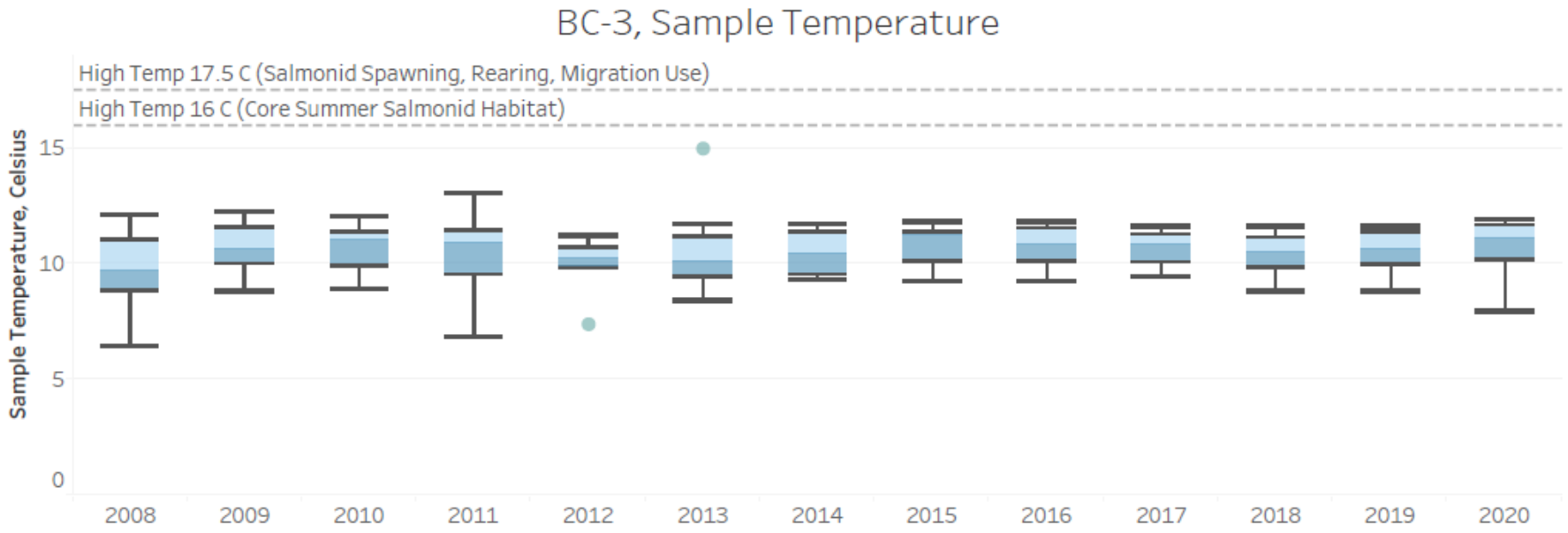
BC-3, Dissolved Oxygen



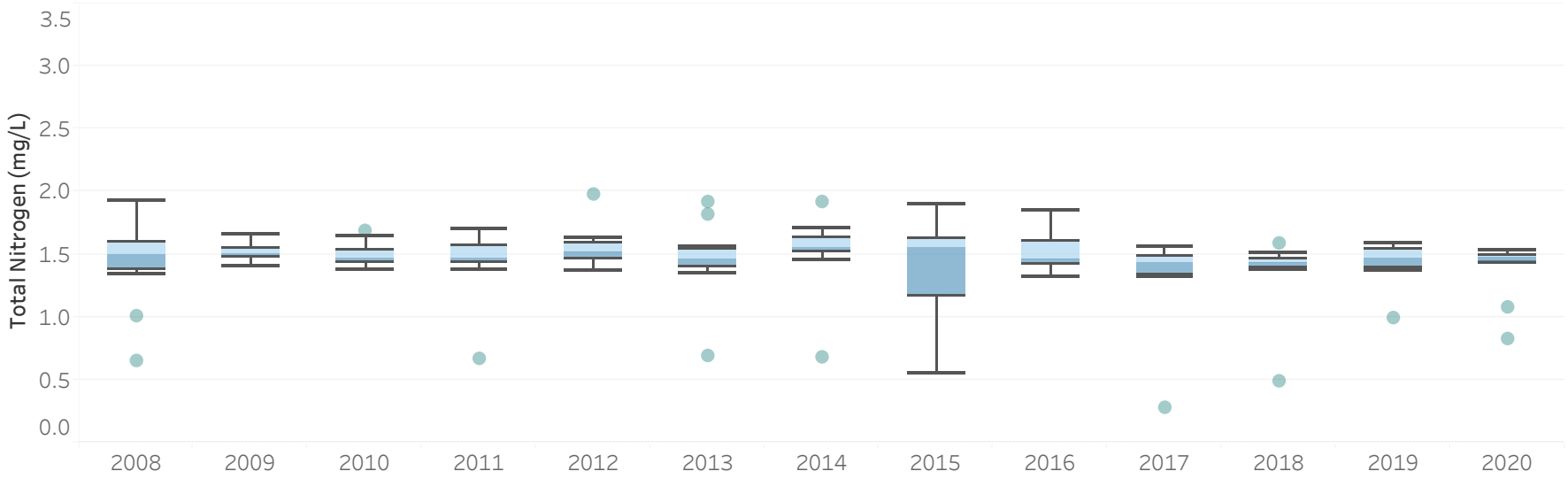
BC-3, Fecal Coliform



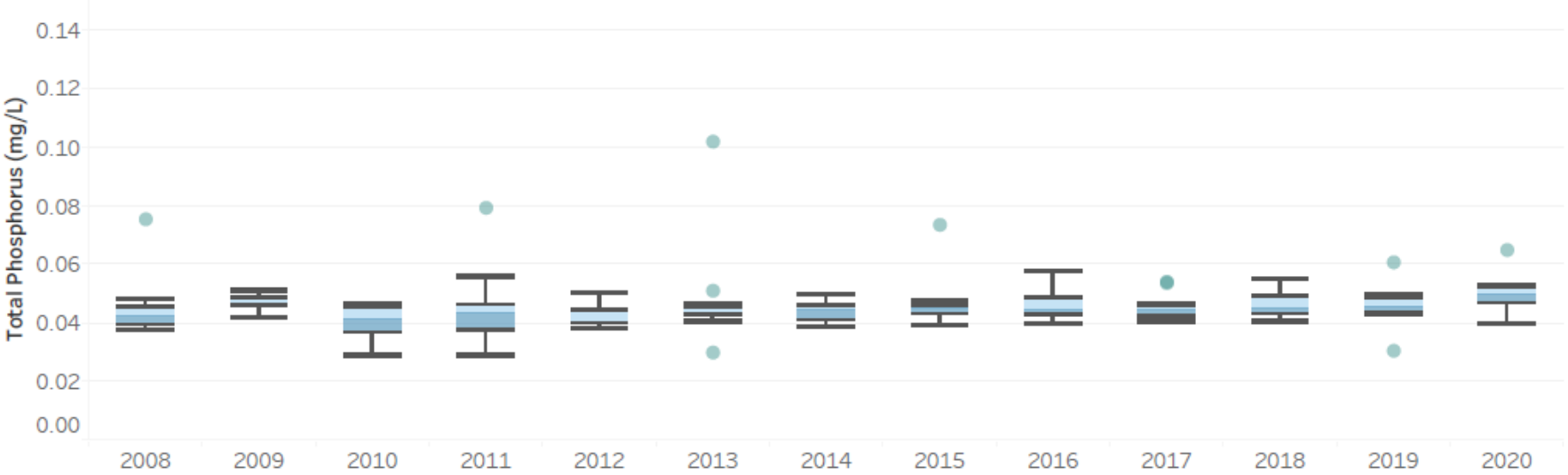

BC-3, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

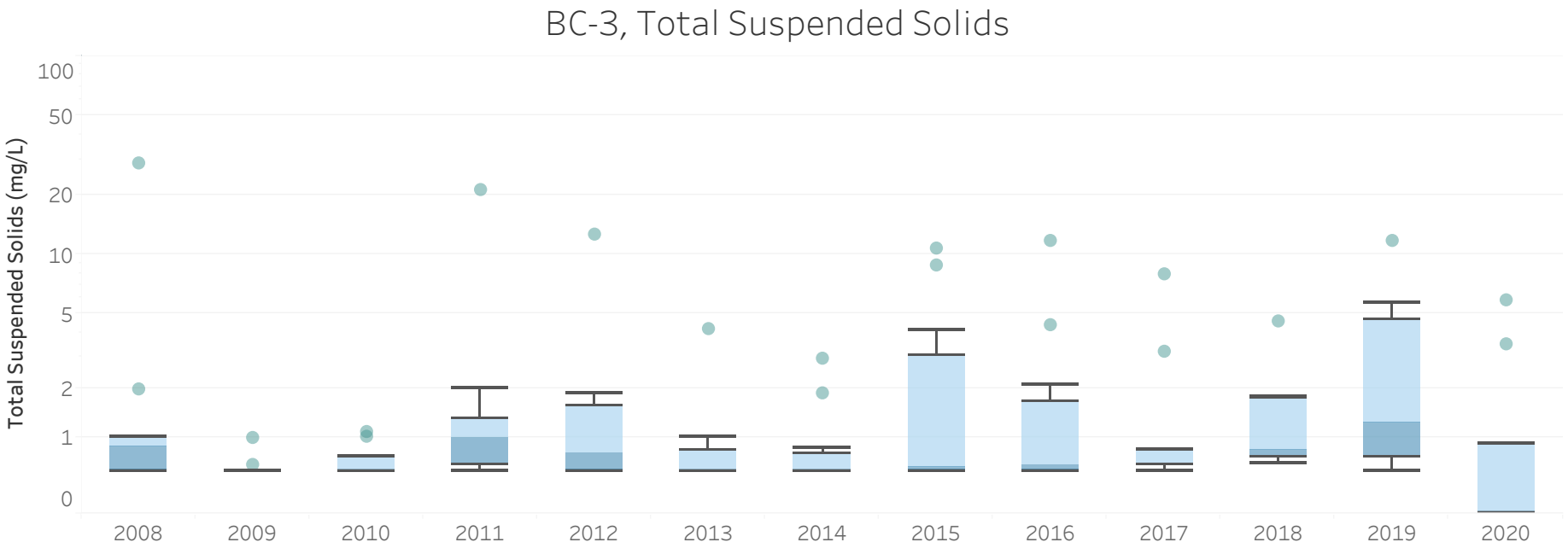

BC-3, Sample Temperature
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
Sample Temperature, Celsius
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

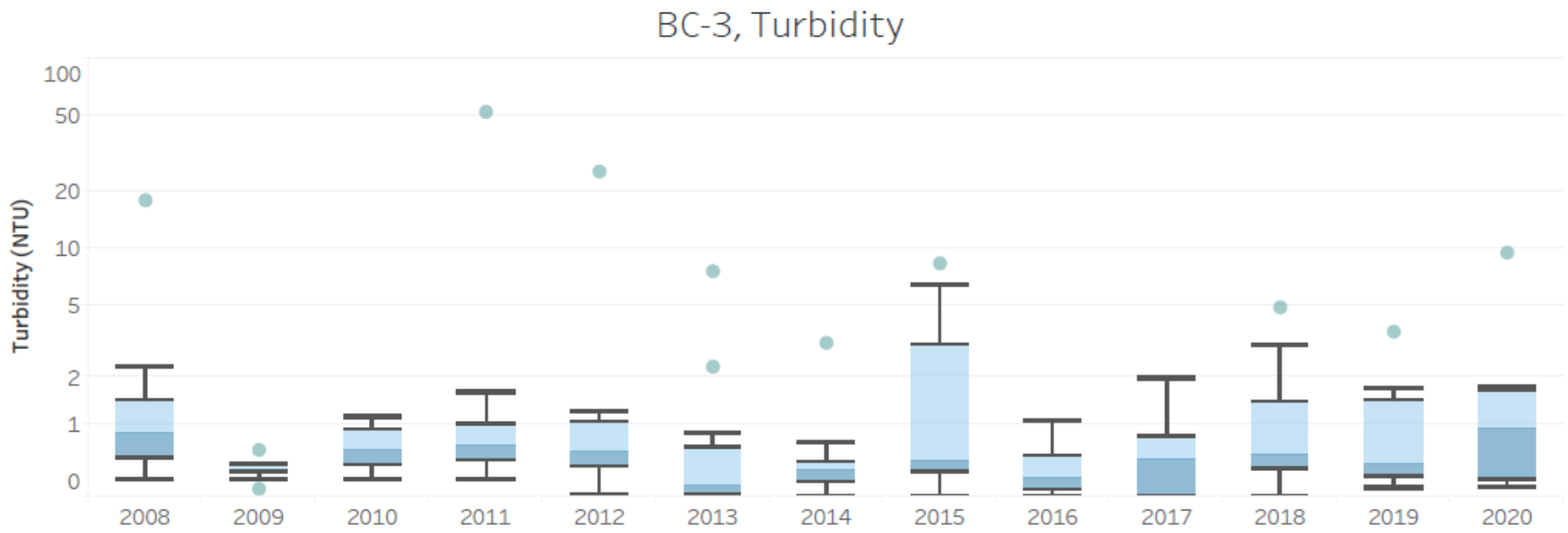
BC-3, Total Nitrogen



BC-3, Total Phosphorus




BC-3, Total Suspended Solids
Total Suspended Solids (mg/L)
100
50
20
10
5
2
1
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


BC-3, Turbidity
Turbidity (NTU)
100
50
20
10
5
2
1
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

A.3 Cedarbrook Creek (CB-1)

Table A.3-1. Aquatic Life Designated Use Support Ratings for Cedarbrook Creek at CB-1

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Cedarbrook Creek (CB-1)	2007-2015	GOOD (100%)	GOOD (100%)	FAIR (90%)	GOOD (99%)	GOOD (98%)	GOOD (97%)
	2016-2020	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (100%)	GOOD (97%)	GOOD (93%)

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 A.3-2. Primary Contact Recreation Designated Use Support Rating for Cedarbrook Creek at CB-1

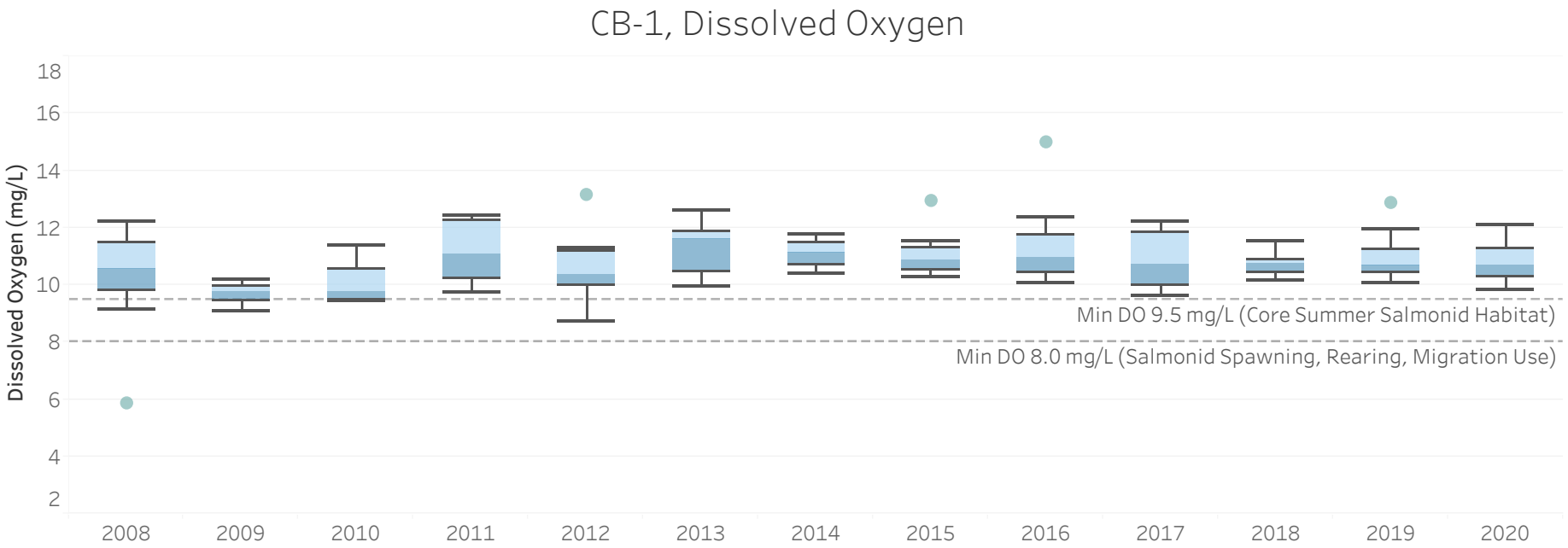
Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Cedarbrook Creek (CB-1)	2008	50.0%	Yes	POOR
	2009	72.7%	Yes	POOR
	2010	40.0%	Yes	POOR
	2011	58.3%	Yes	POOR
	2012	75.0%	Yes	FAIR
	2013	83.3%	Yes	FAIR
	2014	100.0%	No	GOOD
	2015	83.3%	Yes	FAIR
	2016	91.7%	Yes	GOOD
	2017	100.0%	No	GOOD
	2018	66.7%	Yes	POOR
	2019	66.7%	Yes	POOR
	2020	50.0%	Yes	POOR

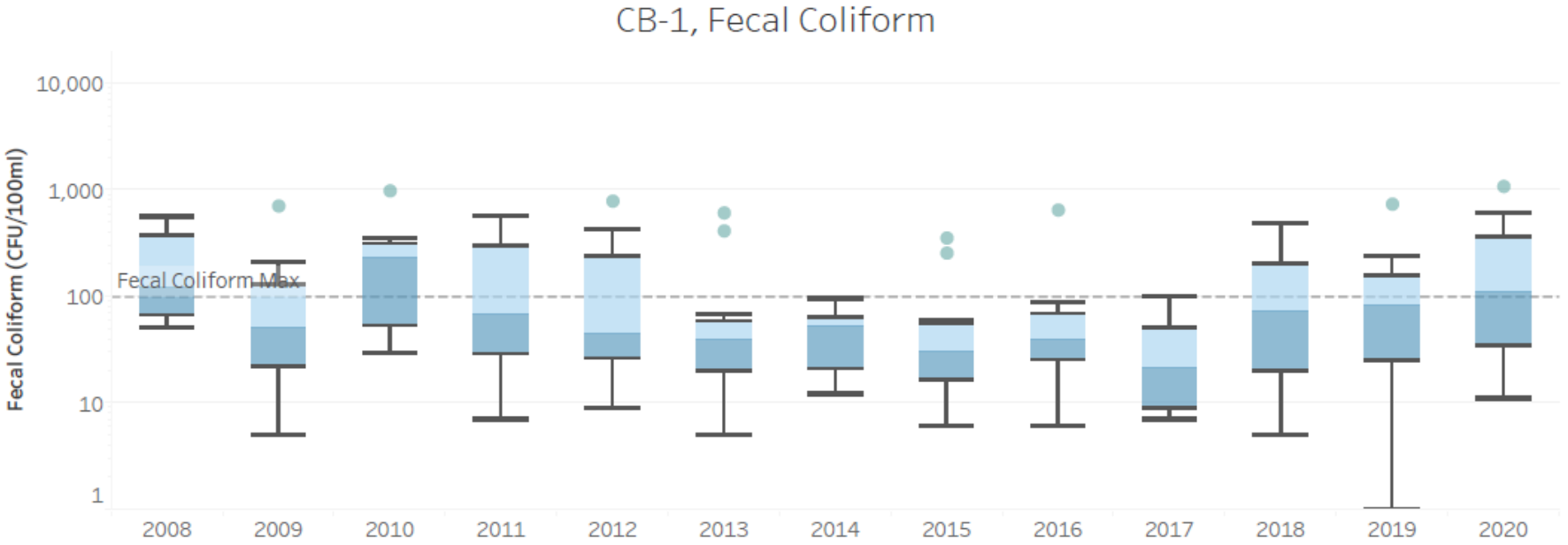
Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

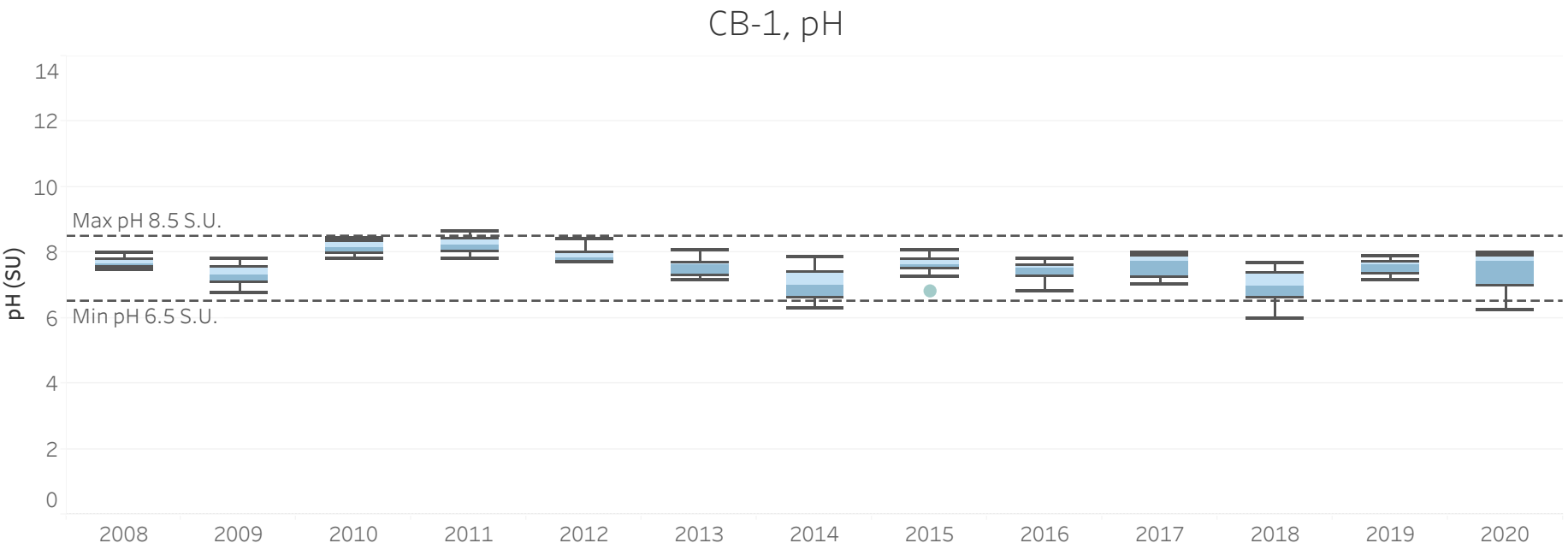
Table A.3-3. Ecology Water Quality Index Scores for Cedarbrook Creek at CB-1

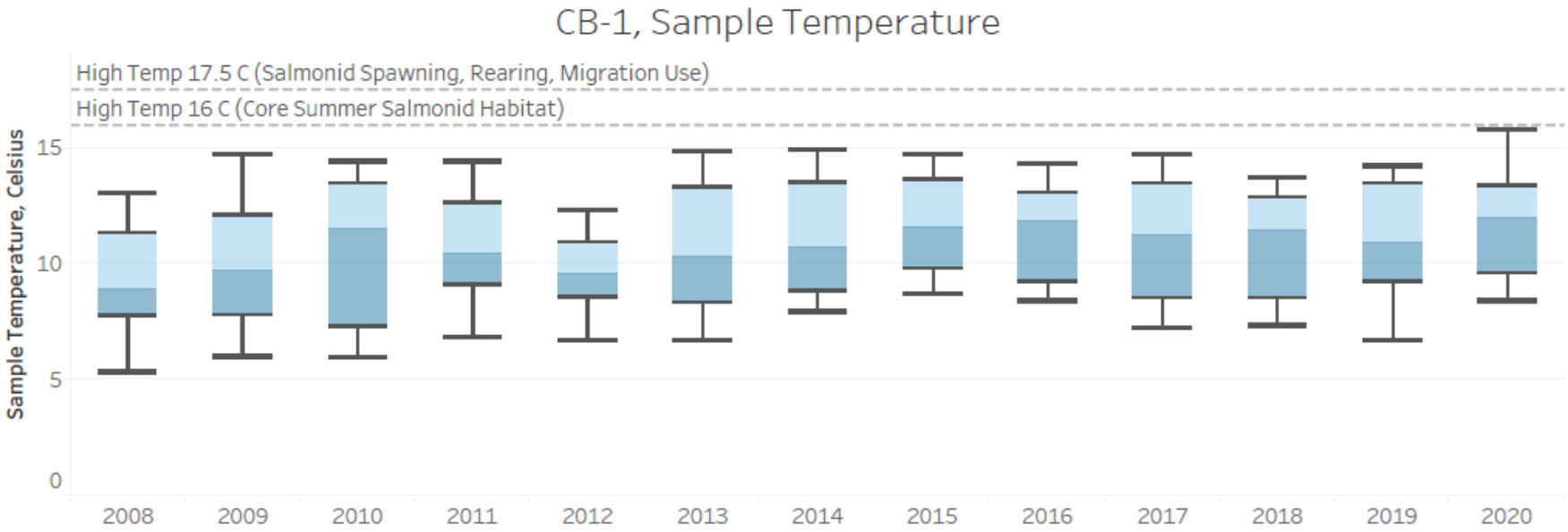
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	48	26	93	77	96	85	43	96	55
2009	55	75	87	80	93	82	41	95	69
2010	47	79	82	76	96	74	47	93	58
2011	49	82	76	73	93	81	43	93	60
2012	56	71	83	77	89	83	54	86	64
2013	57	84	92	58	95	76	46	95	60
2014	74	88	73	68	78	75	37	77	58
2015	63	87	89	58	80	76	46	82	68
2016	63	85	88	67	91	76	50	87	73
2017	74	81	92	71	91	77	47	93	79
2018	54	86	62	70	88	80	45	88	59
2019	53	85	95	74	96	76	52	97	67
2020	43	83	72	73	93	76	56	96	57

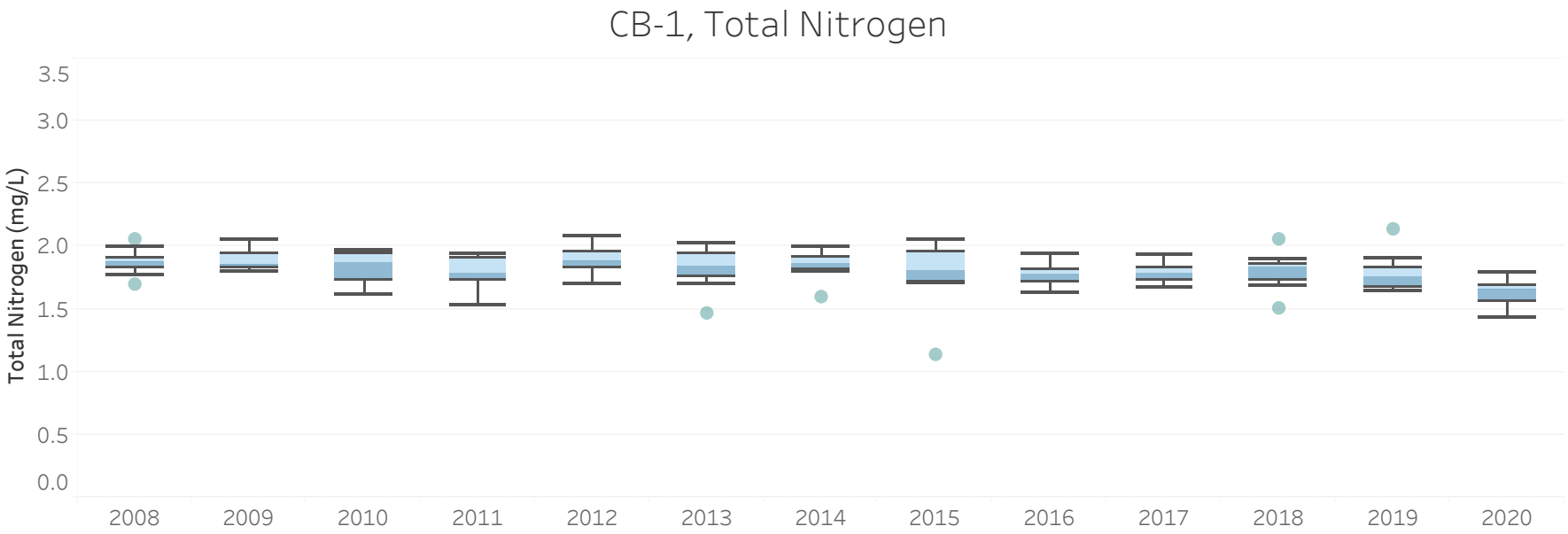
Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

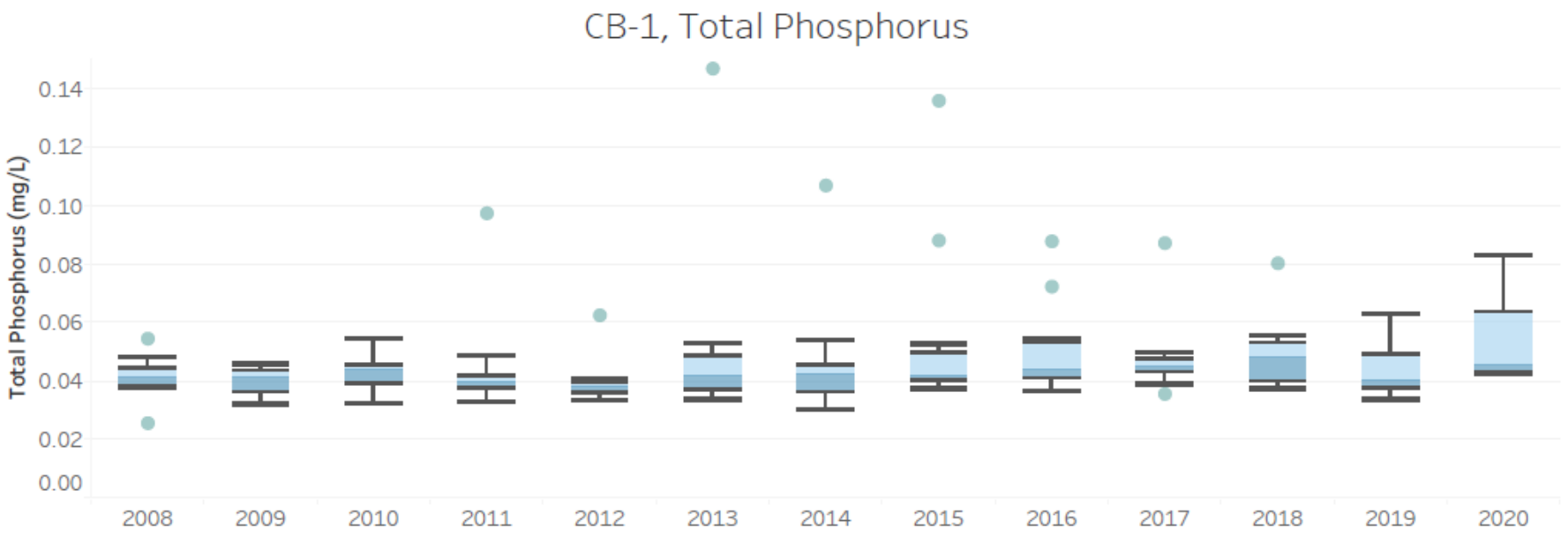

CB-1, Dissolved Oxygen
Dissolved Oxygen (mg/L)
18
16
14
12
10
8
6
4
2
Min DO 9.5 mg/L (Core Summer Salmonid Habitat)
Min DO 8.0 mg/L (Salmonid Spawning, Rearing, Migration Use)
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


CB-1, Fecal Coliform
Fecal Coliform (CFU/100ml)
10,000
1,000
100
10
1
Fecal Coliform Max
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

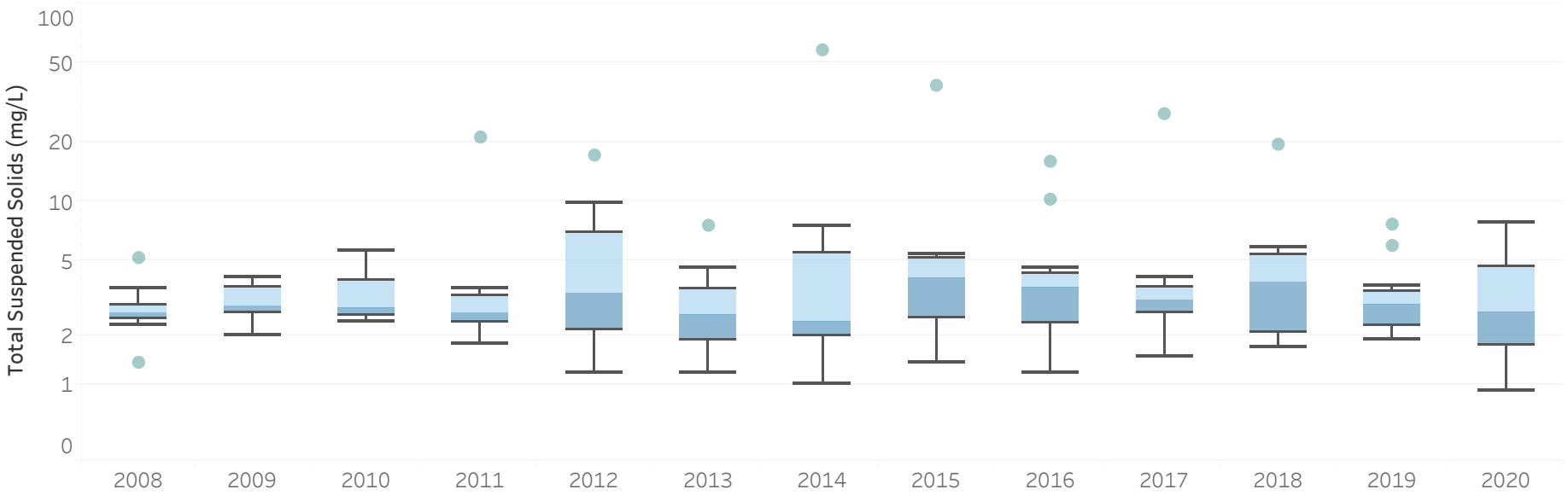

CB-1, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


CB-1, Sample Temperature
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
Sample Temperature, Celsius
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

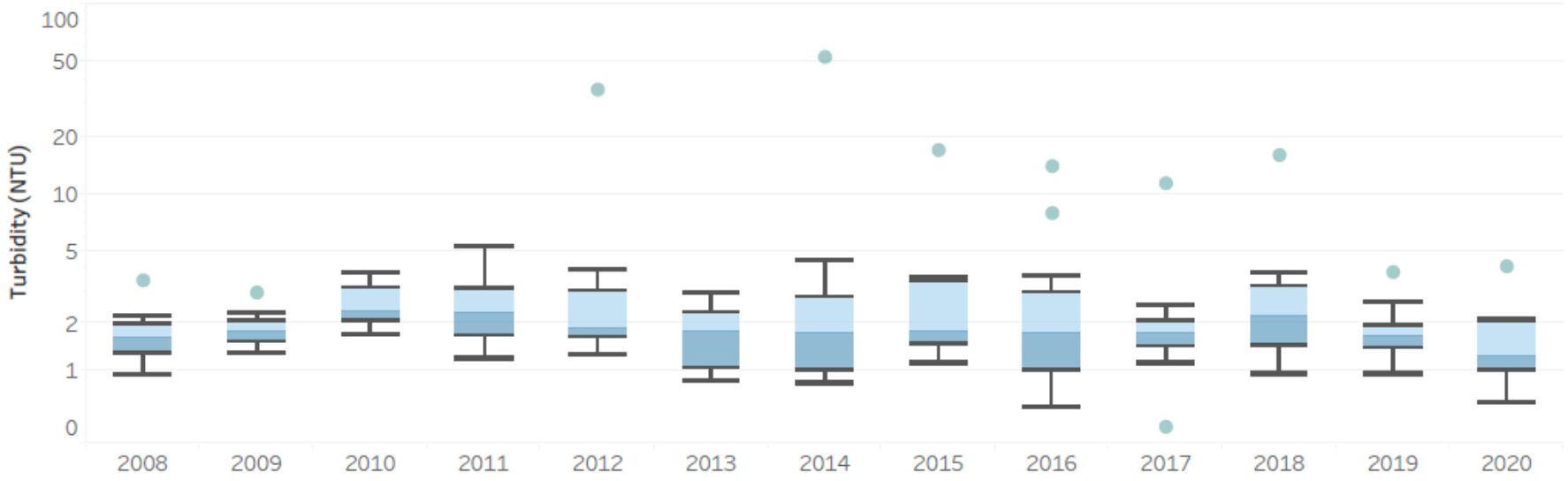

CB-1, Total Nitrogen
Total Nitrogen (mg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


CB-1, Total Phosphorus
Total Phosphorus (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

CB-1, Total Suspended Solids



CB-1, Turbidity



A.4 Littles Creek (LT-1)

Table A.4-1. Aquatic Life Designated Use Support Ratings for Littles Creek at LT-1

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Littles Creek (LT-1)	2007-2015	GOOD (100%)	GOOD (100%)	POOR (22%)	POOR (50%)	GOOD (97%)	GOOD (94%)
	2016-2020	GOOD (100%)	GOOD (100%)	POOR (15%)	POOR (33%)	GOOD (95%)	GOOD (93%)

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 A.4-2. Primary Contact Recreation Designated Use Support Rating for Littles Creek at LT-1

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Littles Creek (LT-1)	2008	16.7%	Yes	POOR
	2009	40.0%	Yes	POOR
	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
	2016	25.0%	Yes	POOR
	2017	75.0%	Yes	FAIR
	2018	33.3%	Yes	POOR
	2019	41.7%	Yes	POOR
	2020	20.0%	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

Table A.4-3. Ecology Water Quality Index Scores for Littles Creek at LT-1

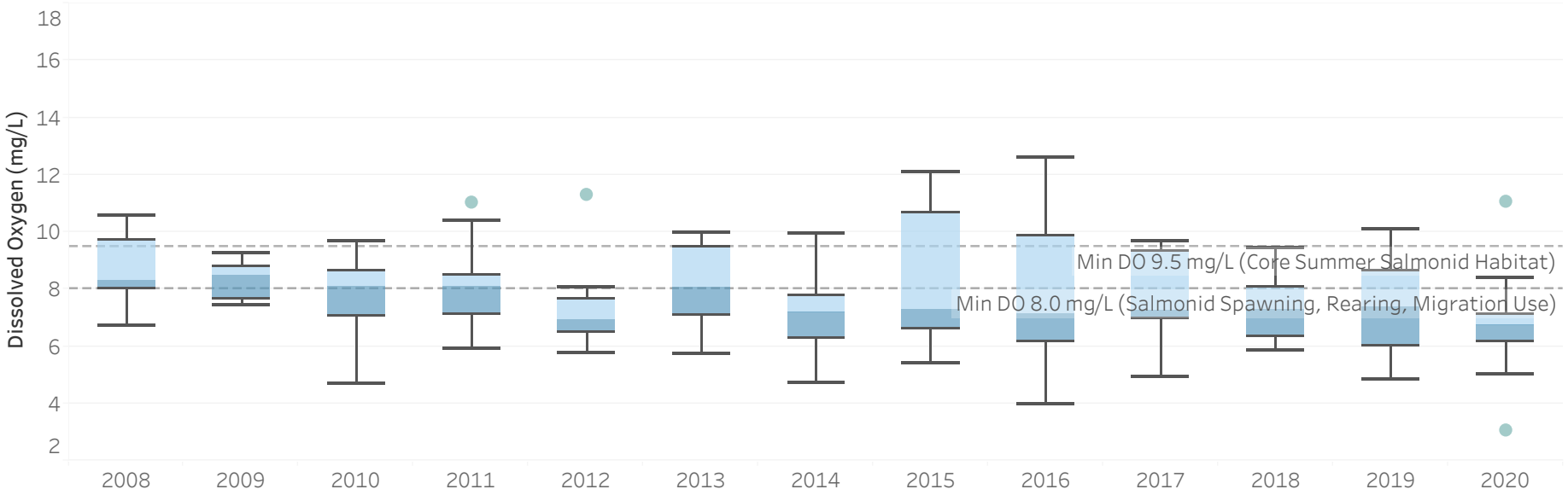
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	35	41	87	65	92	82	41	94	27
2009	14	53	83	78	100	82	41	99	32
2010	35	1	91	77	98	74	59	97	21
2011	35	26	90	65	92	81	41	91	23
2012	42	23	93	75	94	81	63	87	33
2013	21	22	91	75	85	69	59	94	16
2014	24	1	73	81	99	76	63	99	13
2015	7	16	87	67	79	80	75	79	12
2016	29	1	89	78	98	78	73	98	14
2017	58	6	90	73	94	79	66	92	43
2018	22	25	42	68	87	79	72	83	3
2019	40	4	92	75	100	74	74	94	15
2020	40	1	82	72	85	75	70	88	20

Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

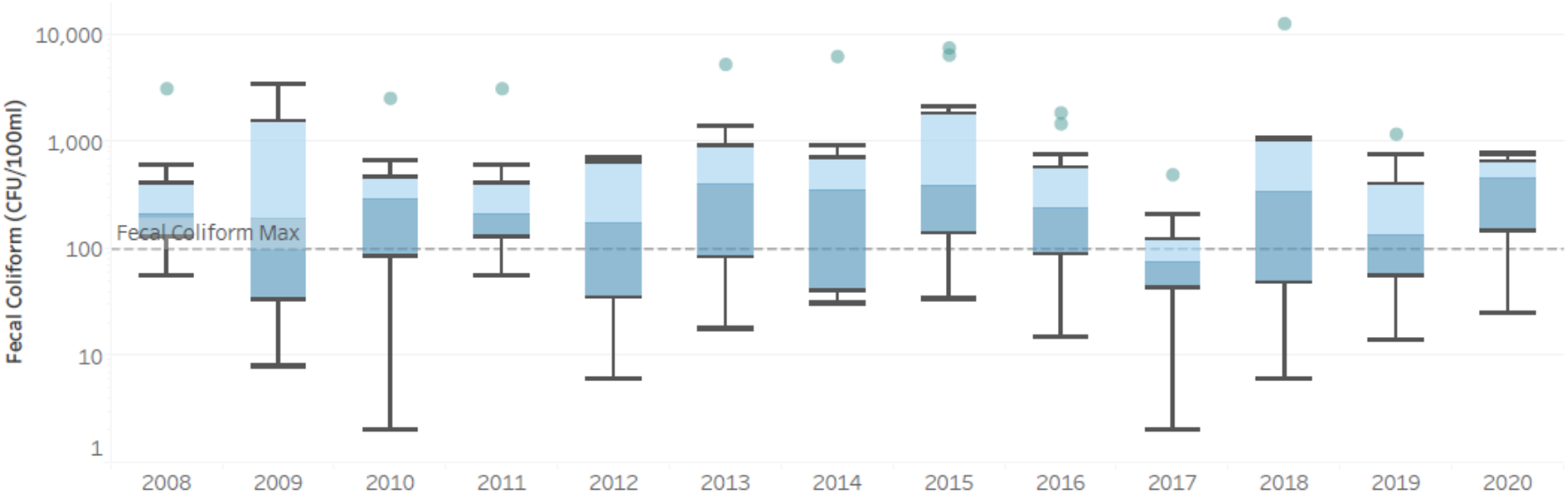
Table A.4-4. B-IBI score for Littles Creek at LT-1

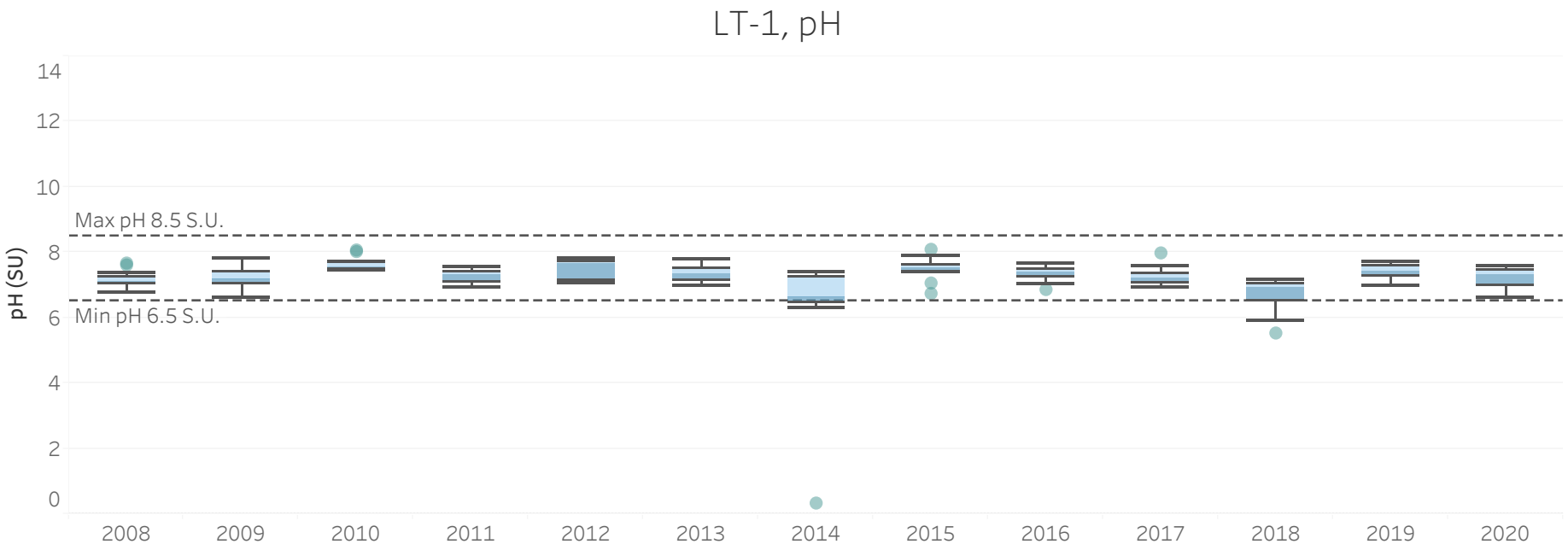
Sampling Site	Year	Score	Level of Impairment
Littles Creek (LT-1)	2003	16	Extreme

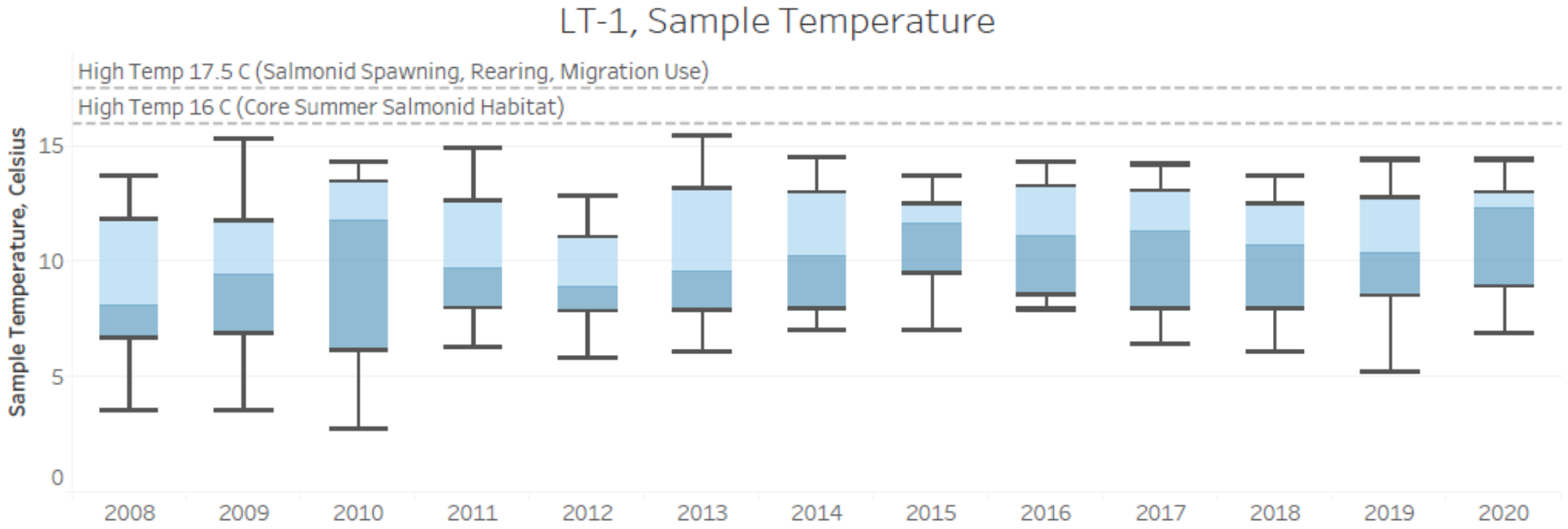
LT-1, Dissolved Oxygen



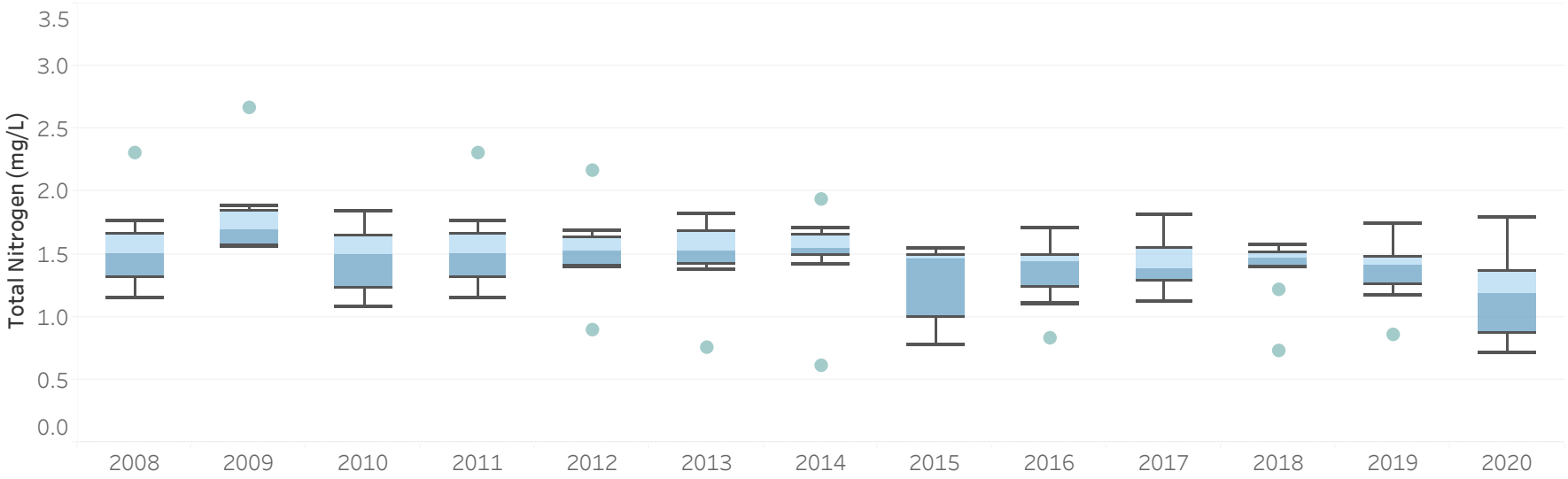
LT-1, Fecal Coliform



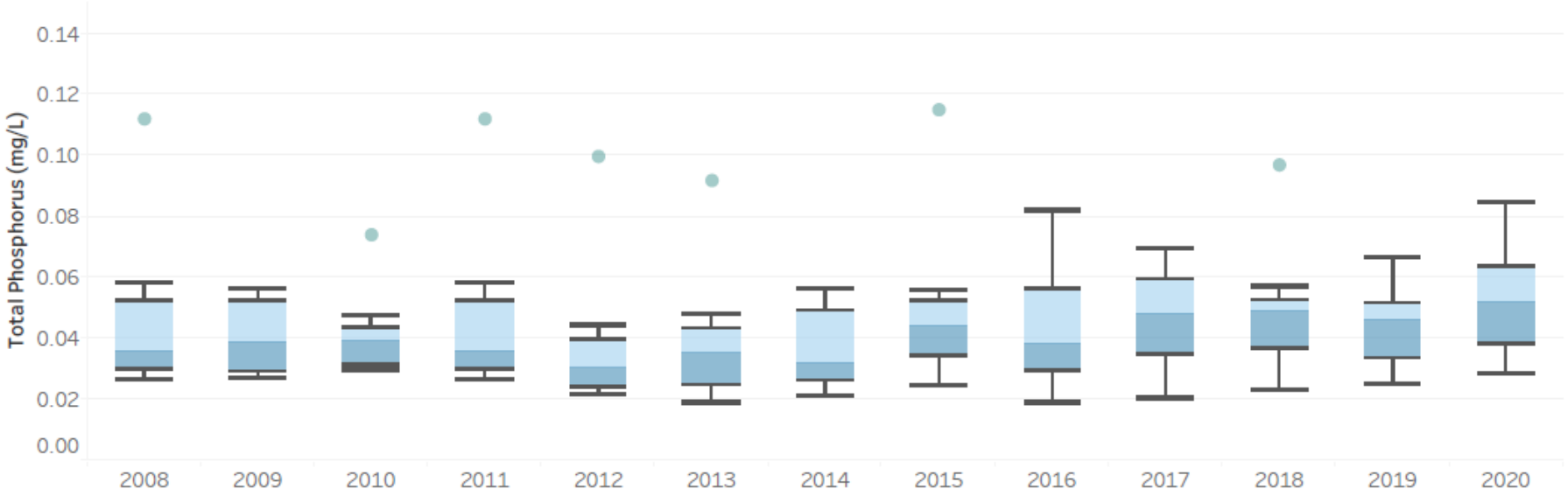

LT-1, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


LT-1, Sample Temperature
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
Sample Temperature, Celsius
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

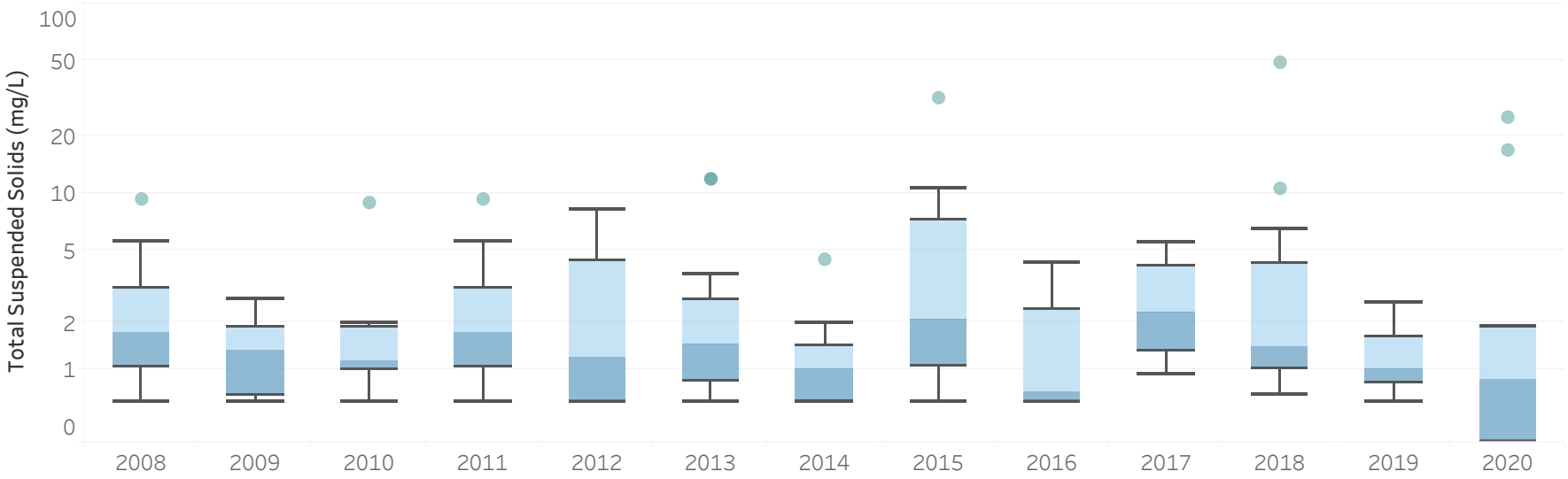
LT-1, Total Nitrogen



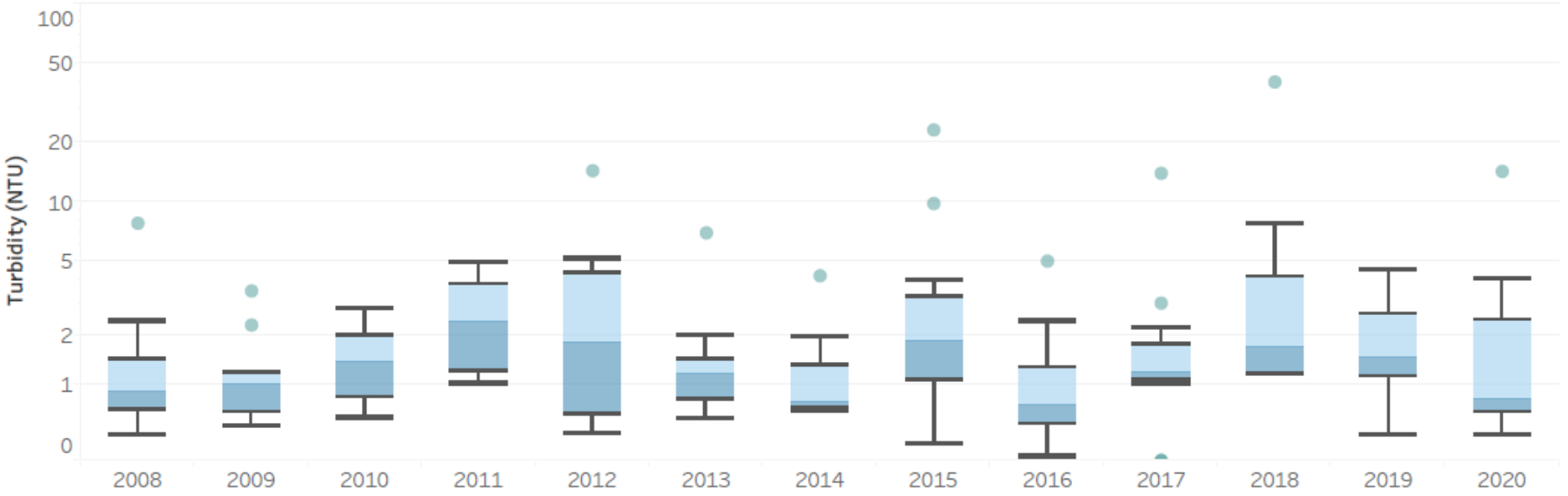
LT-1, Total Phosphorus



LT-1, Total Suspended Solids



LT-1, Turbidity



A.5 McAleer Creek (MC-1)

Table A.5-1. Aquatic Life Designated Use Support Ratings for McAleer Creek at MC-1

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
McAleer Creek (MC-1)	2007-2015	GOOD (92%)	GOOD (99%)	POOR (74%)	GOOD (98%)	GOOD (98%)	GOOD (96%)
	2016-2020	FAIR (90%)	GOOD (100%)	FAIR (87%)	GOOD (98%)	GOOD (95%)	GOOD (97%)

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 A.5-2. Primary Contact Recreation Designated Use Support Rating for McAleer Creek at MC-1

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
McAleer Creek (MC-1)	2008	83.3%	Yes	FAIR
	2009	81.8%	Yes	FAIR
	2010	60.0%	Yes	POOR
	2011	66.7%	Yes	POOR
	2012	75.0%	Yes	FAIR
	2013	91.7%	Yes	GOOD
	2014	81.8%	Yes	FAIR
	2015	50.0%	Yes	POOR
	2016	91.7%	Yes	GOOD
	2017	66.7%	Yes	POOR
	2018	75.0%	Yes	FAIR
	2019	100.0%	No	GOOD
	2020	60.0%	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

Table A.5-3. Ecology Water Quality Index Scores for McAleer Creek at MC-1

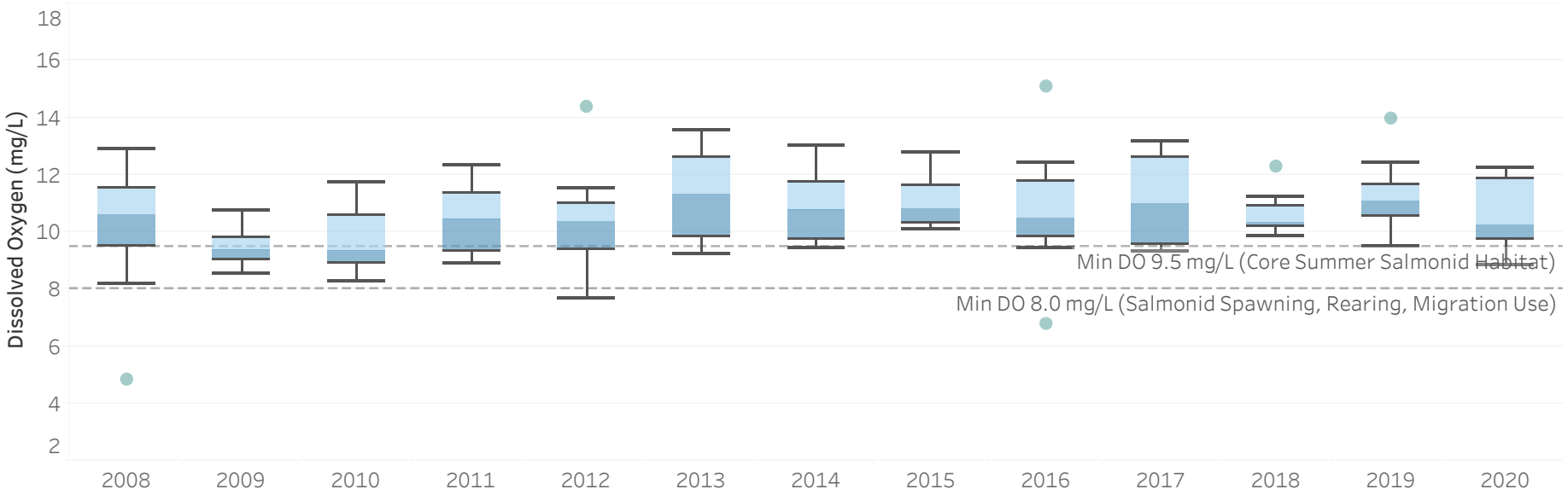
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	63	4	95	78	92	73	63	96	51
2009	61	69	68	78	94	67	41	96	59
2010	52	65	85	85	96	61	67	95	52
2011	51	73	92	81	88	65	81	91	58
2012	61	56	92	81	91	65	88	89	58
2013	67	77	94	75	89	65	65	89	62
2014	65	79	82	54	95	69	35	93	61
2015	51	86	93	76	69	67	45	84	57
2016	71	43	92	79	91	63	68	91	68
2017	51	78	84	76	96	58	62	97	58
2018	60	84	65	76	87	69	59	84	60
2019	74	80	92	67	85	64	60	88	68
2020	56	72	81	72	86	63	65	88	62

Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

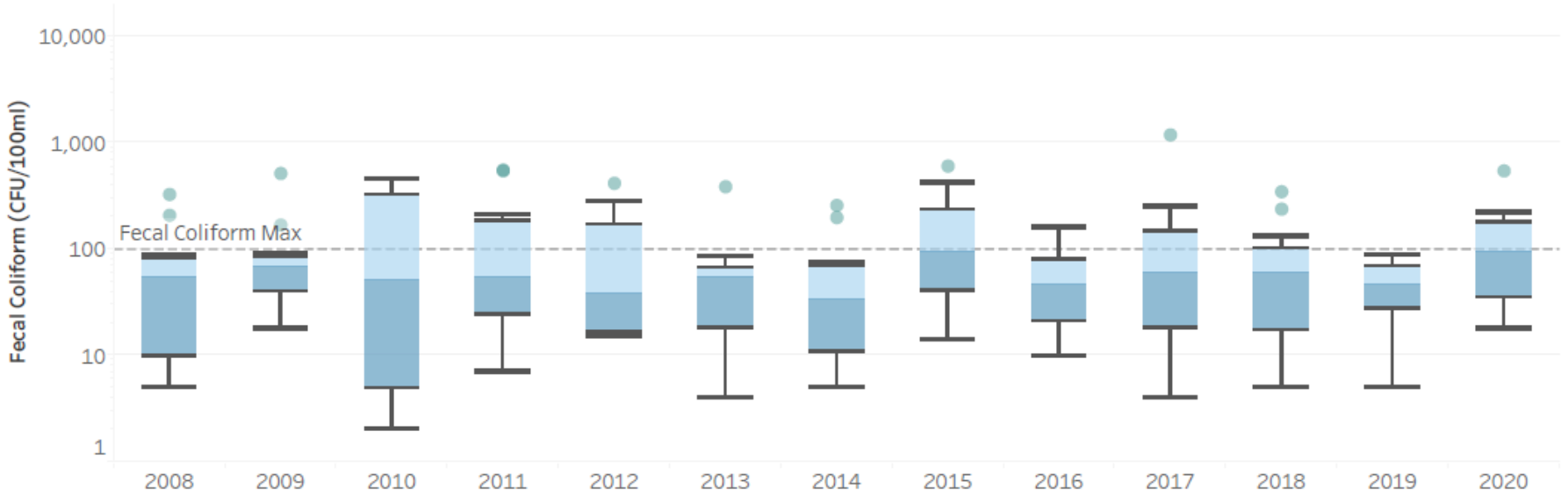
Table A.5-4. B-IBI scores for McAleer Creek at MC-2

Sampling Site	Year	Score	Level of Impairment
McAleer Creek (MC-2)	2003	24	Severe
	2007	18	Extreme

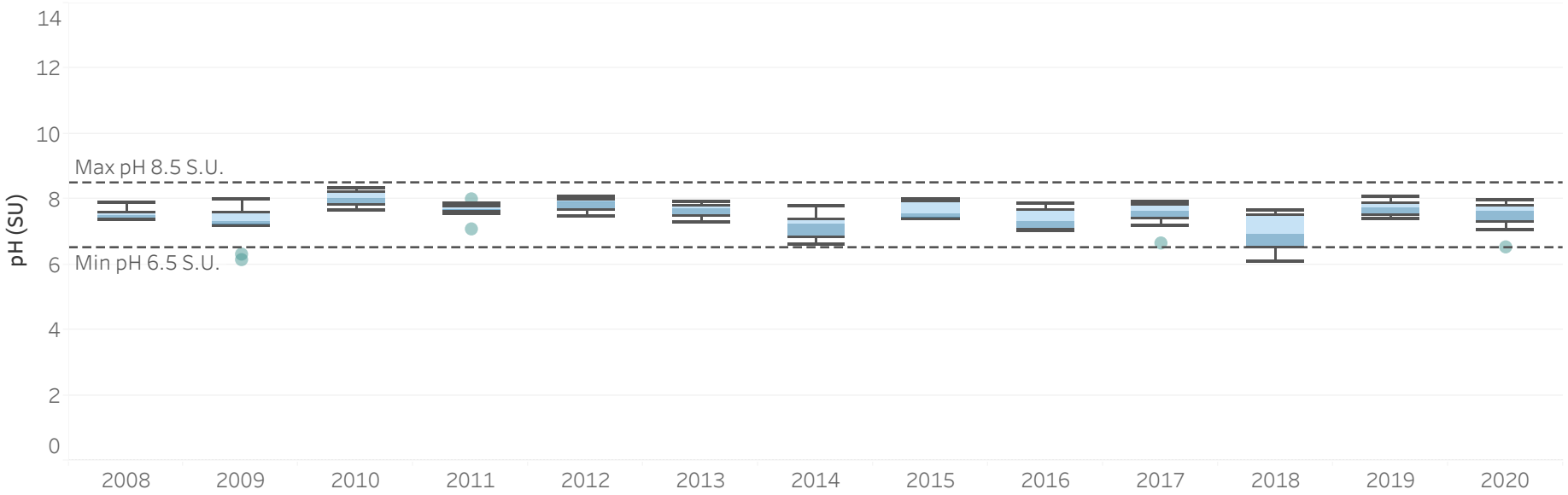
MC-1, Dissolved Oxygen



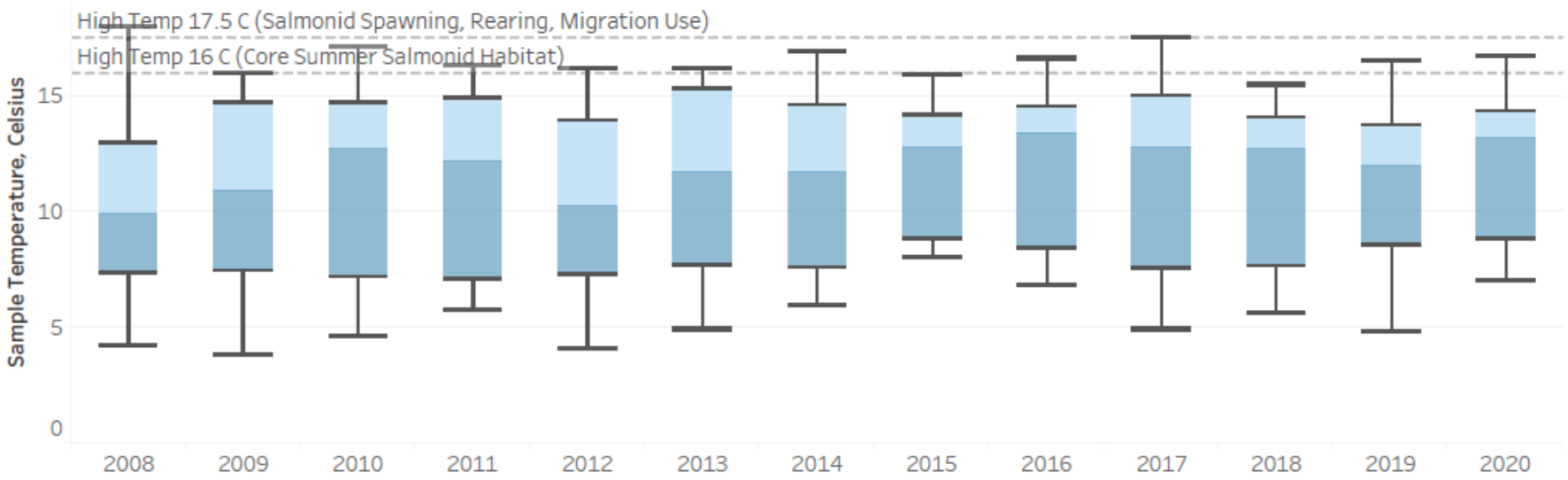
MC-1, Fecal Coliform



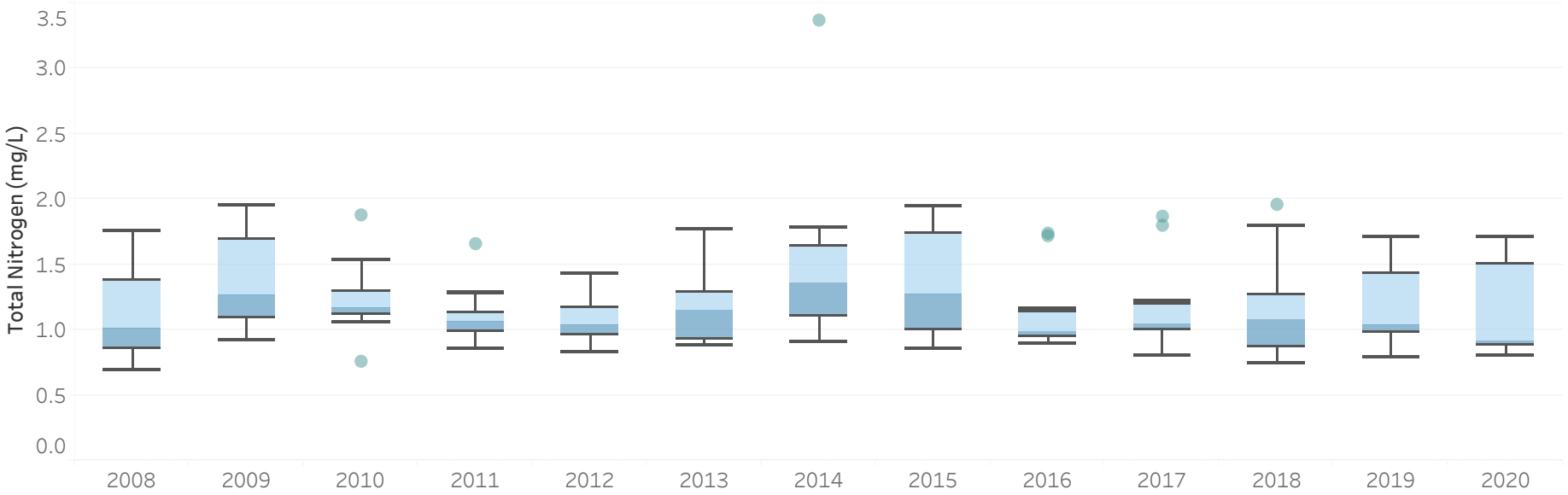
MC-1, pH



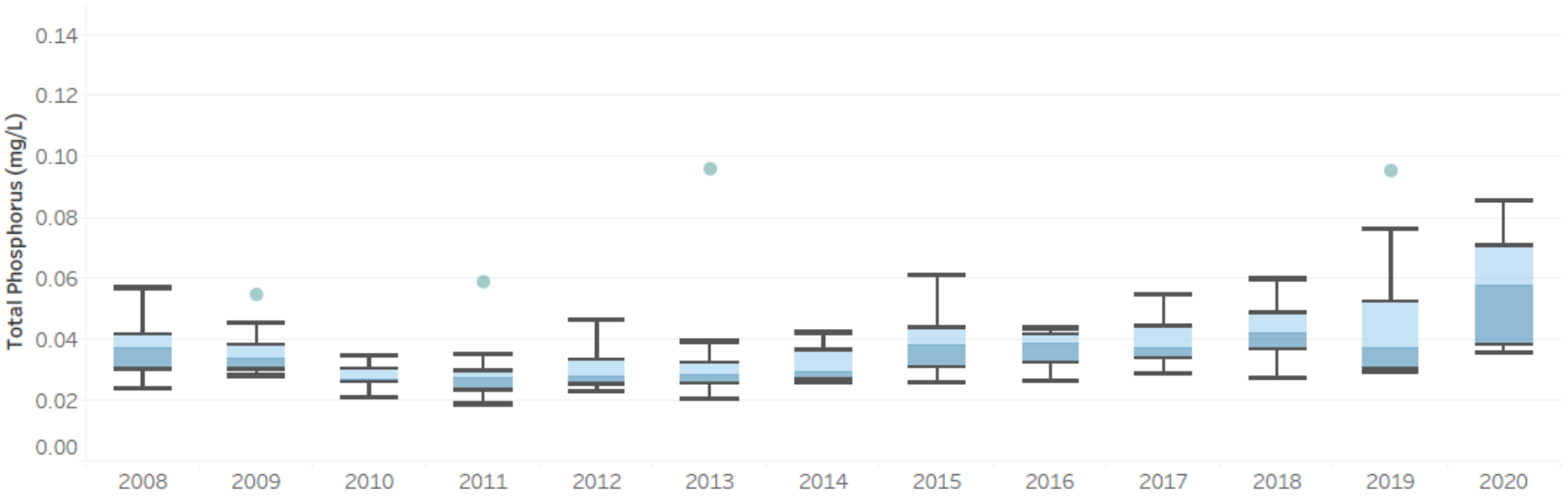
MC-1, Sample Temperature

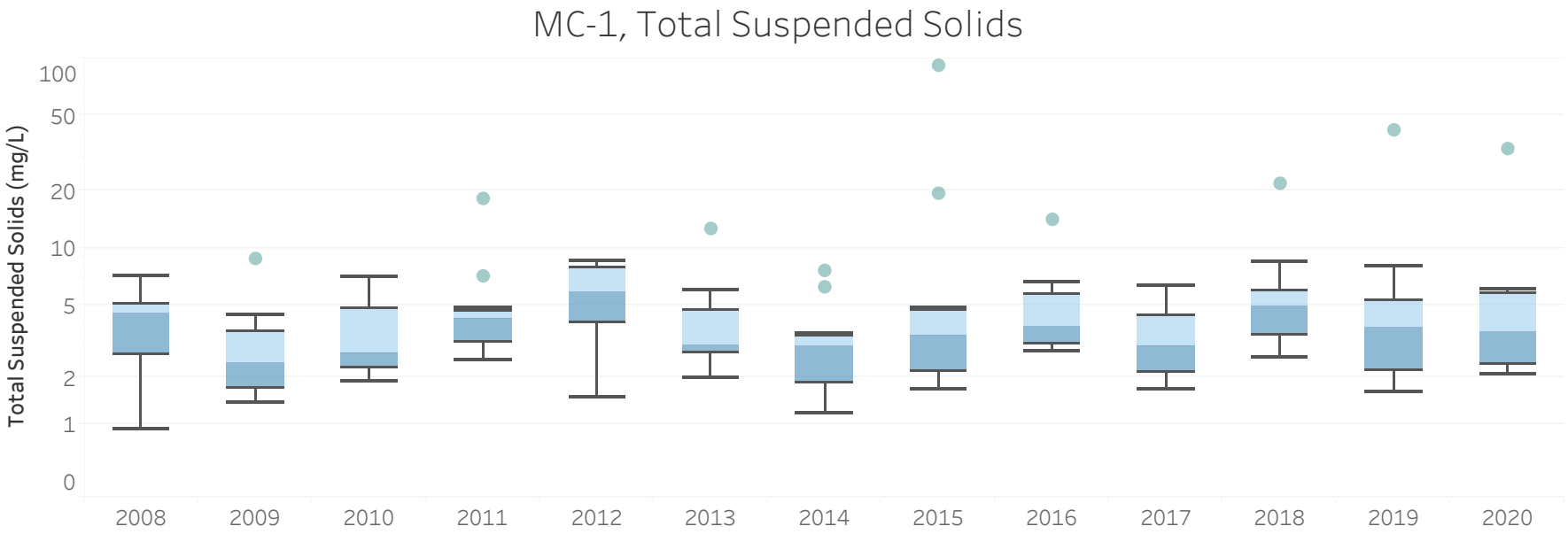


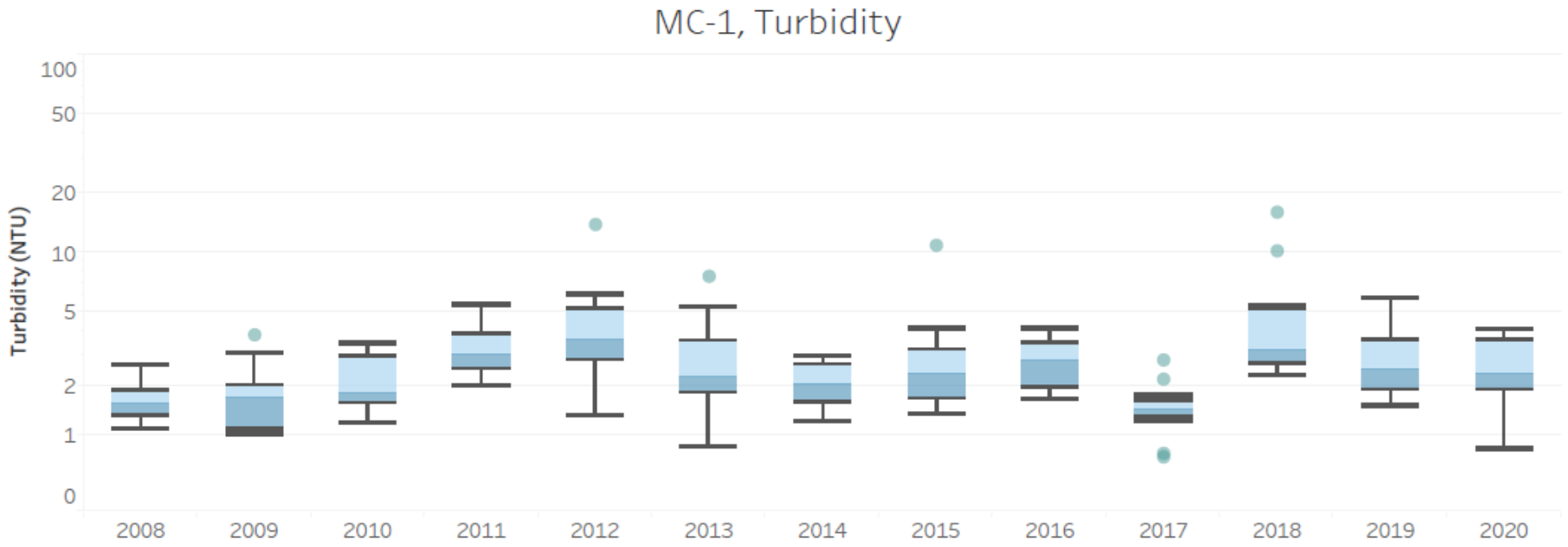
MC-1, Total Nitrogen



MC-1, Total Phosphorus




MC-1, Total Suspended Solids
Total Suspended Solids (mg/L)
100
50
20
10
5
2
1
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


MC-1, Turbidity
Turbidity (NTU)
100
50
20
10
5
2
1
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

A.6 Storm Creek (ST-2)

Table A.6-1. Aquatic Life Designated Use Support Ratings for Storm Creek at ST-2

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Storm Creek (ST-2)	2007-2015	GOOD (100%)	GOOD (100%)	FAIR (80%)	GOOD (98%)	FAIR (85%)	GOOD (92%)
	2016-2020	GOOD (100%)	GOOD (100%)	GOOD (95%)	GOOD (100%)	POOR (71%)	GOOD (93%)

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 A.6-2. Primary Contact Recreation Designated Use Support Rating for Storm Creek at ST-2

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Storm Creek (ST-2)	2008	50.0%	Yes	POOR
	2009	100.0%	Yes	GOOD
	2010	60.0%	Yes	POOR
	2011	50.0%	Yes	POOR
	2012	62.5%	Yes	POOR
	2013	66.7%	Yes	POOR
	2014	41.7%	Yes	POOR
	2015	50.0%	Yes	POOR
	2016	66.7%	Yes	POOR
	2017	58.3%	Yes	POOR
	2018	16.7%	Yes	POOR
	2019	41.7%	Yes	POOR
	2020	50.0%	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

Table A.6-3. Ecology Water Quality Index Scores for Storm Creek at ST-2

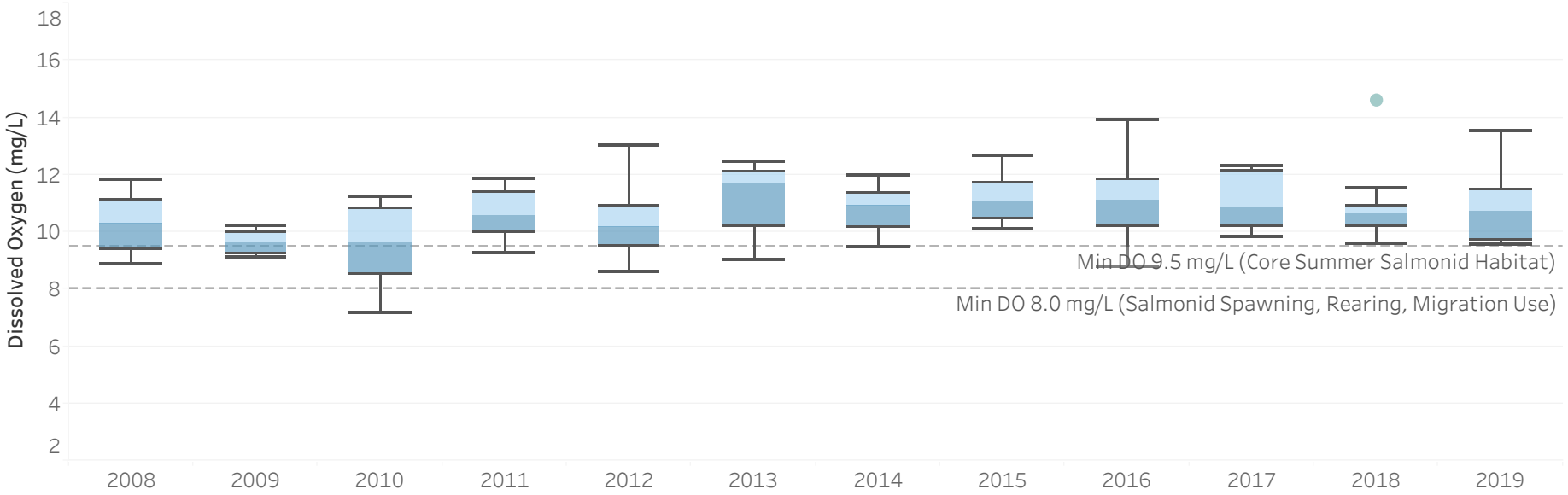
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	42	72	90	65	96	82	87	92	48
2009	77	75	1	65	100	82	71	95	55
2010	34	48	78	67	100	70	86	97	34
2011	34	77	80	67	100	78	55	86	42
2012	42	69	89	66	91	80	82	87	45
2013	35	75	70	45	79	68	76	80	36
2014	31	80	76	65	99	74	78	96	41
2015	40	86	74	49	84	79	84	81	41
2016	49	72	73	53	89	76	72	86	48
2017	32	83	54	69	96	77	80	98	46
2018	28	81	43	59	94	79	80	88	19
2019	36	80	52	67	100	75	61	94	46
2020	52	78	60	59	90	74	95	88	50

Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

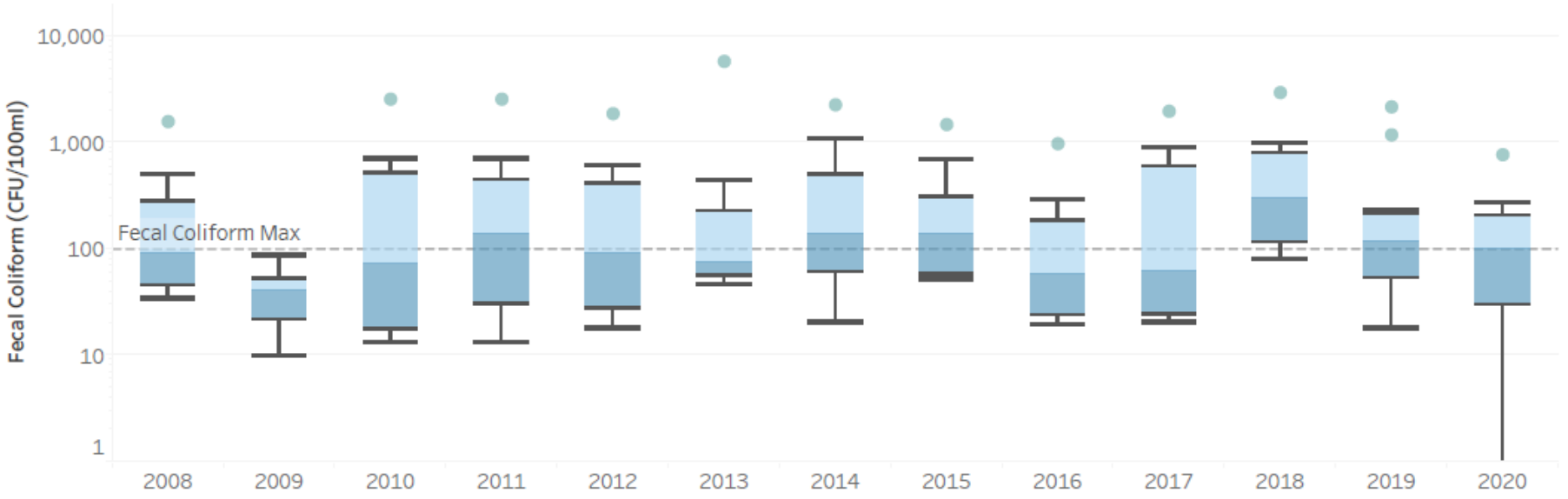
Table A.6-4. B-IBI Scores for Storm Creek at ST-1

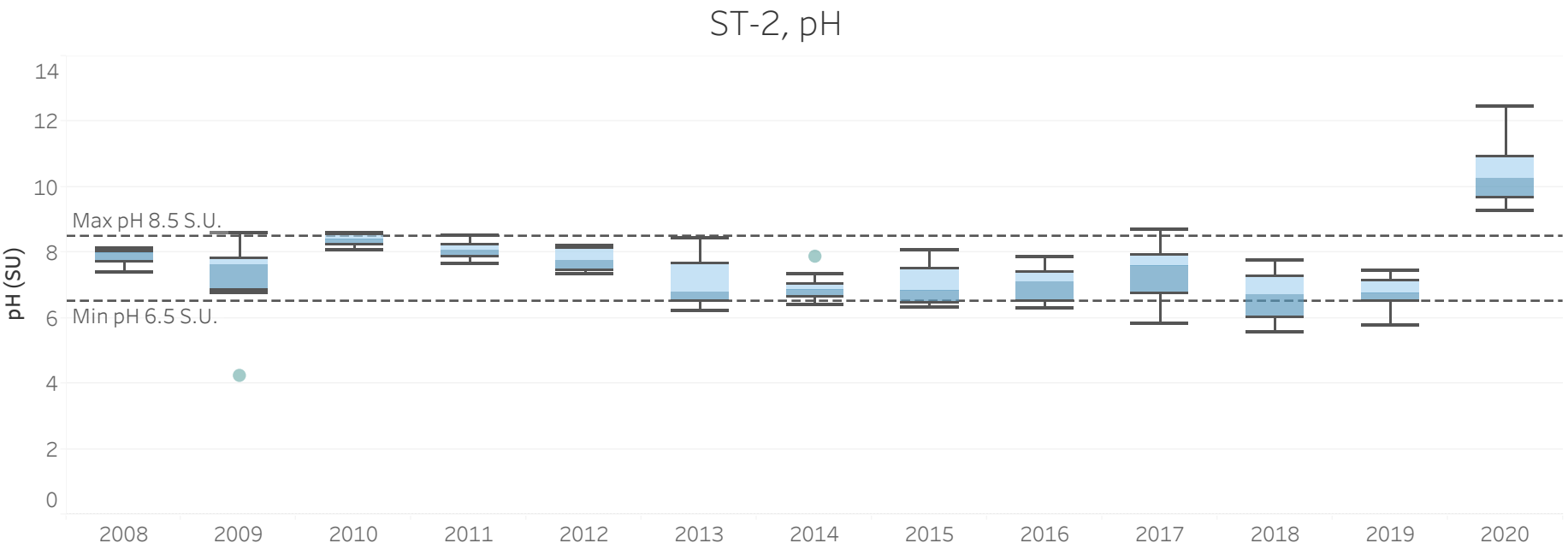
Sampling Site	Year	Score	Level of Impairment
Storm Creek (ST-1)	2003	14	Extreme
	2007	18	Extreme

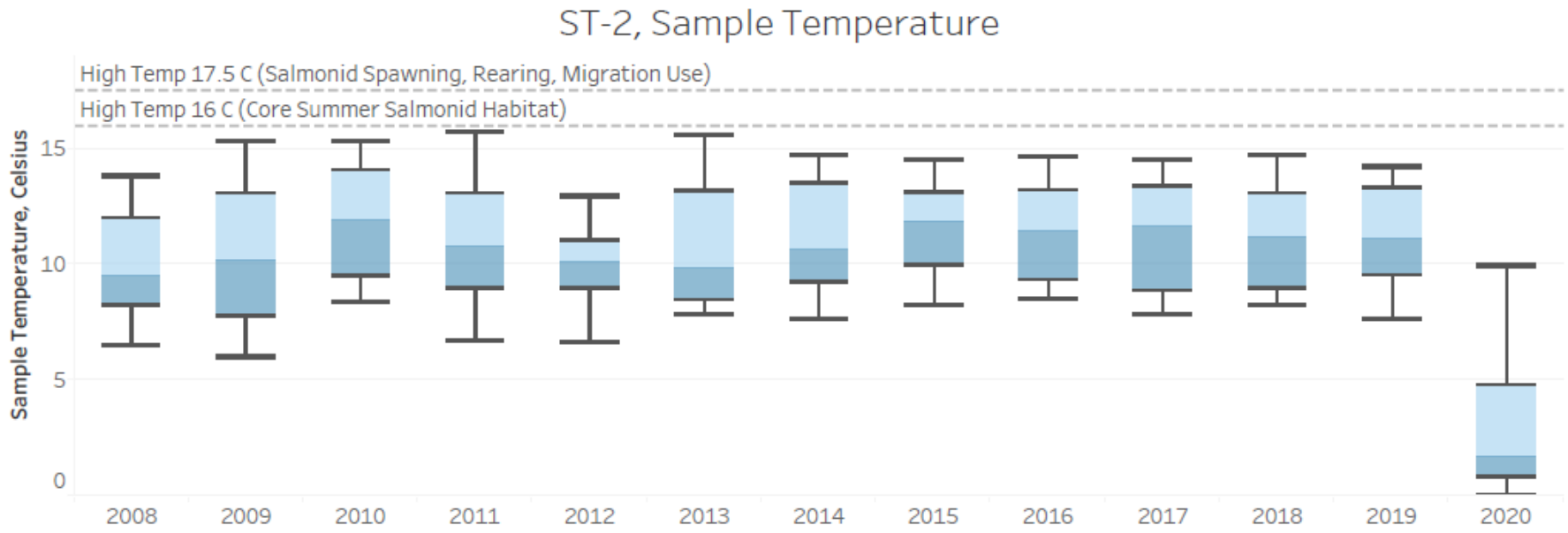
ST-2, Dissolved Oxygen



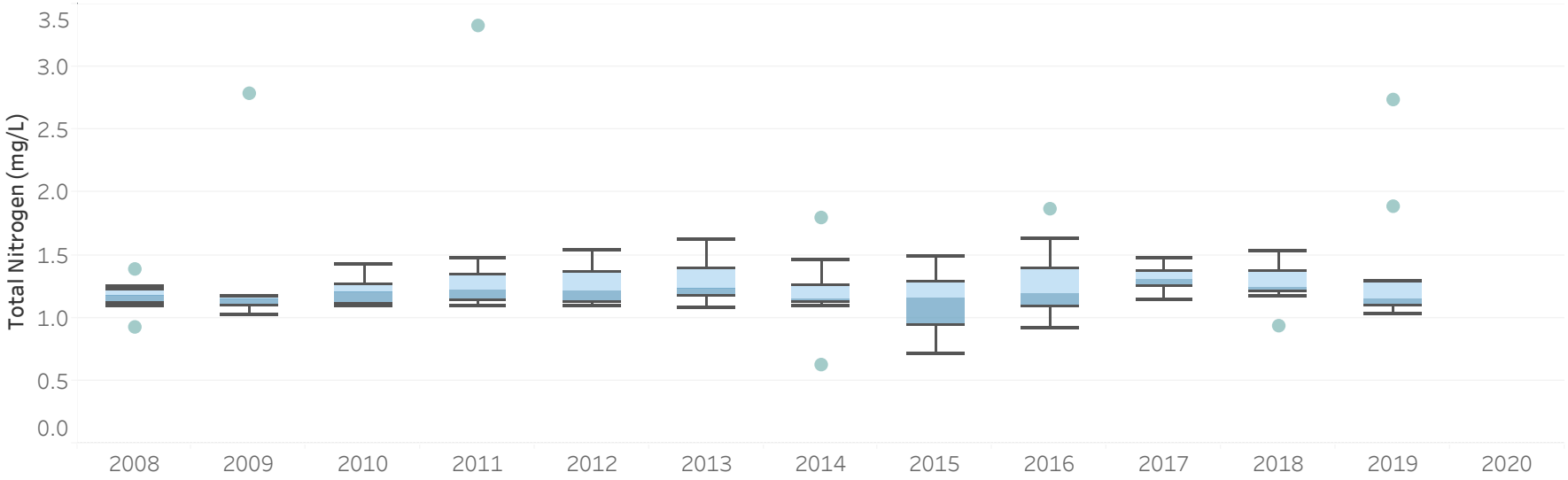
ST-2, Fecal Coliform



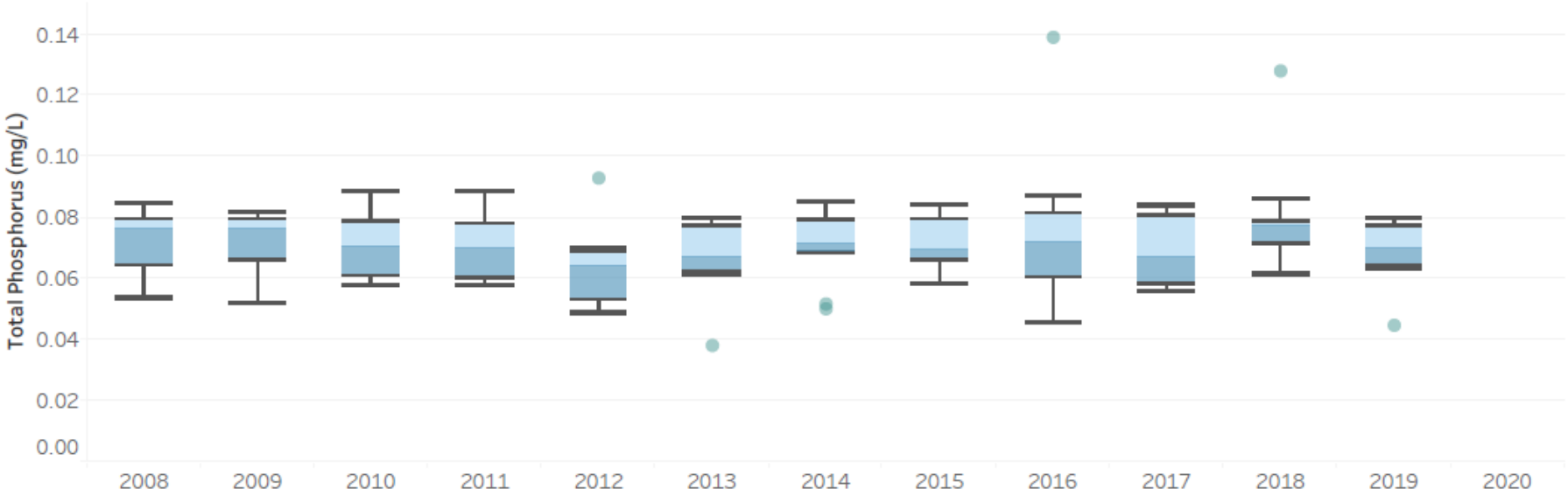

ST-2, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


ST-2, Sample Temperature
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
Sample Temperature, Celsius
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

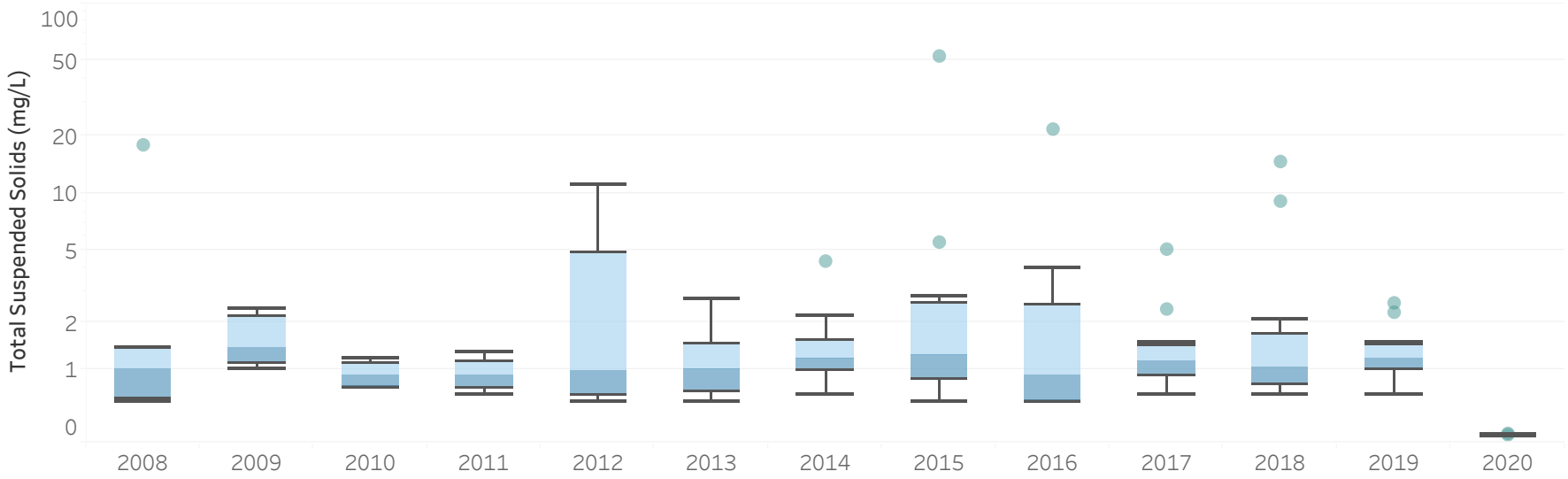
ST-2, Total Nitrogen



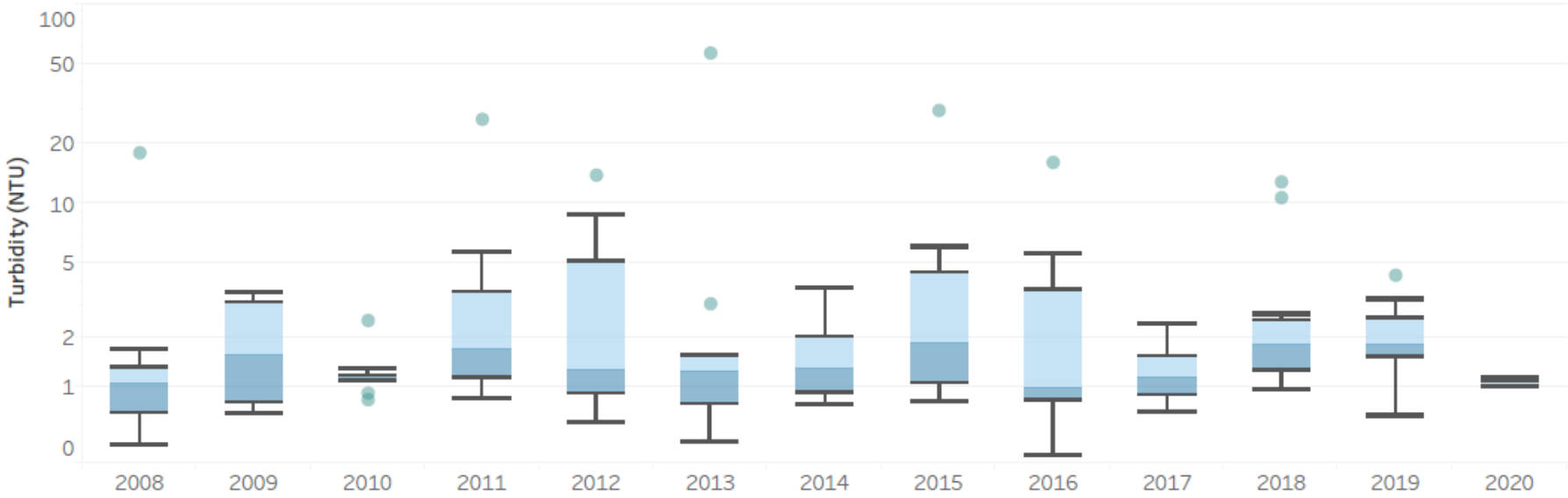
ST-2, Total Phosphorus



ST-2, Total Suspended Solids



ST-2, Turbidity



A.7 Thornton Creek (TH-1)

Table A.7-1. Aquatic Life Designated Use Support Ratings for Thornton Creek at TH-1

Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Thornton Creek (TH-1)	2007-2015	GOOD (96%)	GOOD (99%)	POOR (57%)	GOOD (92%)	GOOD (93%)	FAIR (89%)
	2016-2020	GOOD (100%)	GOOD (100%)	POOR (60%)	GOOD (98%)	GOOD (95%)	GOOD (95%)

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 A.7-2. Primary Contact Recreation Designated Use Support Rating for Thornton Creek at TH-1

Sampling Site	Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
Thornton Creek (TH-1)	2008	33.3%	Yes	POOR
	2009	27.3%	Yes	POOR
	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
	2016	41.7%	Yes	POOR
	2017	83.3%	Yes	FAIR
	2018	75.0%	Yes	FAIR
	2019	58.3%	Yes	POOR
	2020	60.0%	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

Table A.7-3. Ecology Water Quality Index Scores for Thornton Creek at TH-1

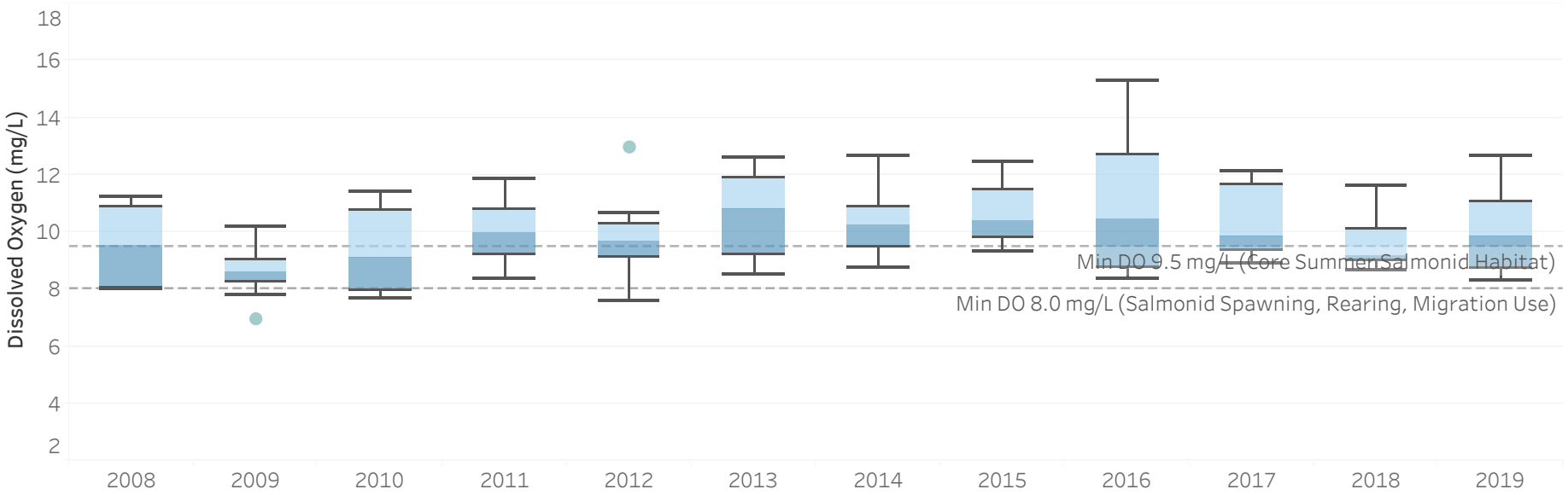
Water Year	Fecal Coliform	Dissolved Oxygen	pH	Total Phosphorous	Total Suspended Solids	Temperature	Total Nitrogen	Turbidity	Overall
2008	35	61	91	75	88	76	20	91	42
2009	35	45	31	74	95	70	16	92	37
2010	53	56	84	59	90	63	50	84	35
2011	48	66	86	76	88	75	70	83	51
2012	26	55	90	59	85	74	78	78	25
2013	23	68	69	79	95	64	60	89	34
2014	19	71	75	63	94	75	35	96	37
2015	31	78	90	37	63	78	29	78	33
2016	34	66	95	73	89	74	42	95	49
2017	55	73	89	74	96	76	49	94	64
2018	61	70	68	66	87	67	51	85	54
2019	38	65	87	73	95	67	63	93	50
2020	37	60	67	52	86	72	39	91	36

Low Concern = WQI score above 80
Moderate Concern = WQI score between 40 and 79
High Concern = WQI score less than 40

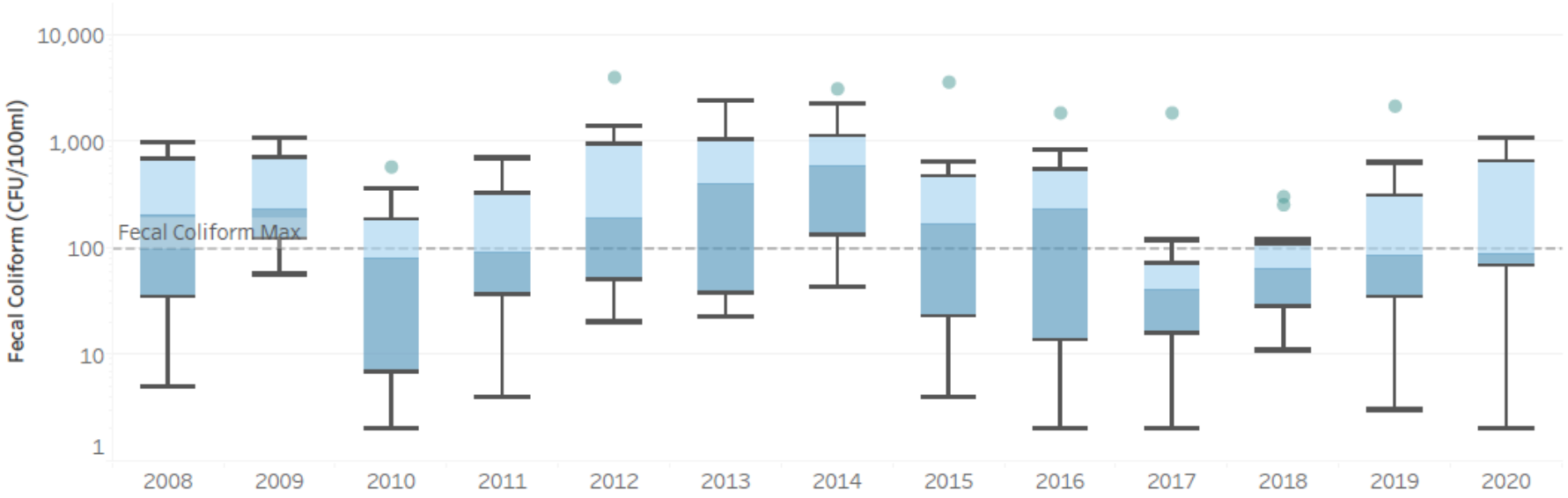
Table A.7-4. B-IBI scores for Thornton Creek at TH-1

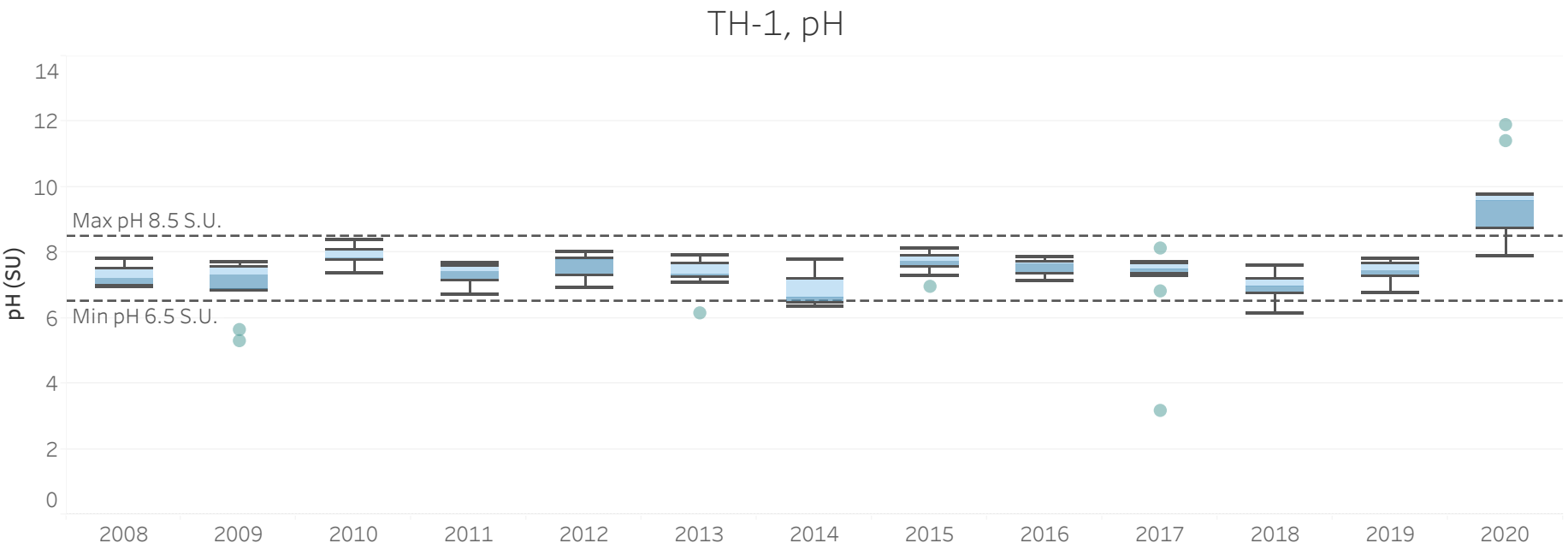
Sampling Site	Year	Score	Level of Impairment
Thornton Creek (TH-1)	2003	14	Extreme
	2007	18	Extreme

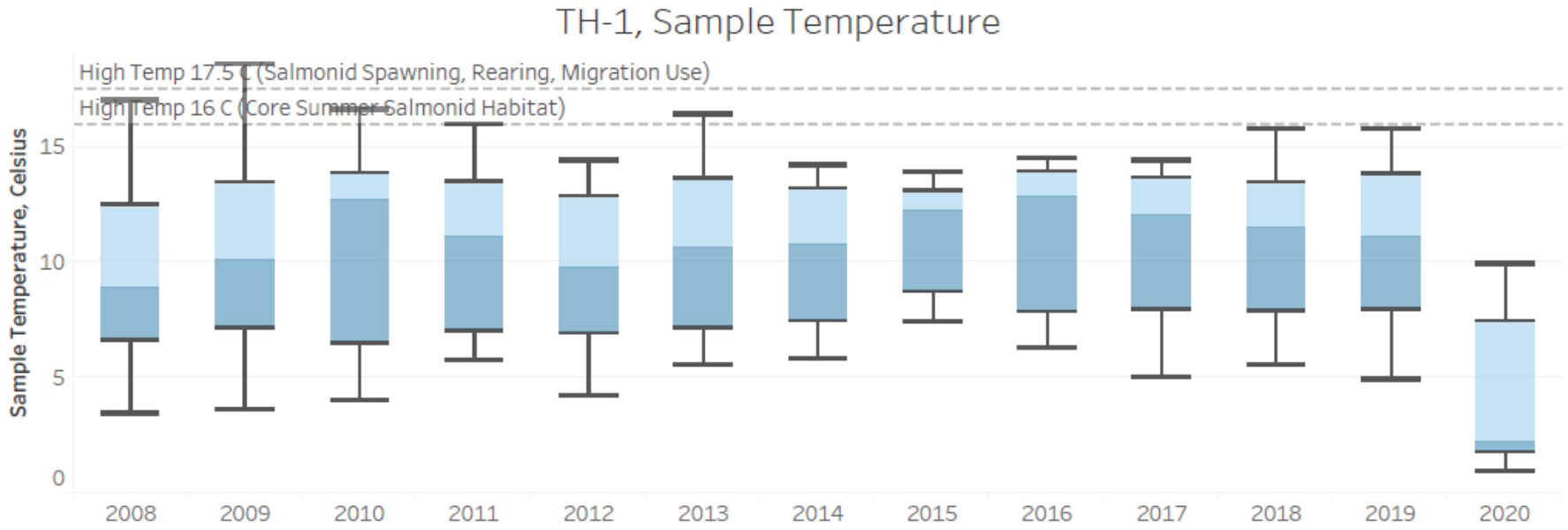
TH-1, Dissolved Oxygen

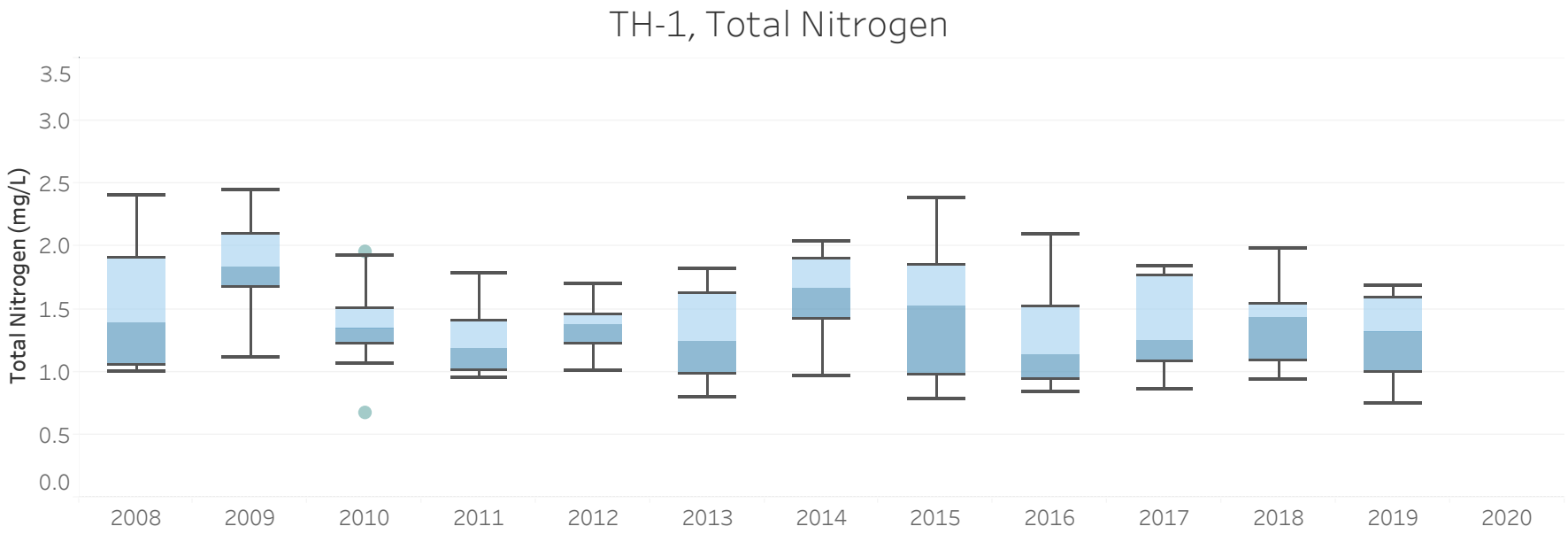


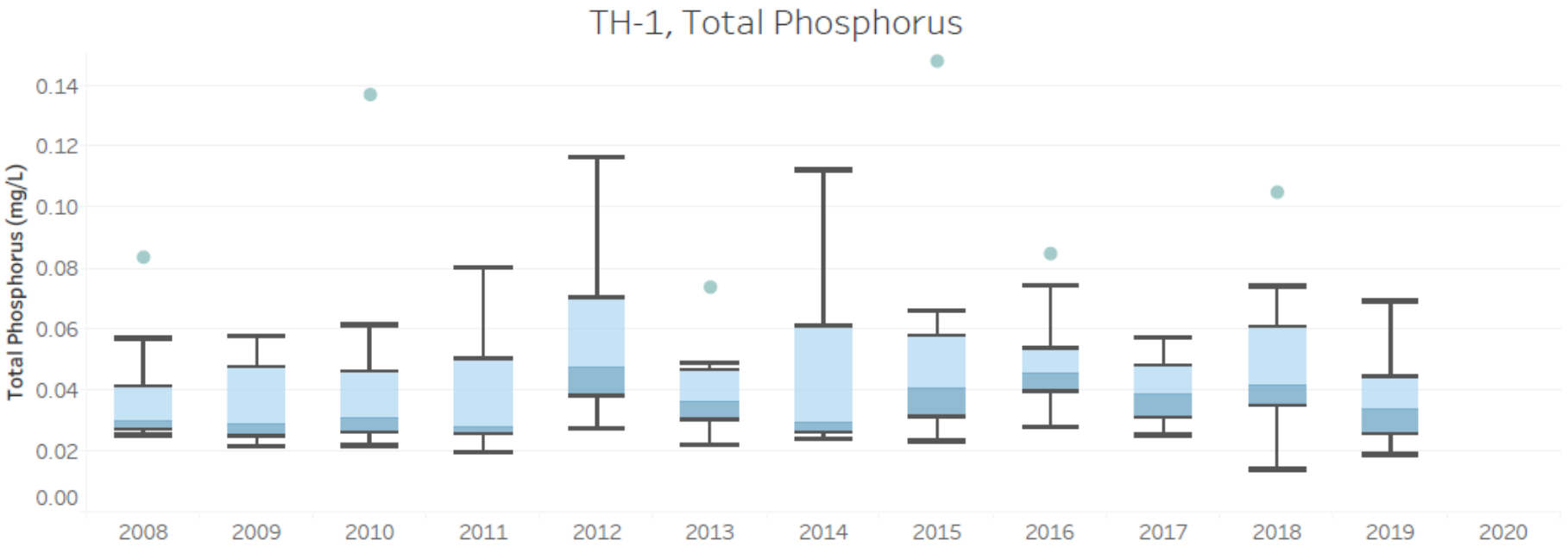
TH-1, Fecal Coliform



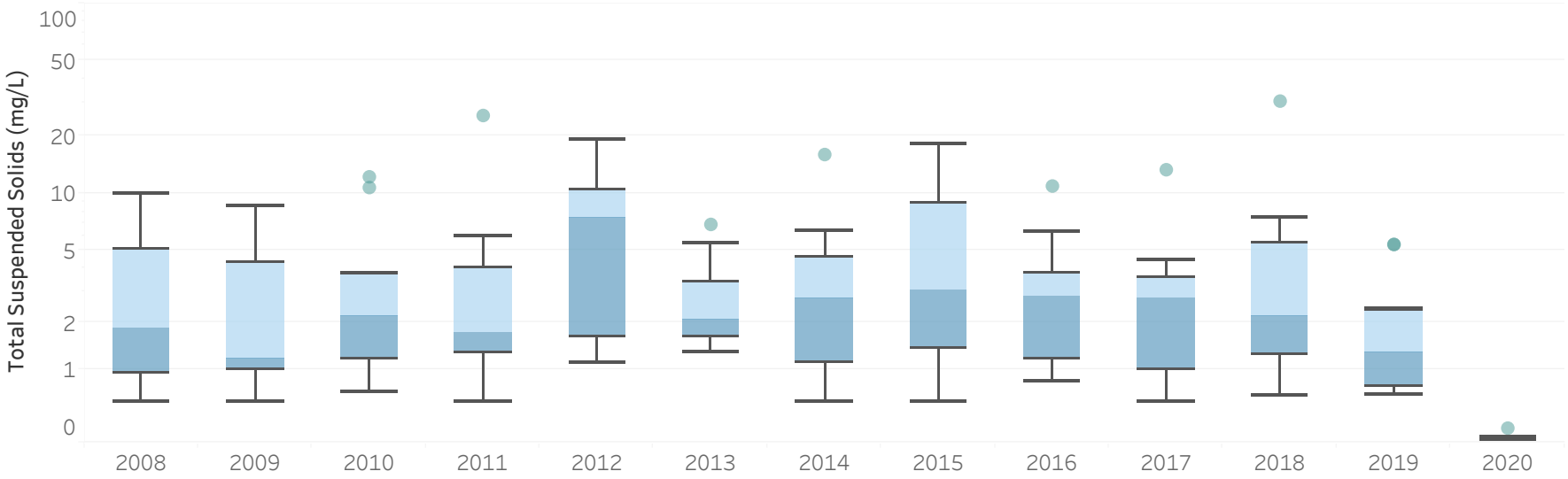

TH-1, pH
pH (SU)
14
12
10
8
6
4
2
0
Max pH 8.5 S.U.
Min pH 6.5 S.U.
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


TH-1, Sample Temperature
Sample Temperature, Celsius
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

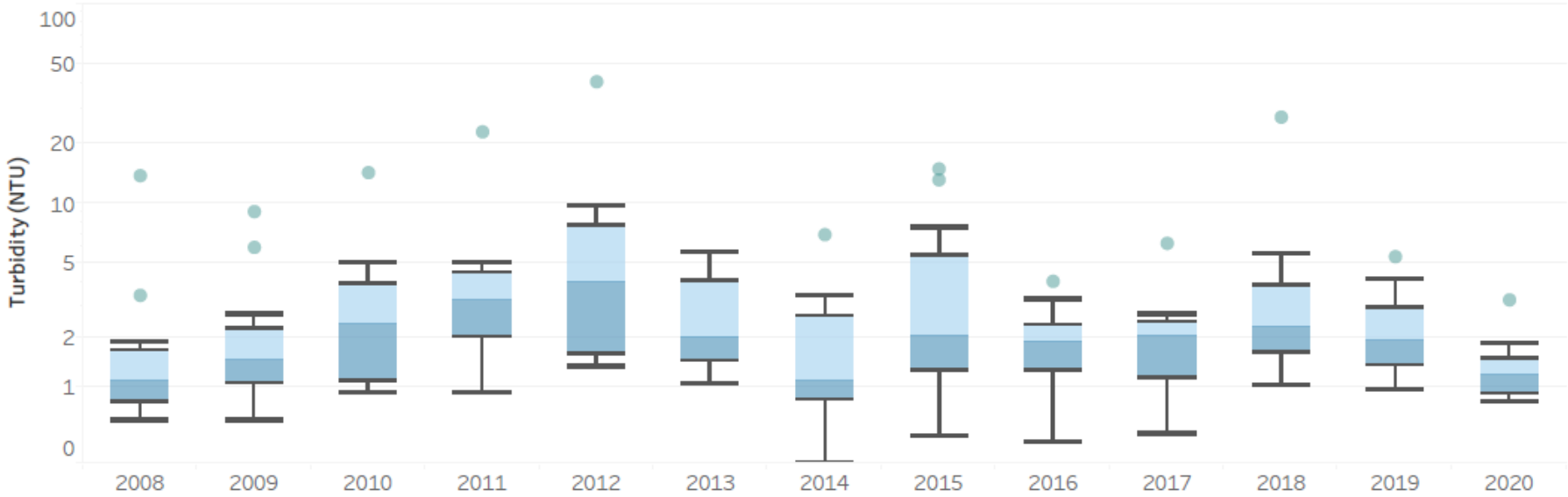

TH-1, Total Nitrogen
Total Nitrogen (mg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


TH-1, Total Phosphorus
Total Phosphorus (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

TH-1, Total Suspended Solids



TH-1, Turbidity



APPENDIX B

Lake Water Quality Results

B.1 Echo Lake

Table B.1-1. Aquatic Life Designated Use Support Ratings for Echo Lake at A746B and EL-Profile

Station	Period	Temp.; Core Summer Salmonid Habitat	Temp.; Salmonid Spawning, Rearing and Migration	Dissolved Oxygen; Core Summer Salmonid Habitat	Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration
Echo Lake surface	1931	POOR (64%)	POOR (71%)	POOR (38%)	GOOD (100%)	GOOD (100%)	
Echo Lake A746B	2004-2015	POOR (4%)	POOR (6%)				
	2016-2020	POOR (1%)	POOR (2%)				
Echo Lake EL-Profile	2012-2015	POOR (13%)	POOR (28%)	POOR (36%)	FAIR (82%)	POOR (73%)	FAIR (76%)
	2016-2020	POOR (21%)	POOR (32%)	POOR (27%)	POOR (58%)	FAIR (77%)	FAIR (79%)

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 1. Primary Contact Recreation Designated Use Support Rating for Echo Lake at A746B

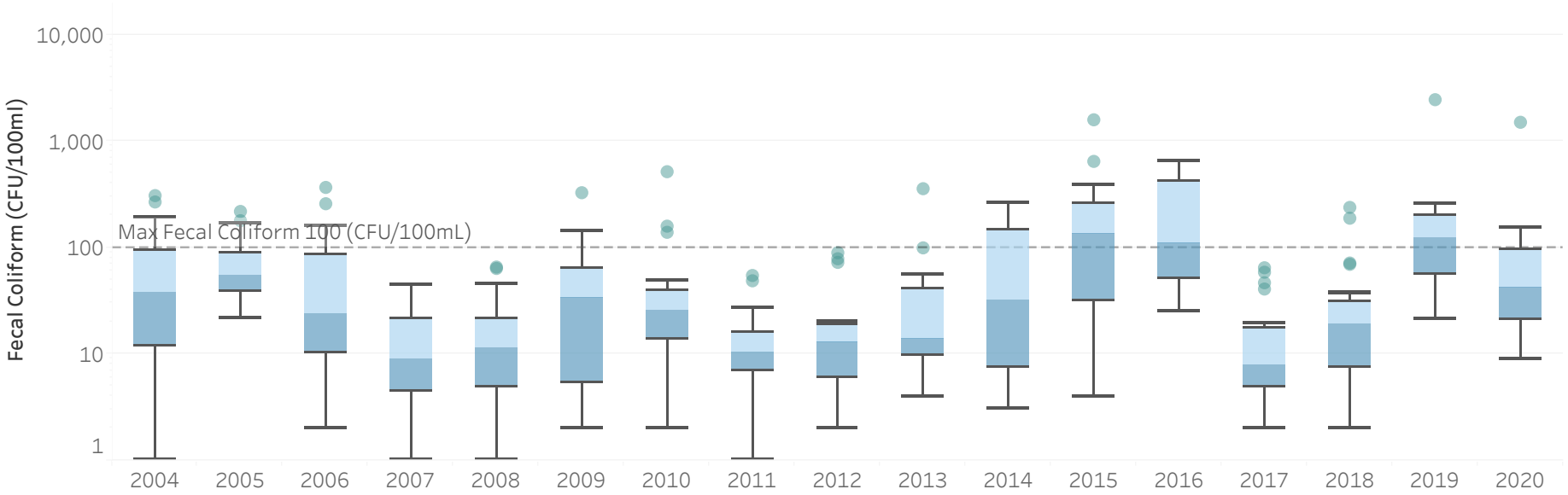
Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2004	78.9%	Yes	FAIR
2005	78.9%	Yes	FAIR
2006	78.9%	Yes	FAIR
2007	100.0%	No	GOOD
2008	100.0%	No	GOOD
2009	85.0%	Yes	FAIR
2010	83.3%	Yes	FAIR
2011	94.7%	No	GOOD
2012	100.0%	No	GOOD
2013	94.7%	No	GOOD
2014	71.4%	Yes	POOR
2015	43.5%	Yes	POOR
2016	47.6%	Yes	POOR
2017	95.0%	No	GOOD
2018	89.5%	Yes	FAIR
2019	45.0%	Yes	POOR
2020	76.2%	Yes	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

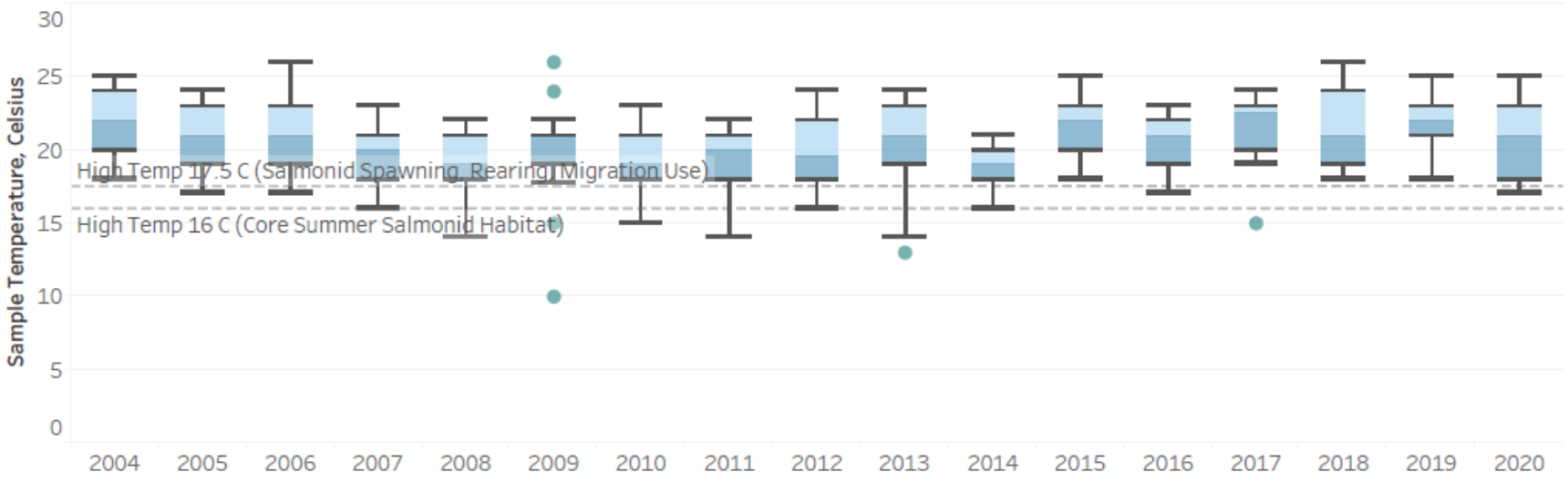
Table B.1-3. Algal Toxin Sampling Results for Echo Lake

Toxin	Number of Samples	Exceedances
Microcystin	83	9
Anatoxin-a	66	0
Cylindrospermopsin	3	0
Saxitoxin	4	0

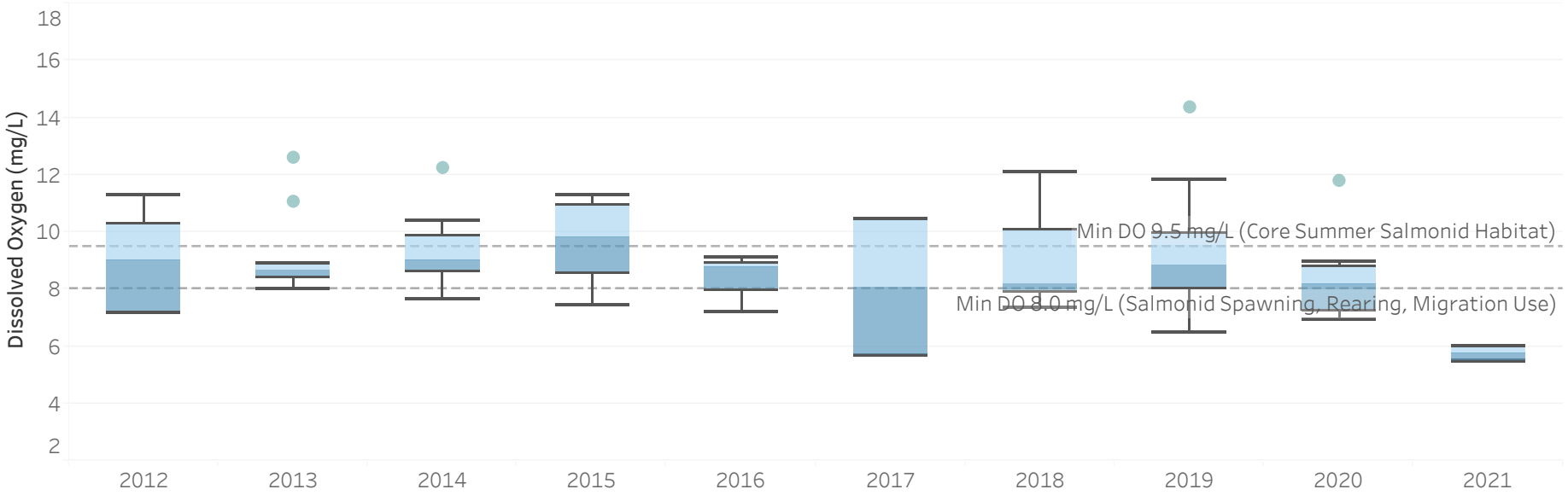
EL-A476B, Fecal Coliform



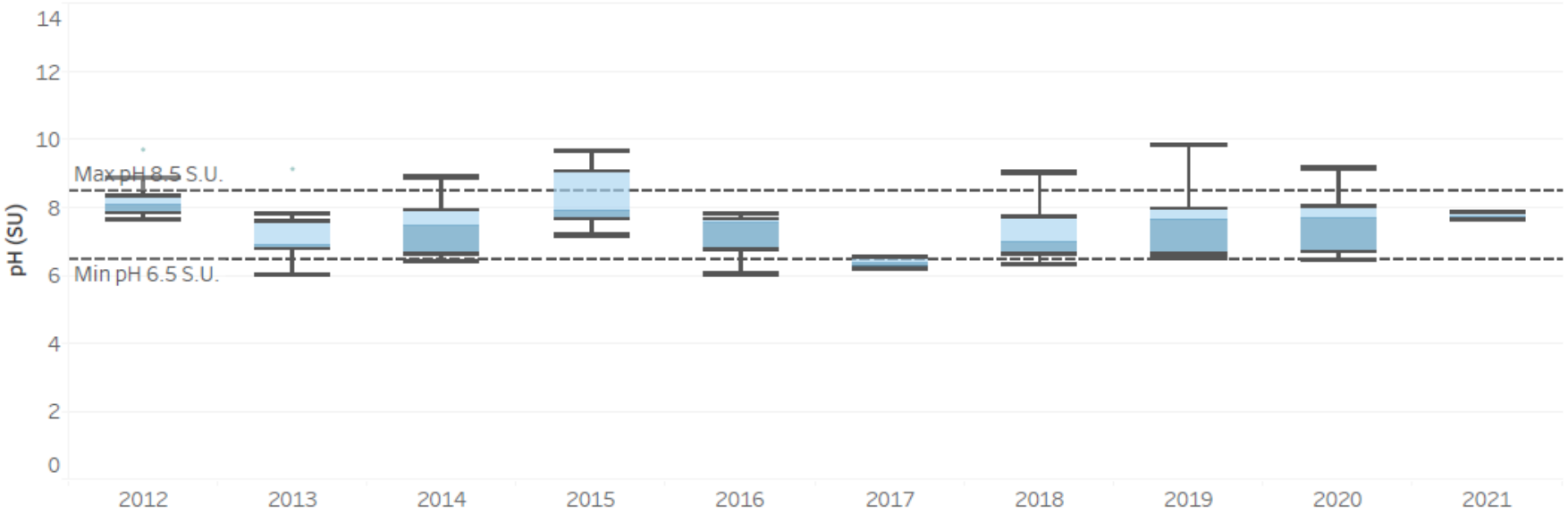
EL-A476B, Sample Temperature

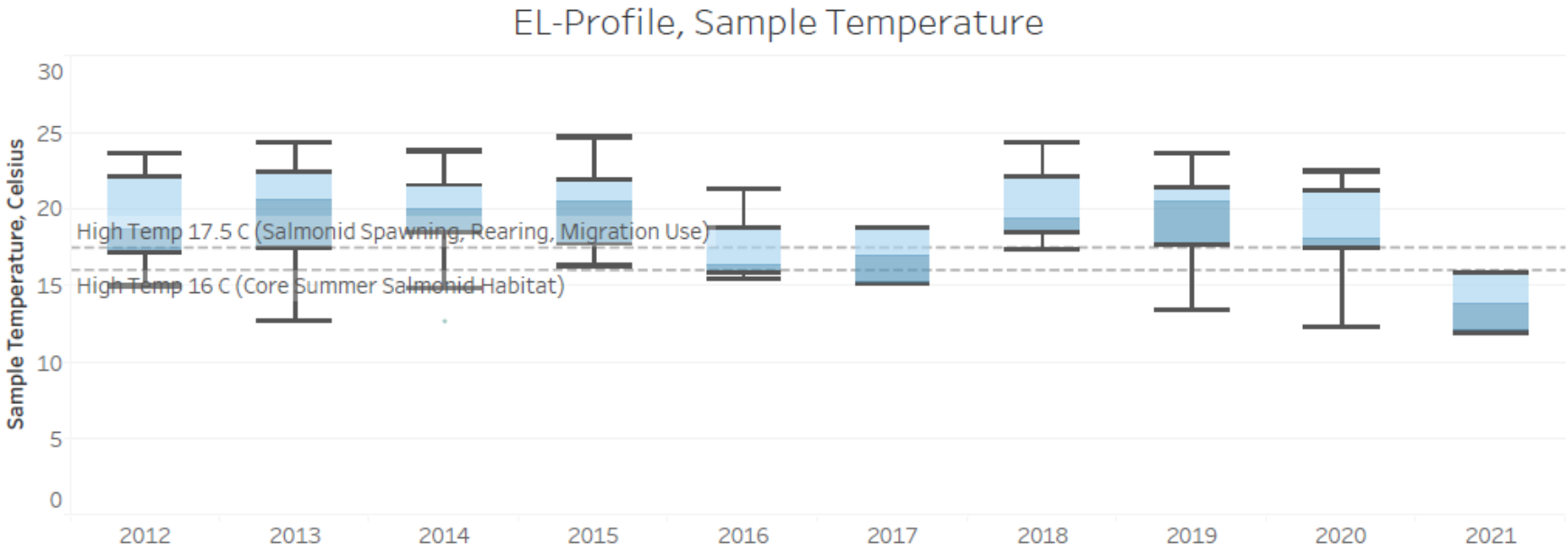


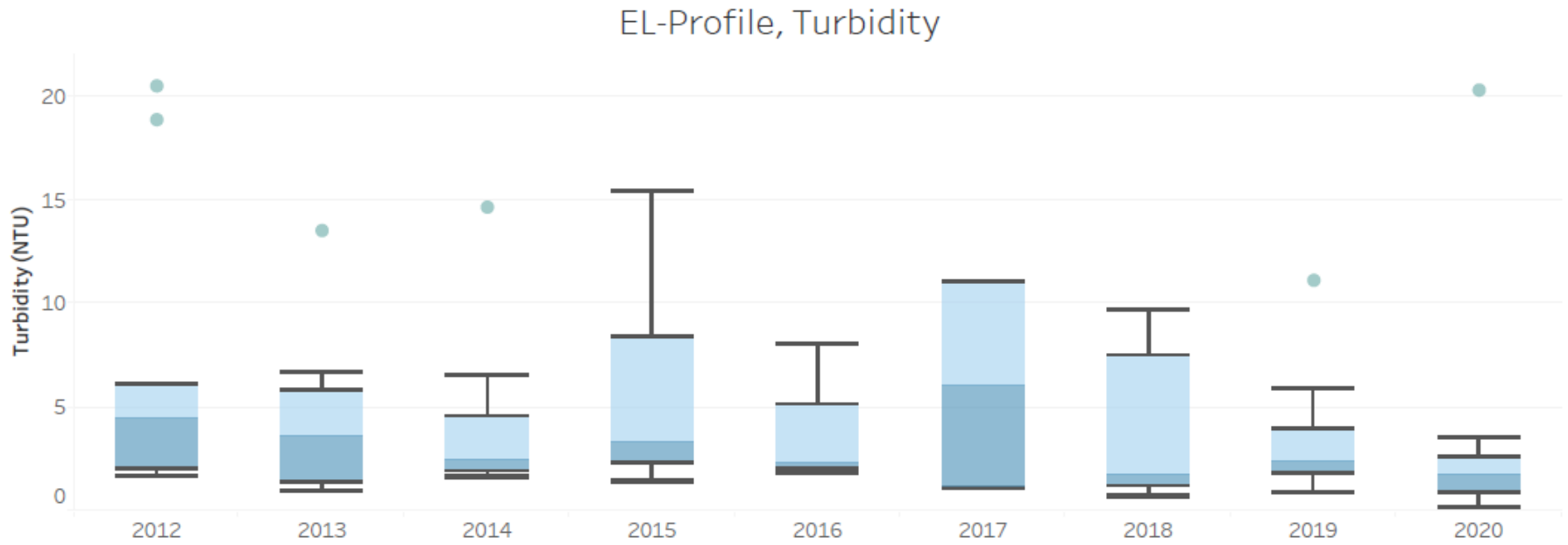
El-Profile, Dissolved Oxygen



EL-Profile, pH




EL-Profile, Sample Temperature
Sample Temperature, Celsius
30
25
20
15
10
5
0
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


EL-Profile, Turbidity
Turbidity (NTU)
20
15
10
5
0
2012
2013
2014
2015
2016
2017
2018
2019
2020

B.2 Hidden Lake

Table B.2-1. Aquatic Life Designated Use Support Ratings for Hidden Lake at 0207SB

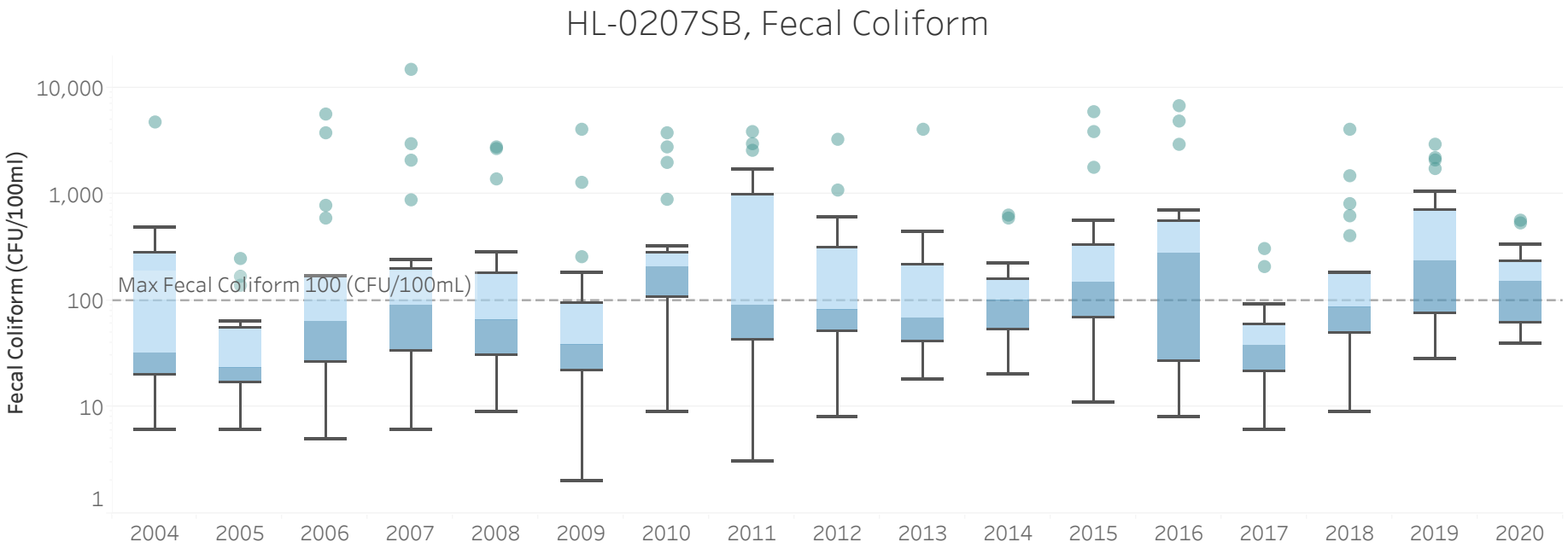
Station	Period	Temperature; Core Summer Salmonid Habitat	Temperature; Salmonid Spawning, Rearing and Migration
Hidden Lake 0207SB	2004-2015	POOR (50%)	POOR (50%)
	2016-2020	POOR (49%)	POOR (49%)

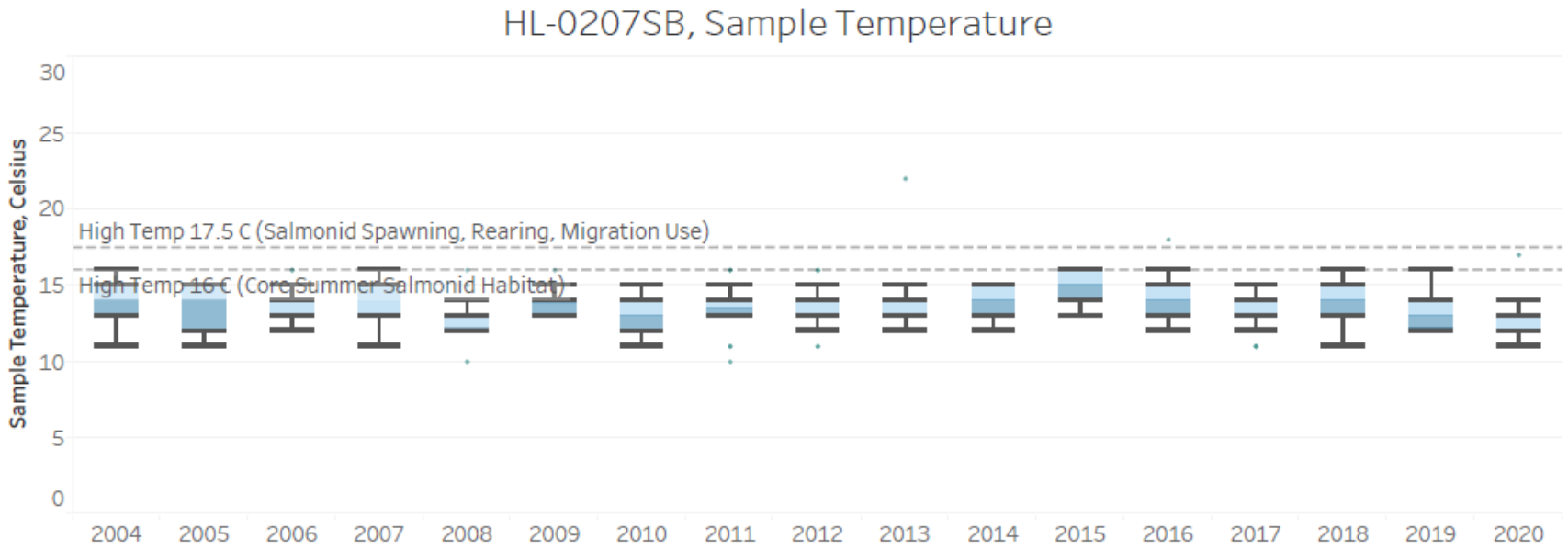
Good = >90% of data points meet water quality standards
Fair = 75-90% of data points meet water quality standards
Poor = <75% of data points meet water quality standards

Table B.2-2. Primary Contact Recreation Designated Use Support Rating for Hidden Lake at 0207SB

Water Year	Percent Compliance with Standards	Exceeded Water Quality Standard	Designated Use Support Rating
2004	72.2%	Yes	POOR
2005	83.3%	Yes	FAIR
2006	65.0%	Yes	POOR
2007	60.0%	Yes	POOR
2008	63.2%	Yes	POOR
2009	78.9%	Yes	FAIR
2010	26.3%	Yes	POOR
2011	52.6%	Yes	POOR
2012	61.1%	Yes	POOR
2013	61.1%	Yes	POOR
2014	57.9%	Yes	POOR
2015	39.1%	Yes	POOR
2016	36.4%	Yes	POOR
2017	90.0%	Yes	GOOD
2018	52.4%	Yes	POOR
2019	25.0%	Yes	POOR
2020	42.1%	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


HL-0207SB, Fecal Coliform
Fecal Coliform (CFU/100ml)
10,000
1,000
100
10
1
Max Fecal Coliform 100 (CFU/100mL)
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


HL-0207SB, Sample Temperature
Sample Temperature, Celsius
30
25
20
15
10
5
0
High Temp 17.5 C (Salmonid Spawning, Rearing, Migration Use)
High Temp 16 C (Core Summer Salmonid Habitat)
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

APPENDIX C

Salmon-Safe Monitoring Approach Details

APPENDIX C

Salmon-Safe Monitoring Approach Details

C.1. Salmon-Safe Monitoring Option 1: Establish a 3-year water quality baseline then follow up every 5th year

This approach seeks to establish current baseline water quality over 3 years, then reassess it every fifth year. This approach would target five automated sample events each year for the first 3 years. In addition, continuous flow monitoring would be established at each station for the purpose of pacing the autosampler to collect flow-weighted composites and to estimate loading for metals and nutrients at each station. Sondes would be deployed at each station and continuously collect temperature, dissolved oxygen, pH, and conductivity. In addition, B-IBI samples would be collected during the first year of the monitoring. The initial 3 years of data collection would serve as a baseline for water quality in each basin.

In year 5 of the study, an additional round of five samples will be collected at each site, along with the B-IBI sampling and continuous sonde and flow monitoring; and this will be repeated in year 10 of the study and so on. This will allow the City of Shoreline (City) to track water quality and overall stream health at each station, and document improvements over time within each watershed. In between monitoring years, the equipment will be removed and stored in a protected environment.

Estimated cost to establish baseline over 3 years is just over $400,000, and the follow-up year of monitoring is estimated near $157,000. These costs would be affected by labor rates and annual price increases for supplies, but can serve as a point of comparison between approaches. A more detailed breakout of the labor estimates and associated expenses are shown in Tables C.1-1 through C.1-4.

C.2. Salmon-Safe Monitoring Option 2: Establish a 1-year water quality baseline, then follow up every 5th year

This approach seeks to establish a water quality baseline in 1 year, then reassess it every fifth year. This approach would target 12 automated sample events in the first year of the study. In addition, continuous flow monitoring would be established at each station for the purpose of pacing the autosampler to collect flow-weighted composites and to estimate loading for metals and nutrients at each station. Sondes would be deployed at each station and continuously collect temperature, dissolved oxygen, pH, and conductivity. In addition, B-IBI samples would be collected during the first year of the monitoring. The initial year of data collection would serve as a baseline for water quality in each basin.

In year 5 of the study, an additional round of 12 samples will be collected at each site, along with the B-IBI sampling and continuous sonde and flow monitoring; and this will be repeated in year 10 of the study and so on. This will allow the City to track water

quality and overall stream health at each station, and document improvements over time within each watershed. In between monitoring years, the equipment will be removed and stored in a protected environment.

Estimated cost to establish baseline over 1 year is just over $4242,000, and the follow-up year of monitoring is estimated near $196,000. These costs would be affected by labor rates and annual price increases for supplies, but can serve as a point of comparison between approaches. A more detailed breakout of the labor estimates and associated expenses are shown in Tables C.2-1 and C.2-2.

S:\City of Shoreline\Surface Water Quality and NPDES Services - 200383\Task 1 files\Appendix C Salmon-Safe Monitoring Approach Details\AppxC_Salmon-Safe Monitoring Approch Details.docx

TABLES

Table C.1-1. Cost Estimate for 3-Year Baseline, Year 1

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours Staff 1 $ 110.00	Staff 1 $ 110.00	Senior 1 $ 175.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Installation						Labor covers site reconnaissance to select sites, procuring equipment, installing the monitoring equipment and then removing the equipment and storing at the end of the monitoring year. ODCs cover vehicle usage and tools for installation and recon. Equipment purchased for monitoring includes autosamplers, pressure transducers, datalogger/controller, water quality sondes, telemetry charges and associated items like enclosures, batteries, fasteners, conduit, etc. In addition, project startup includes purchase of consumables like gloves, calibration standards, bags, desiccant ,etc.
Site recon	8		8	$ 2,280	$ 110	
Equipment purchase and install (3 sites)						
ordering parts	8		1	$ 1,055	$ 60,000	
procure supplies	8	4	1	$ 1,495	$ 750	
installation	24	24	6	$ 6,330	$ 600	
Procuring other general supplies	8		4	$ 1,580	$ 500	
Pull gear at end of the year						
prep for long term storage						
Task 2 - Stream gaging						Labor covers collecting up to 8 stream discharge measurements to develop stage-discharge rating curves and reviewing and correcting data as needed. ODC covers the purchase of a FlowTracker or equivalent velocity meter and vehicle usage for measurements
Flows and ratings (1 yr)-8 flow measurements	48	48	16	$ 13,360	$ 11,835	
Develop rating curve			24	$ 4,200		
Flow data QAQC	24		12	$ 4,740		
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction. ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if needed.
Monthly maintenance	84	72		$ 17,160	$ 3,900	
Sonde data QAQC	36		12	$ 6,060		
troubleshooting	16	8	8	$ 4,040	$ 2,000	
Task 4 - Automated sampling (5 events)						Labor covers the sampling 5 events under variable conditions and includes weather tracking, setting stations up for monitoring, collecting and delivering samples and up to 1 false starts to cover unsuccessful sample events. Task also includes brief summary reports documenting each sample event and the associated data. ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes analysis for 21 samples which includes 15 primary smaples and duplicate and blank samples for QC. Analysis cost per sample is $220
weather tracking			6	$ 1,050		
station setup	30	30		$ 6,600	$ 625	
sample collection	30	30		$ 6,600	$ 625	
sample delivery	10			$ 1,100	$ 100	
false starts 1 setup and shut down, no delivery	6	6		$ 1,320	$ 225	
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 4,620	
Reporting	15		7.5	$ 2,963		
WQ data QAQC	15		5	$ 2,525		
Task 5 - B-IBI						Labor covers B-IBI sampling at all three sites for 1 sample event and the associated reporting. ODC covers the analys charges for 6 samples and supplies for sampling. Analysis costs are $350 per sample.
Sample Collection		20	12	$ 4,300	$ 2,400	
Reporting		10	12	$ 3,200		
Task 6 - Overall management and reporting						Labor covers general project coordination, the development of a health and safety plan and a brief summary report for all the monitoring activities in the year.
Project Communication	12	12	24	$ 6,840		
data management	12		9	$ 2,895		
Invoicing			12	$ 2,100		
develop health and safety plan	6		2	$ 1,010		
Annual reporting	24		30	$ 7,890		
Total	424	264	211.5	$ 112,693	$ 88,290	**Yearly Total $ 200,982.50**

Table C.1-2. Cost Estimate for 3-Year Baseline, Year 2

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours Staff 1 $ 110.00	Staff 1 $ 110.00	Senior 1 $ 175.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Installation						
Site recon						
Equipment purchase and install (3 sites)						
ordering parts						
procure supplies						No installation needed
installation						
Procuring other general supplies						
Pull gear at end of the year						
prep for long term storage						
Task 2 - Stream gaging						Labor covers collecting up to 5 stream discharge measurements to maintain stage-discharge rating curves and
Flows and ratings (1 yr)-5 flow measurements	30	30	5	$ 7,475	$ 1,432	reviewing and correcting data as needed.
Maintain rating curve			15	$ 2,625		ODC covers rental of the FlowTracker or equivalent velocity meter and vehicle usage for measurements, and
Flow data QAQC	24		12	$ 4,740		telemetry
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra
Monthly maintenance	84	72		$ 17,160	$ 3,900	hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction.
Sonde data QAQC	36		12	$ 6,060		ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if
troubleshooting	16	8	8	$ 4,040	$ 2,000	needed.
Task 4 - Automated sampling (5 events)						
weather tracking			6	$ 1,050		
station setup	30	30		$ 6,600	$ 625	Labor covers the sampling 5 events under variable conditions and includes weather tracking, setting stations up
sample collection	30	30		$ 6,600	$ 625	for monitoring, collecting and delivering samples and up to 1 false starts to cover unsuccessful sample events.
sample delivery	10			$ 1,100	$ 100	Task also includes brief summary reports documenting each sample event and the associated data.
false starts 1 setup and shut down, no delivery	6	6		$ 1,320	$ 225	ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 4,620	analysis for 21 samples which includes 15 primary smaples and duplicate and blank samples for QC. Analysis
Reporting	15		7.5	$ 2,963		cost per sample is $220
WQ data QAQC	15		5	$ 2,525		
Task 5 - B-IBI						
Sample Collection						No Sampling
Reporting						
Task 6 - Overall management and reporting						
Communication	12	12	24	$ 6,840		
data management	12		9	$ 2,895		Labor covers general project coordination and a brief summary report for all the monitoring activities in the
Invoicing			12	$ 2,100		year.
develop health and safety plan	4		2	$ 790		
Annual reporting	20		24	$ 6,400		
Total	344	188	141.5	$ 83,283	$ 13,527	**Yearly Total $ 96,809.50**

Table C.1-3. Cost Estimate for 3-Year Baseline, Year 3

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours Staff 1 $ 115.00	Staff 1 $ 115.00	Senior 1 $ 180.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Removal						
Site recon						
Equipment purchase and install (3 sites)						
ordering parts						
procure supplies						Gear removal covers vehicle and tool usage and supplies to properly store and preserve sensors and equipment.
installation						
Procuring other general supplies	8	8	1	$ 2,020	$ 110	
Pull gear at end of the year	8		1	$ 1,100	$ 600	
prep for long term storage						
Task 2 - Stream gaging						Labor covers collecting up to 5 stream discharge measurements to maintain stage-discharge rating curves and
Flows and ratings (1 yr)-5 flow measurements	30	30	5	$ 7,800	$ 1,432	reviewing and correcting data as needed.
Maintain rating curve			15	$ 2,700		ODC covers rental of the FlowTracker or equivalent velocity meter and vehicle usage for measurements, and
Flow data QAQC	24		12	$ 4,920		telemetry
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra
Monthly maintenance	84	72		$ 17,940	$ 3,900	hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction.
Sonde data QAQC	36		12	$ 6,300		ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if
troubleshooting	16	8	8	$ 4,200	$ 2,000	needed.
Task 4 - Automated sampling (5 events)						
weather tracking			6	$ 1,080		
station setup	30	30		$ 6,900	$ 625	Labor covers the sampling 5 events under variable conditions and includes weather tracking, setting stations up
sample collection	30	30		$ 6,900	$ 625	for monitoring, collecting and delivering samples and up to 1 false starts to cover unsuccessful sample events.
sample delivery	10			$ 1,150	$ 100	Task also includes brief summary reports documenting each sample event and the associated data.
false starts 1 setup and shut down, no delivery	6	6		$ 1,380	$ 225	ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 5,082	analysis for 21 samples which includes 15 primary smaples and duplicate and blank samples for QC. Assumed 10% price increase in analysis to $242 per sample.
Reporting	15		7.5	$ 3,075		
WQ data QAQC	15		5	$ 2,625		
Task 5 - B-IBI						
Sample Collection						No Sampling
Reporting						
Task 6 - Overall management and reporting						
Communication	12	12	24	$ 7,080		
data management	12		9	$ 3,000		Labor covers general project coordination and a brief summary report for all the monitoring activities in the
Invoicing			12	$ 2,160		year.
develop health and safety plan	4		2	$ 820		
Annual reporting	20		24	$ 6,620		
Total	360	196	143.5	$ 89,770	$ 14,699	**Yearly Total $ 104,469.00**

Table C.1-4. Cost Estimate for 3-Year Baseline, Year 5

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours: Staff 1 $ 120.00	Staff 1 $ 120.00	Senior 1 $ 190.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Installation						Labor covers site reconnaissance to reconfirm sites, procuring any needed equipment replacements, reconditioning and re-installing the monitoring equipment and then removing the equipment and storing at the end of the monitoring year. ODCs cover vehicle usage and tools for installation and recon. Equipment purchased for monitoring includes $3,000 per site for replacement parts as needed and $500 to restart telemetry modems. In addition, project startup includes purchase of consumables like gloves, calibration standards, bags, desiccant ,etc. Gear removal covers vehicle and tool usage and supplies to properly store and preserve sensors and equipment.
Site recon	6		6	$ 1,860	$ 110	
Equipment purchase and install (3 sites)						
ordering parts/recondiioning	8	8	1	$ 2,110	$ 9,500	
procure supplies	6	2	1	$ 1,150	$ 750	
installation	24	24	6	$ 6,900	$ 600	
Procuring other general supplies	8		4	$ 1,720	$ 500	
Pull gear at end of the year	8	8	1	$ 2,110	$ 600	
prep for long term storage	8		1	$ 1,150	$ 110	
Task 2 - Stream gaging						Labor covers collecting up to 8 stream discharge measurements to develop stage-discharge rating curves and reviewing and correcting data as needed. ODC covers $2,000 for maintenance of the FlowTracker or equivalent velocity meter and vehicle usage for measurements
Flows and ratings (1 yr)-8 flow measurements	48	48	16	$ 14,560	$ 2,800	
Develop rating curve			24	$ 4,560		
Flow data QAQC	24		12	$ 5,160		
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction. ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if needed.
Monthly maintenance	84	72		$ 18,720	$ 3,900	
Sonde data QAQC	36		12	$ 6,600		
troubleshooting	16	8	8	$ 4,400	$ 3,000	
Task 4 - Automated sampling (5 events)						Labor covers the sampling 5 events under variable conditions and includes weather tracking, setting stations up for monitoring, collecting and delivering samples and up to 1 false starts to cover unsuccessful sample events. Task also includes brief summary reports documenting each sample event and the associated data. ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes analysis for 21 samples which includes 15 primary smaples and duplicate and blank samples for QC. Assumed 10% price increase in analysis to $242 per sample.
weather tracking			6	$ 1,140		
station setup	30	30		$ 7,200	$ 625	
sample collection	30	30		$ 7,200	$ 625	
sample delivery	10			$ 1,200	$ 100	
false starts 1 setup and shut down, no delivery	6	6		$ 1,440	$ 225	
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 5,082	
Reporting	15		7.5	$ 3,225		
WQ data QAQC	15		5	$ 2,750		
Task 5 - B-IBI						Labor covers B-IBI sampling at all three sites for 1 sample event and the associated reporting. ODC covers the analys charges for 6 samples and supplies for sampling. Aassumed 10% cost increase for analysis to $385 per sample.
Sample Collection		20	12	$ 4,680	$ 2,610	
Reporting		10	12	$ 3,480		
Task 6 - Overall management and reporting						Labor covers general project coordination, the update of a health and safety plan and a brief summary report for all the monitoring activities in the year.
Communication	12	12	24	$ 7,440		
data management	12		9	$ 3,150		
Invoicing			12	$ 2,280		
update health and safety plan	4		2	$ 860		
Annual reporting	24		30	$ 8,580		
Total	434	278	211.5	$ 125,625	$ 31,137	**Yearly Total $ 156,762.00**

Table C.2-1. Cost Estimate 1-Year Baseline, Year 1

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours: Staff 1 $ 110.00	Staff 1 $ 110.00	Senior 1 $ 175.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Installation and demob						Labor covers site reconnaissance to select sites, procuring equipment, installing the monitoring equipment and then removing the equipment and storing at the end of the monitoring year. ODCs cover vehicle usage and tools for installation and recon. Equipment purchased for monitoring includes autosamplers, pressure transducers, datalogger/controller, water quality sondes, telemetry charges and associated items like enclosures, batteries, fasteners, conduit, etc. In addition, project startup includes purchase of consumables like gloves, calibration standards, bags, desiccant ,etc. Gear removal covers vehicle and tool usage and supplies to properly store and preserve sensors and equipment.
Site recon	8		8	$ 2,280	$ 110	
Equipment purchase and install (3 sites)						
ordering parts	8		1	$ 1,055	$ 60,000	
procure install supplies	8	4	1	$ 1,495	$ 750	
installation	24	24	6	$ 6,330	$ 600	
Procuring other general supplies	8		4	$ 1,580	$ 500	
Pull gear at end of the year	8	8	1	$ 1,935	$ 600	
prep for long term storage	8		1	$ 1,055	$ 110	
Task 2 - Stream gaging						Labor covers collecting up to 8 stream discharge measurements to develop stage-discharge rating curves and reviewing and correcting data as needed. ODC covers the purchase of a FlowTracker or equivalent velocity meter and vehicle usage for measurements
Flows and ratings (1 yr)-8 flow measurements	48	48	16	$ 13,360	$ 11,835	
Develop rating curves			18	$ 3,150		
Flow data QAQC	24		12	$ 4,740		
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction. ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if needed.
Monthly maintenance	84	72		$ 17,160	$ 3,900	
Sonde data QAQC	36		12	$ 6,060		
troubleshooting	16	8	8	$ 4,040	$ 2,000	
Task 4 - Automated sampling (12 events)						Labor covers the sampling 12 events under variable conditions and includes weather tracking, setting stations up for monitoring, collecting and delivering samples and up to 2 false starts to cover unsuccessful sample events. Task also includes brief summary reports documenting each sample event and the associated data. ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes analysis for 45 samples which includes 36 primary smaples and duplicate and blank samples for QC. Analysis cost per sample is $220
weather tracking			6	$ 1,050		
station setup	72	72		$ 15,840	$ 1,500	
sample collection	72	72		$ 15,840	$ 1,500	
sample delivery	24			$ 2,640	$ 240	
2 false starts setup and shut down, no delivery	12	12		$ 2,640	$ 1,225	
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 9,240	
Reporting	36		18	$ 7,110		
WQ data QAQC	36		12	$ 6,060		
Task 5 - B-IBI all 3 sites						Labor covers B-IBI sampling at all three sites for 1 sample event and the associated reporting. ODC covers the analysis charges for 6 samples and supplies for sampling. Analysis costs are $350 per sample.
Sample Collection		20	12	$ 4,300	$ 2,400	
Reporting		10	12	$ 3,200		
Task 6 - Overall management and reporting						Labor covers general project coordination, the development of a health and safety plan and a brief annual summary report for all the monitoring activities in the year.
Communication	12	12	24	$ 6,840		
Data management	12		12	$ 3,420		
Invoicing			12	$ 2,100		
develop health and safety plan	6		2	$ 1,010		
Annual reporting	24		36	$ 8,940		
Total	586	362	234	$ 145,230	$ 96,510	**Yearly Total $ 241,740.00**

Table C.2-2. Cost Estimate for 1-Year Baseline, Year 5

Project No. 200383, City of Shoreline, WA

Work Element	Labor Budget Basis in Hours: Staff 1 $ 120.00	Staff 1 $ 120.00	Senior 1 $ 190.00	Total Labor Budget	Other Direct Charges (ODC)	Notes
Task 1 - Site Installation						Labor covers site reconnaissance to reconfirm sites, procuring any needed equipment replacements, reconditioning and re-installing the monitoring equipment and then removing the equipment and storing at the end of the monitoring year. ODCs cover vehicle usage and tools for installation and recon. Equipment purchased for monitoring includes $3,000 per site for replacement parts as needed and $500 to restart telemetry modems. In addition, project startup includes purchase of consumables like gloves, calibration standards, bags, desiccant ,etc. Gear removal covers vehicle and tool usage and supplies to properly store and preserve sensors and equipment.
Site recon	6		6	$ 1,860	$ 110	
Equipment purchase and install (3 sites)						
ordering parts/recondiioning	8	8	1	$ 2,110	$ 9,500	
procure install supplies	8	4	1	$ 1,630	$ 600	
installation	18	18	6	$ 5,460	$ 600	
Procuring other general supplies	8		4	$ 1,720	$ 500	
Pull gear at end of the year	8	8	1	$ 2,110	$ 600	
prep for long term storage	8		1	$ 1,150	$ 110	
Task 2 - Stream gaging						Labor covers collecting up to 8 stream discharge measurements to develop stage-discharge rating curves and reviewing and correcting data as needed. ODC covers $2,000 for maintenance of the FlowTracker or equivalent velocity meter and vehicle usage for measurements
Flows and ratings (1 yr)-8 flow measurements	48	48	16	$ 14,560	$ 2,800	
Develop rating curves			18	$ 3,420		
Flow data QAQC	24		12	$ 5,160		
Task 3 - Sonde operation and maintenance						Labor covers 12 site visits for 2 people to maintain and calibrate the water quality sondes. 1 field staff has extra hours for calibrating and checking hand-held sonde. This task also includes time for sonde repairs if needed and data review and correction. ODC's cover vehicle usage, hand-held sonde use, sonde calibration standards, and replacement sensors if needed.
Monthly maintenance	84	72		$ 18,720	$ 3,900	
Sonde data QAQC	36		12	$ 6,600		
troubleshooting	16	8	8	$ 4,400	$ 3,000	
Task 4 - Automated sampling (12 events)						Labor covers the sampling 12 events under variable conditions and includes weather tracking, setting stations up for monitoring, collecting and delivering samples and up to 2 false starts to cover unsuccessful sample events. Task also includes brief summary reports documenting each sample event and the associated data. ODCs cover consumables like gloves and ice, vehicle usage and analytical costs. This cost estimate assumes analysis for 45 samples which includes 36 primary smaples and duplicate and blank samples for QC. Assumed 10% price increase in analysis to $242 per sample.
weather tracking			6	$ 1,140		
station setup	72	72		$ 17,280	$ 1,500	
sample collection	72	72		$ 17,280	$ 1,500	
sample delivery	24			$ 2,880	$ 240	
false starts 1 setup and shut down, no delivery	12	12		$ 2,880	$ 1,225	
Analytical for Cu, Zn,Pb, N, TP, TSS, hardness, fecal					$ 10,164	
Reporting	36		18	$ 7,740		
WQ data QAQC	36		12	$ 6,600		
Task 5 - B-IBI						Labor covers B-IBI sampling at all three sites for 1 sample event and the associated reporting. ODC covers the analys charges for 6 samples and supplies for sampling. Aassumed 10% cost increase for analysis to $385 per sample.
Sample Collection		20	12	$ 4,680	$ 2,610	
Reporting		10	12	$ 3,480		
Task 6 - Overall management and reporting						Labor covers general project coordination, the update of a health and safety plan and a brief annual summary report for all the monitoring activities in the year.
Communication	12	12	24	$ 7,440		
data management	12		12	$ 3,720		
Invoicing			12	$ 2,280		
update health and safety plan	4		2	$ 860		
Annual reporting	24		36	$ 9,720		
Total	576	364	232	$ 156,880	$ 38,959	**Yearly Total $ 195,839.00**