East Fork Lewis River Watershed Bacteria and Temperature

Source Assessment Report

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East Fork Lewis River near boat ramp at river mile 3.35. Photo by Sheelagh McCarthy.

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Source Assessment Report

by

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Abstract

The East Fork (EF) Lewis River watershed has fecal coliform bacteria (FC) and temperature impairments that exceed (do not meet) criteria in Washington State's Water Quality Standards. This report completes the source assessment study for the EF Lewis River watershed using data from the 2005-06 study and also FC data collected in 2017 to compare with current water quality conditions.

FC exceedances were found throughout the watershed based on the 2005-06 data. FC concentrations tended to increase moving from the upper EF Lewis River subbasin through the lower watershed. The highest FC concentrations were found in tributaries in the lower subbasin, McCormick and Brezee Creeks. Similar sites sampled in 2017 showed that FC exceedances were consistently high in the lower subbasin, and FC concentrations in both sampling periods were generally higher during the dry season than during the wet season. FC loading was typically higher during the wet season due to increased flows. A routine monitoring site on the EF Lewis River showed increasing levels of FC since the 2005-06 sampling.

All EF Lewis River and tributary temperature monitoring sites exceeded the 7-day average of the daily maximum temperatures (7-DADMax) criteria. Average temperatures in the EF Lewis River mainstem increased further downstream. In order to address temperature issues along the mainstem, a shade analysis was completed to assess current effective shade and system potential shade. The largest shade deficits occurred in the middle section of the EF Lewis River.

This report includes general recommendations, based on both the 2005-06 and 2017 FC and temperature data, as well as previous hydrologic and water quality studies in this watershed. These recommendations are used to help guide restoration strategies to improve water quality and meet Washington State Water Quality Standards in the EF Lewis River watershed.

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    - Other Ecology staff who helped throughout this project, including 2005-06 field work.
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Executive Summary

Introduction

Washington State's Department of Ecology selected the East Fork (EF) Lewis River for a water quality improvement project in 2004 because segments of the river and its tributaries exceeded (did not meet) water quality standards for fecal coliform bacteria (FC) and temperature. Field work was conducted in 2005-06 to study areas with high levels of FC and elevated temperatures. Supplemental FC sampling occurred in 2017 to identify and confirm areas with high FC concentrations. This water quality improvement report contains the technical analysis for FC and temperature results and recommendations to improve the overall water quality in the EF Lewis River watershed.

Watershed Description

The EF Lewis River watershed is located primarily within Clark County in southwest Washington. The study area extends from the mouth of the EF Lewis River to the boundary with the Gifford Pinchot National Forest near river mile (RM) 32. The watershed is located within Water Resources Inventory Area (WRIA) 27.

The headwaters of the EF Lewis River are located in the western crest of the Cascade Mountain range, and the river flows west until reaching its confluence with the North Fork Lewis River. The upper watershed is primarily timber land. Throughout the middle and lower watersheds, land use changes to a more mixed-used landscape of forest, agriculture, developed, and residential areas. The towns of La Center and Yacolt are located within the watershed, and Battle Ground and Ridgefield are at its boundaries.

Goals and Objectives

This source assessment study for the EF Lewis River uses data from 2005-06 and 2017 to identify and confirm sources of pollutants in the watershed. The technical analysis for FC and temperature was completed by taking the following actions:

- Determining which sites met the water quality criteria for FC based on the 2005-06 data. A loading analysis was performed to identify seasonal loading patterns.
- Performing a Seasonal Kendall Trend Test using data from Ecology's ambient monitoring site (27D090) to identify trends in FC concentrations since 2005.
- Completing a statistical rollback analysis to develop target FC concentrations from the 2005-06 data.
- Conducting FC sampling in 2017 to assess current FC concentrations. The 2017 data were compared with the 2005-06 data to confirm areas with high FC concentrations.
- Identifying tributary and river segments with high temperatures from a summary of the 2005-06 temperature data.

- Conducting a shade analysis to determine current effective shade and system potential shade for the mainstem of the EF Lewis River. This was used to identify areas with large shade deficits to help guide implementation and restoration efforts.

Conclusions and Recommendations

Conclusions

A summary of conclusions from the FC analysis include the following:

- A seasonal trend analysis showed FC concentrations increasing from 2005-2016 based on long-term ambient monitoring data at EF Lewis River RM 10.1 (27D090).
- The 2005-06 data showed highest FC concentrations and water quality criteria exceedances occurred during the dry season. Sites with the highest FC concentrations were located along McCormick Creek and Brezee Creek, including a stormwater outfall on Brezee Creek.
- The 2017 supplemental data confirmed areas with high levels of FC. Similar to the 2005-06 results, the highest FC concentration and water quality exceedances occurred along McCormick Creek and Brezee Creek.
- FC loads were generally higher during the wet season than during the dry season, particularly at McCormick Creek, Brezee Creek, and Lockwood Creek.
- EF Lewis River mainstem sites generally met FC water quality criteria, with the exception of some sites in the lower watershed. These patterns were consistent between the 2005-06 and 2017 data.

A summary of conclusions from the temperature analysis include the following:

- Long-term temperature monitoring at Ecology's EF Lewis River ambient site at RM 10.1 displays similar temperature conditions since the 2005-06 sampling.
- The temperature data from 2005-06 showed all of the temperature monitoring sites exceeded the 7-DADMax temperature water quality criterion at some point during the sampling period.
- The Upper EF Lewis River and tributaries had the lowest overall temperatures, and temperatures tended to increase moving from the upper to lower watershed.
- A shade analysis compared the current effective shade with system potential effective shade, by calculating a shade deficit along the EF Lewis River mainstem. The segments of the river with the highest shade deficits were located from RM 9-13.
- The results of the shade analysis can help guide restoration efforts and activities to improve temperature conditions in the watershed. These activities are recommended for the middle watershed along waterfront parks and greenways.

Recommendations

The following are general recommendations to improve water quality in the EF Lewis River watershed based on the technical analysis completed for this source assessment report:

- Implement best management practices (BMPs) to reduce FC loading from agricultural land into waters. This is needed for sites that showed high FC concentrations that were located in agricultural areas including at Rock Creek North, Mason Creek and McCormick Creek.
- Continue the management of stormwater through appropriate BMPs to reduce water quality impacts at Brezee Creek stormwater outfalls, particularly during the wet season.
- Continue education and outreach work in the watershed community about the effects of nonpoint pollution to water quality and human health.
- Conduct investigative stream walks along McCormick and Brezee Creeks to identify and sample unknown or unmapped outfalls (e.g., pipes and culverts). These tributaries had sites with high FC levels in both the wet and dry seasons. Upstream of Lockwood Creek should be further investigated based on high, dry season FC loads.
- Restore and protect wetlands in areas that will benefit the stream and enhance habitat.
- Continue to add native vegetation plantings on stream banks in order to increase riparian shade. Focus this restoration work in areas with large shade deficits in the middle watershed, as determined through the shade analysis.
- Implement flood plain restoration as well as habitat and microclimate enhancements that increase the number of cold water refuges available in the stream for salmonids and other fish species to help improve overall habitat quality.
- Continue restoration and conservation projects and activities led by Clark County, LCFRB, and other local stakeholders and groups to improve salmon recovery efforts and overall water quality in the watershed.

Introduction

The EF Lewis River and several of its tributaries exceed (do not meet) Washington State's freshwater quality criteria and designated beneficial uses due to high temperatures and elevated levels of FC. In 2004, the Washington State Department of Ecology (Ecology) started this water quality improvement project to address these water quality exceedances. Field work was completed from 2005-06. Although originally intended as a total maximum daily load (TMDL) study, this project was changed to a source assessment study.

Regardless of the approach, the need to cool the water and eliminate sources of FC remain the same. These rivers and creeks will stay on the 303(d) list of impaired waters until they meet water quality standards. If standards are not met, Ecology is required by the Clean Water Act to write a TMDL in the future. Ecology will track stream temperatures and FC concentrations over time to determine our next course of action.

The study area extends west from the boundary with Skamania County and the Gifford Pinchot National Forest boundary through Clark County to the confluence with the North Fork Lewis River (Figure 1).

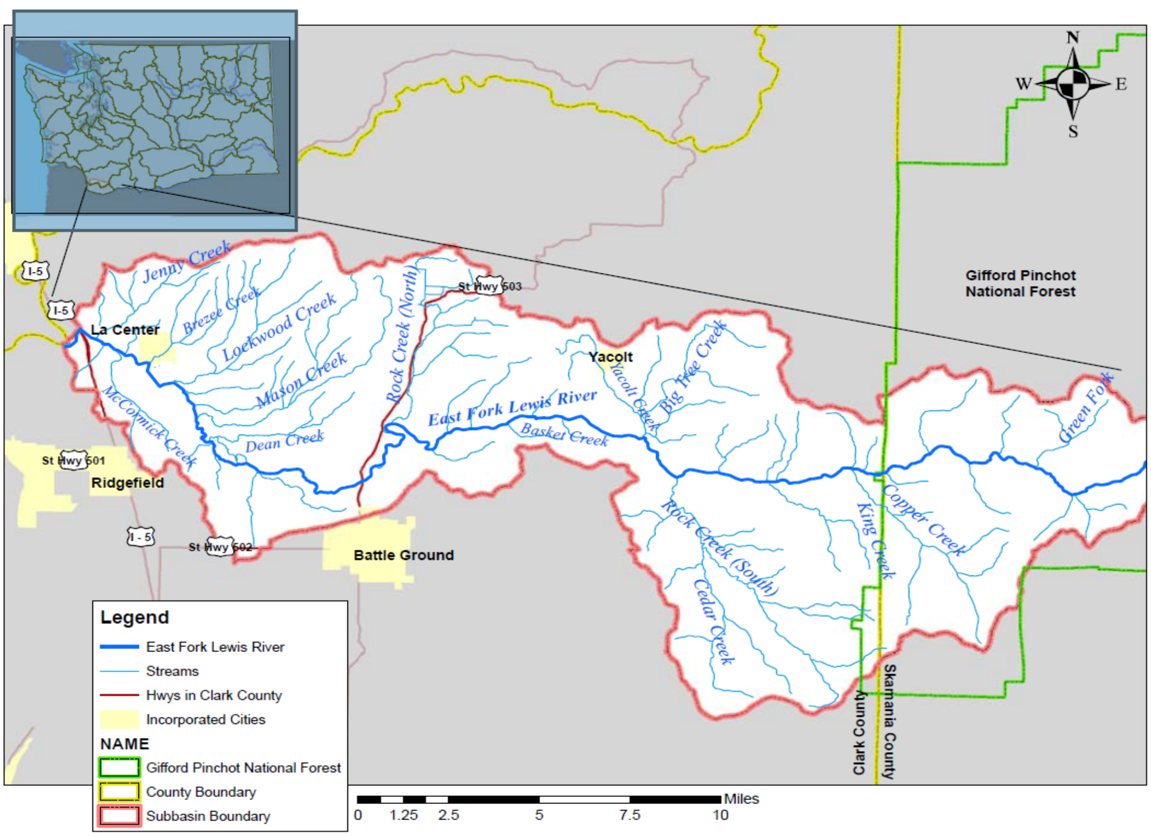


Figure 1. Overview of EF Lewis River watershed (Bilhimer et al., 2005).

Many of these river and stream exceedances addressed in the original study are on the current 303(d) list. Figure 2 is a map of the most recent water quality exceedance listings for FC and temperature in the EF Lewis River watershed. Segments of Rock, Lockwood, Mason, McCormick, Jenny, Riley, Brezee and Yacolt Creeks are listed on the most recent 303(d) list from 2014 for FC exceedances. These FC listings were used to help guide supplemental FC monitoring efforts in 2017.

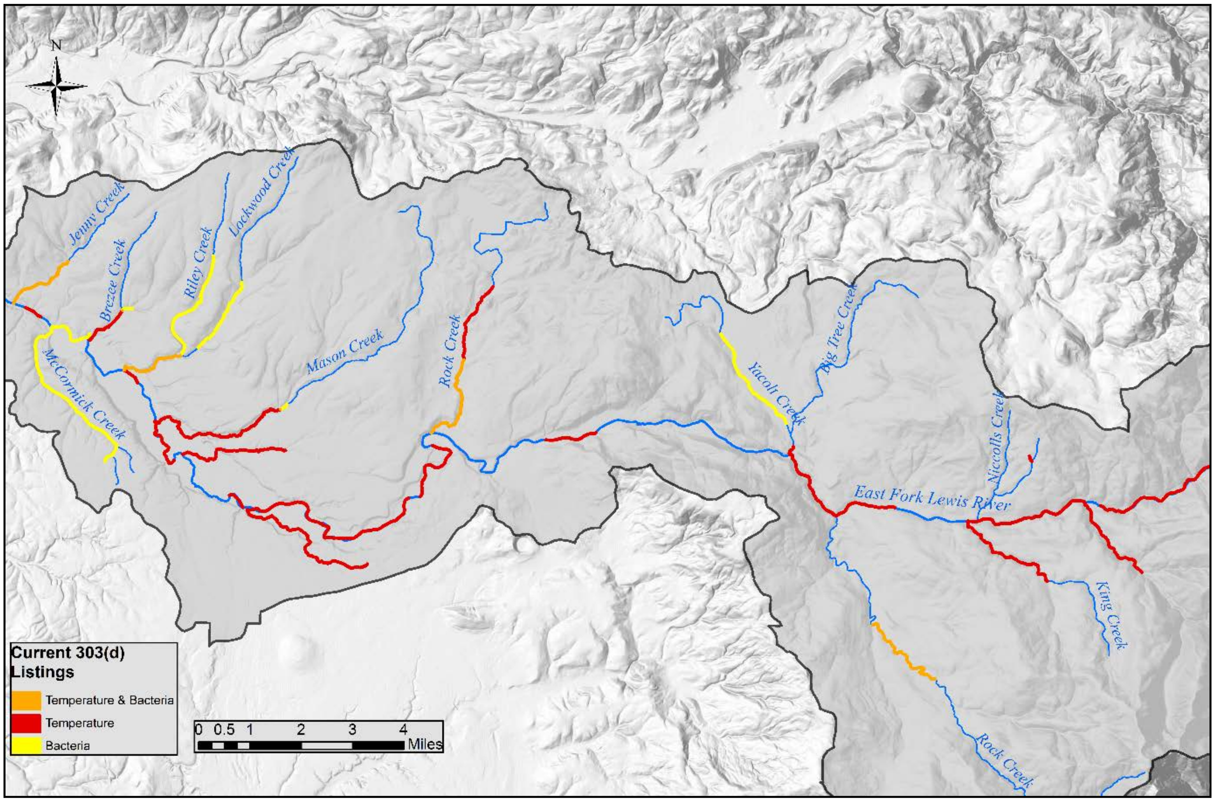


Figure 2. Current 303(d) listings for FC and temperature, 2014.

A *Surface Water and Groundwater Exchange* report (Carey and Bilhimer, 2009) and a *Streamflow Summary* (Springer, 2009) for the EF Lewis River based on the 2005-06 data field collection were completed. The technical analysis for FC and temperature was also started following the completion of field sampling in 2006 by Ecology staff.

While this project was on hold, active stakeholders and local partners continued to support and implement water quality improvement projects. These included restoration and conservation projects and activities in tributaries in the lower watershed. Clark County's *Comprehensive Growth Management Plan* (2016) included information about land use changes in the county from 2007 to 2014, and this was used to assess if the 2005-06 data continues to be representative of current watershed conditions.

Water Quality Standards and Beneficial Uses

The state's Water Quality Standards are the basis for protecting and regulating the quality of surface waters in Washington State. The standards implement portions of the federal Clean Water Act by specifying the designated and potential uses of water bodies in the state. They set water quality criteria to protect those uses and acknowledge limitations. The standards also contain policies to protect high quality waters (antidegradation) and, in many cases, specify how criteria will be implemented, such as through permits.

The standards are established to sustain public health and public enjoyment of the waters, and the propagation and protections of fish, shellfish, and wildlife. A three-part approach was designed to set limits on pollution in water systems in order to protect beneficial uses such as aquatic life, swimming, and fishing. The aquatic life uses contain categories of aquatic communities and are described using key species and life-stage conditions (WAC 173-201A-200). Categories for recreational uses are found in these tables as well.

The water quality standards and designated beneficial uses for the EF Lewis River watershed are presented in Table 1 for FC and temperature. Figure 3 is a map that shows the areas of the water quality standards throughout the watershed.

Table 1. Water quality standards for FC and temperature and in the EF Lewis River watershed (WAC 173-201A-200).

Waterbody Reach	Recreation Uses	Bacteria Criteria
EF Lewis River from mouth to Moulton Falls (RM 24.6)	Primary Contact	Geometric Mean: 100 cfu/100mL
		10% of samples not to exceed: 200cfu/100mL
EF Lewis River from Moulton Falls (RM 24.6) to headwaters	Extraordinary Primary Contact	Geometric Mean: 50 cfu/100mL
		10% of samples not to exceed: 100cfu/100mL

Waterbody Reach	Aquatic Life Uses	Temperature Standard Highest 7-DADMax
EF Lewis River	Core Summer Habitat	16.0°C (60.8°F)

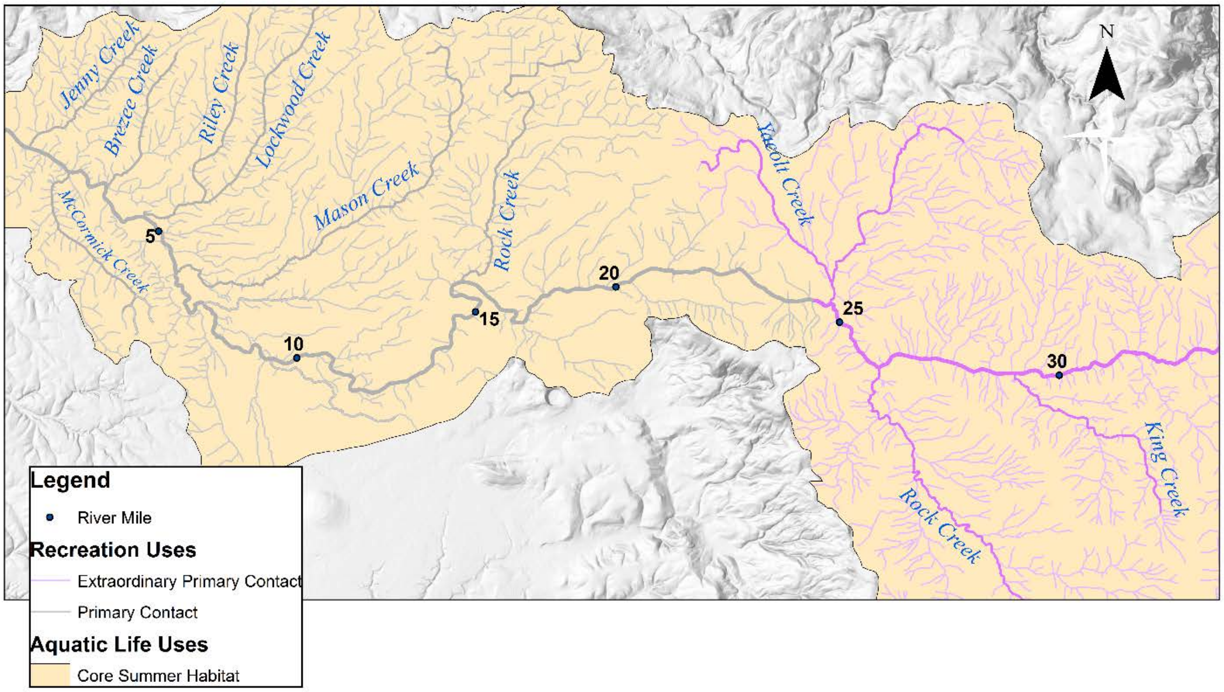


Figure 3. Areas of recreation and aquatic life uses in the EF Lewis River watershed.

Washington State uses the temperature criteria to ensure a water body's natural capability for providing full support for its designated aquatic life uses. These cool temperature requirements are expressed as the highest allowable 7-day average of the daily maximum temperatures (7-DADMax) in a water body. The 7-DADMax temperatures represent conditions in the thalweg or main stream channel; therefore, it is assumed that aquatic species have access to cold water refugia where they can reside in water that is cooler than the 7-DADMax temperatures. The 7-DADMax temperature criterion also assumes that colder temperatures are available to protect fish at night.

Washington State uses these criteria to ensure full protection for its designated aquatic life uses. The standards recognize, however, that waters display thermal heterogeneity—some are naturally cooler, and some are naturally warmer. When a water body is naturally warmer than the above-described numeric criteria, the State limits the allowance for additional warming due to human activities. The combined effects of all human activities must not cause more than a 0.3 °C (0.54 °F) increase above the naturally warmer temperature condition.

Additionally, some river and creek segments of the EF Lewis River watershed have supplemental spawning and incubation protection for salmonid species. A spawning temperature of 13.0C (7-DADMax) is used to protect summer reproduction areas for salmon and trout from February 15 – June 15 (Figure 4).

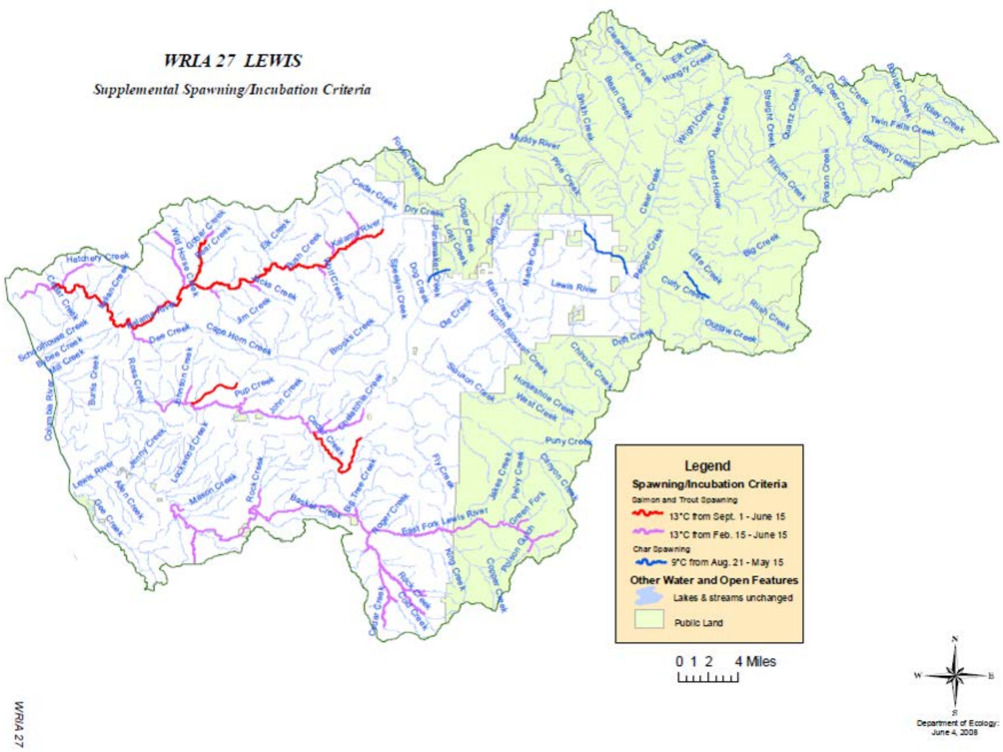


Figure 4. Supplemental Spawning/Incubation Criteria for Water Resources Inventory Area 27 (Ecology, 2011).

For FC, compliance is based on meeting both the geometric mean criterion and the criterion for 10% of samples limit (or a single sample if less than ten total samples); this is calculated as the 90^{th} percentile. The 90^{th} percentile is a measure of statistical distribution that determines the value for which 90% of the data points are smaller and 10% are higher. These two measures used in combination ensure that FC pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended.

Watershed Description

The EF Lewis River watershed is located within Water Resource Inventory Area (WRIA) 27 in southwestern Washington. The headwaters of the EF Lewis River originate in the western crest of the Cascade Mountain range. Elevation at the headwaters of the EF Lewis River is 4,442 feet about mean sea level. The river flows west 42 miles to its confluence with the North Fork Lewis River. The EF Lewis River is influenced by the tide from the Columbia River affecting water levels from its mouth to a short distance below Daybreak Park Bridge at approximately river mile (RM) 10.2 (Pacific Groundwater Group, 2003).

The study area begins at the border of Skamania County and at the Gifford Pinchot National Forest boundary and continues through the mouth of the EF Lewis River. It includes waterbody segments, both along the river's mainstem and its tributaries, impaired by FC and heat (measured as temperature), as listed in the Clean Water Act Section 303(d) lists. These exceedances were identified based on multiple sampling collections conducted by Ecology, Clark County, and other entities.

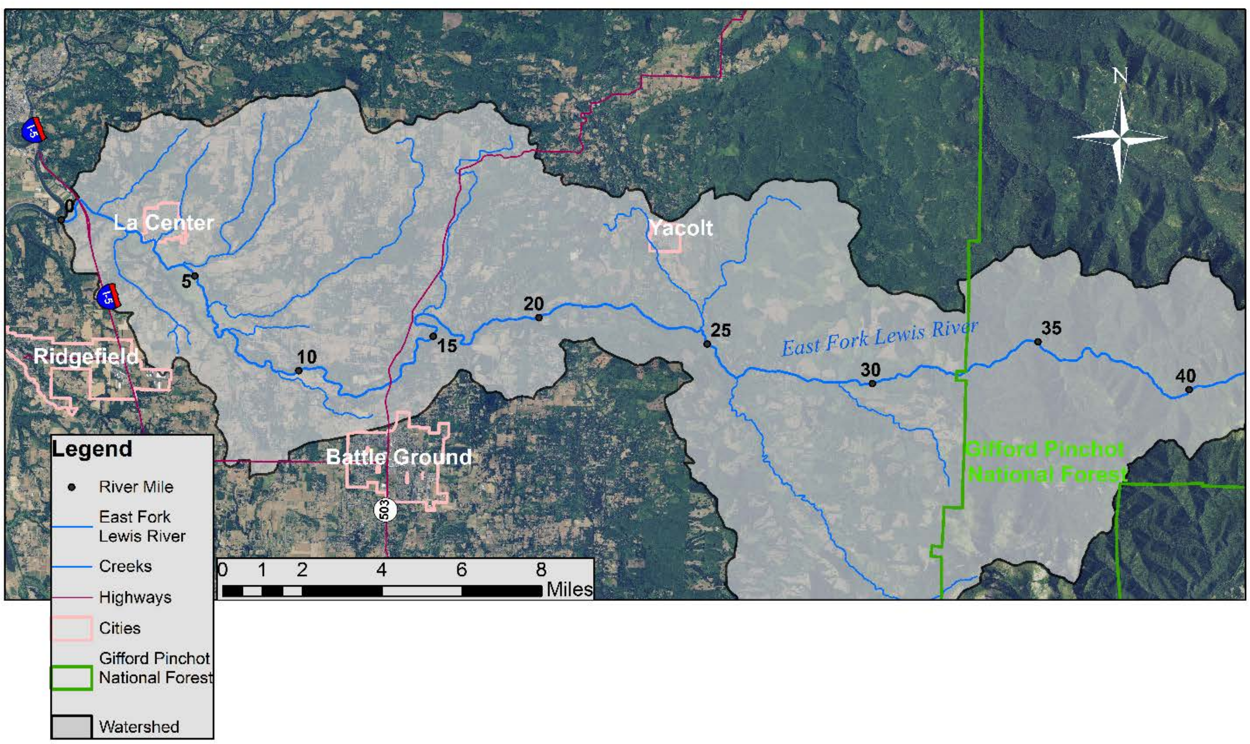


Figure 5. EF Lewis River watershed.

Climate

The climate of the EF Lewis River watershed is influenced by the Pacific Ocean to the west and the Cascade Mountains directly to the east. Figure 6 shows the distribution of average annual precipitation. The headwaters of the EF Lewis River receive between 100 and 120 inches of precipitation annually, much of which is snow during the late winter through the spring. As the river progresses downstream, the lower watershed receives between 40 and 50 inches of precipitation per year—roughly half of the precipitation received near the headwaters.

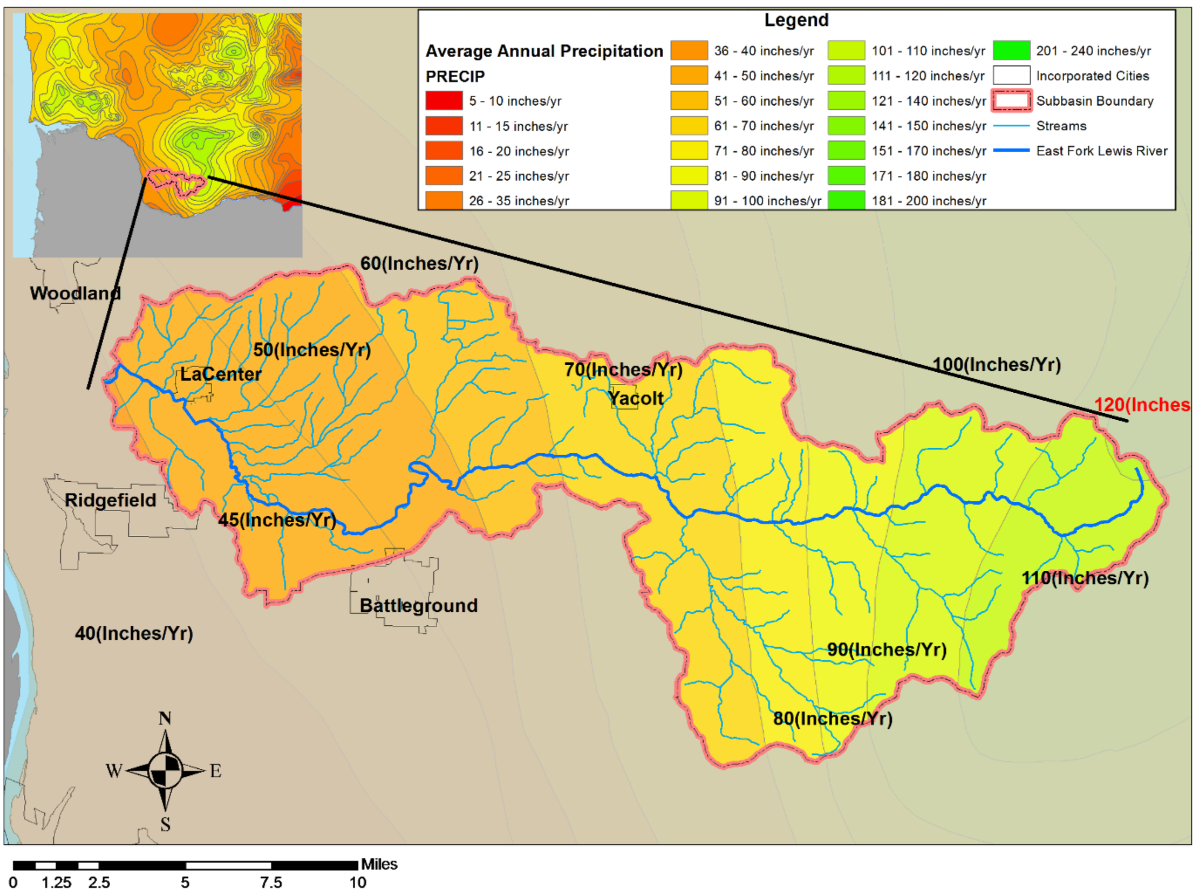


Figure 6. Average annual precipitation for the EF Lewis River watershed (Bilhimer et al., 2005).

A weather station located near RM 7.3 measured precipitation from June 2005 – October 2006. The total daily precipitation values are shown in Figure 7.

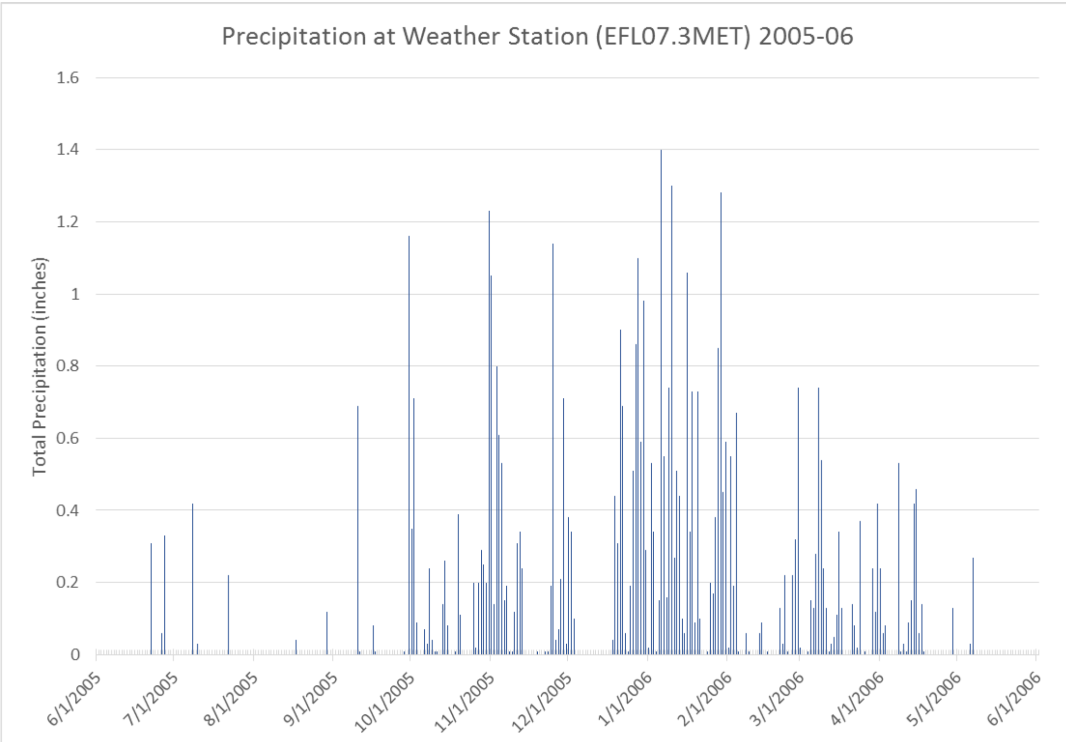


Figure 7. Total daily precipitation at weather station (EFL07.3 MET).

Hydrology and Hydrogeology

The headwaters of the EF Lewis River begin on the western slope of the Cascades and receive most of their baseflow from groundwater. The upper part of the watershed, from approximately RM 20.3 through the headwaters, consists of substrate comprised primarily of andesite and other older rocks of volcanic origin (Washington State DNR). There is limited unconsolidated material in the streambed and the bedrock is exposed in many places. The upper subbasin consists of V-shaped valleys with steep banks that confine stream channels and restrict lateral movement.

The EF Lewis River downstream of Heisson Road (RM 20.3) cuts through the Lower Troutdale gravel aquifer, which overlays the larger undifferentiated fine-grained sediments of Pliocene origin. These layers are topped by a layer of unconsolidated materials consisting of Pleistocene sediments that were washed down during catastrophic floods of the Columbia River and Holocene pyroclastic debris deposits. The unconsolidated layer is a highly productive aquifer (Swanson et al., 1993).

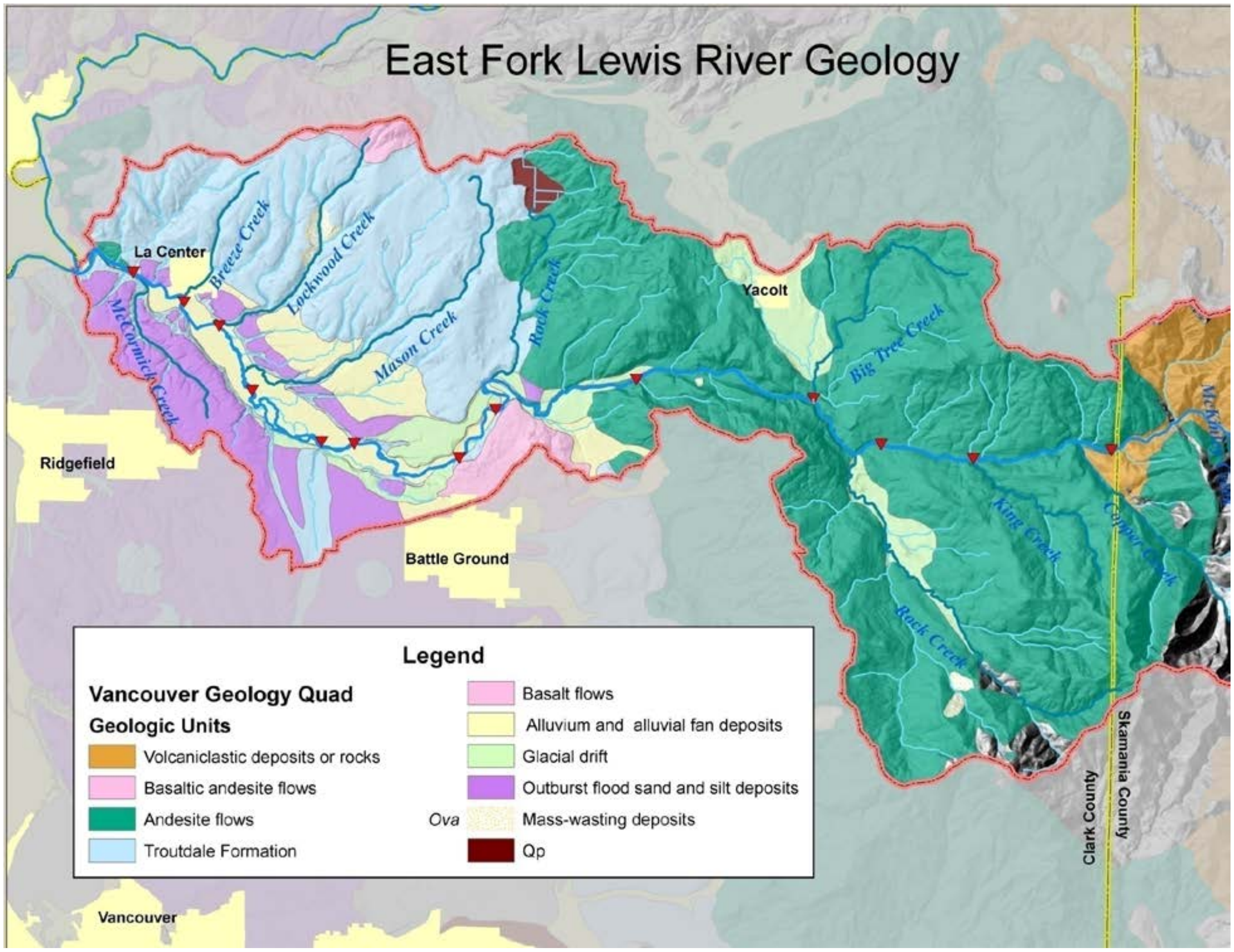


Figure 8. Surficial geology of the EF Lewis River watershed and seepage streamflow sites. (Washington State Department of Natural Resources, 2005; Carey and Bilhimer, 2009).

The USGS has maintained a streamflow gage near Heisson Road at RM 20.3 (USGS 14222500) with a historical record going back to 1929. The lowest 7-day average flow that can be expected to occur once every ten years on average (7Q10) is 38 cubic feet per second (cfs) based on the period of record from 1929 – 2003. The lowest 7-day average flow that has an expected recurrence interval of two years (7Q2) is 51.1 cfs based on the period of record from 1929 – 1979 (Williams and Pearson, 1985). Low summer baseflows typically occur from late July through August, and peak flows occur during storm events from October through June.

Streamflow Study

A streamflow assessment was conducted along the EF Lewis River as part of this study (Springer, 2009). Continuous streamflow was recorded by four streamflow gages along the EF Lewis River mainstem. Ecology established continuous stage height recorders at sites 1 and 2 on the EF Lewis River, and data from sites 3 and 4 were also used. The sites with streamflow gages included the following:

1. EF Lewis River near La Center (RM 1.8): Ecology installed a streamflow gage near La Center, upstream of Paradise Point State Park. This station was installed to monitor stage changes due to the tidal influence on water levels from the Columbia River. However, this streamflow gage was flooded during a large storm event in December 2005 and was not re-established for the study.
2. EF Lewis River near Dollar Corner (RM 10.1): Ecology maintained a long-term streamflow monitoring site on the EF Lewis River mainstem at Daybreak Park as part of its statewide streamflow monitoring network.
3. EF Lewis River at Heisson USGS (RM 20.3): USGS maintains a streamflow gage on the EF Lewis River near Heisson Road, and data were used from this site for this Ecology study.
4. EF Lewis River at Sunset Campground (RM 32.5): Ecology installed a streamflow gage at the Gifford Pinchot National Forest boundary.

The *Streamflow Summary for Gaging Stations on the EF Lewis River, 2005-06* (Springer, 2009) provides more details on field methods and quality assurance.

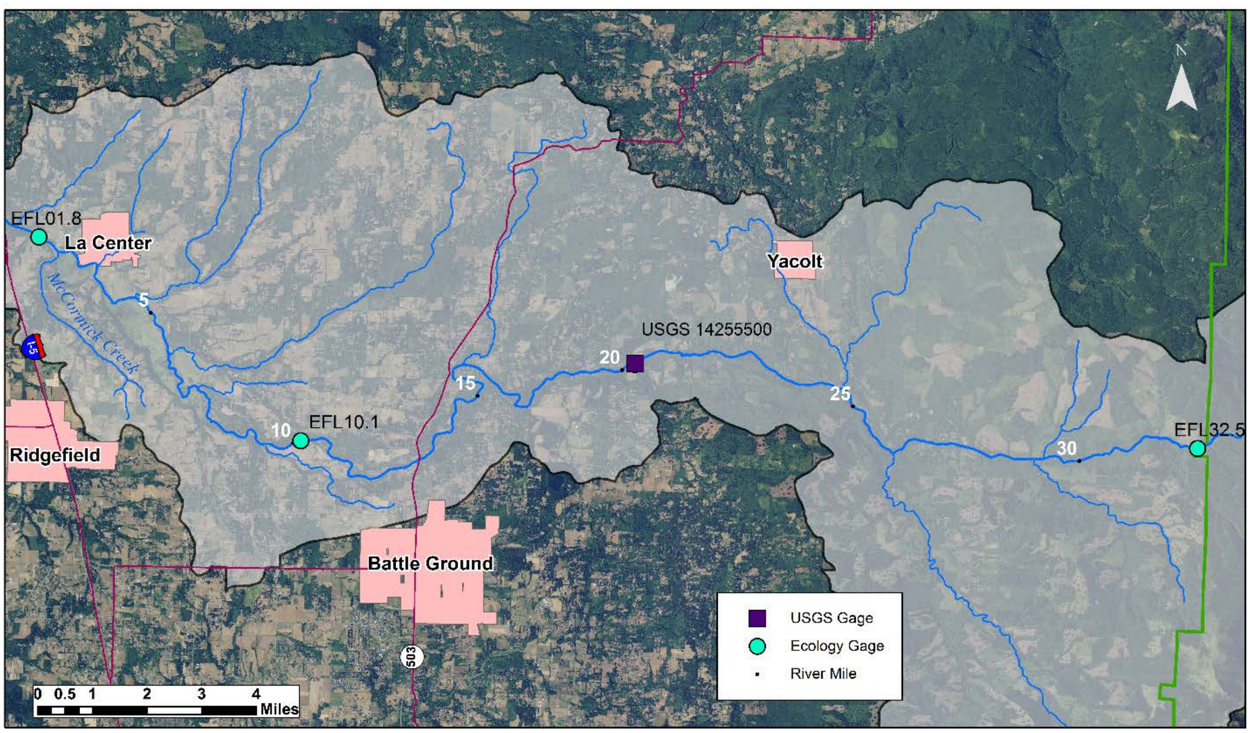


Figure 9. Locations of streamflow gages.

A hydrograph for the continuous gages at the headwater site (RM 32.3), Daybreak Park (RM 10.1), and USGS station (RM 20.3) along with precipitation data recorded from 2005 is shown in Figure 10. The headwater site has a quicker reaction to rain events. Reactions to storm events at the Daybreak Park gage were generally at a lower magnitude than the USGS gage in August as the stream was reaching baseflow conditions. The lowest flows measured at all three sites were during late September.

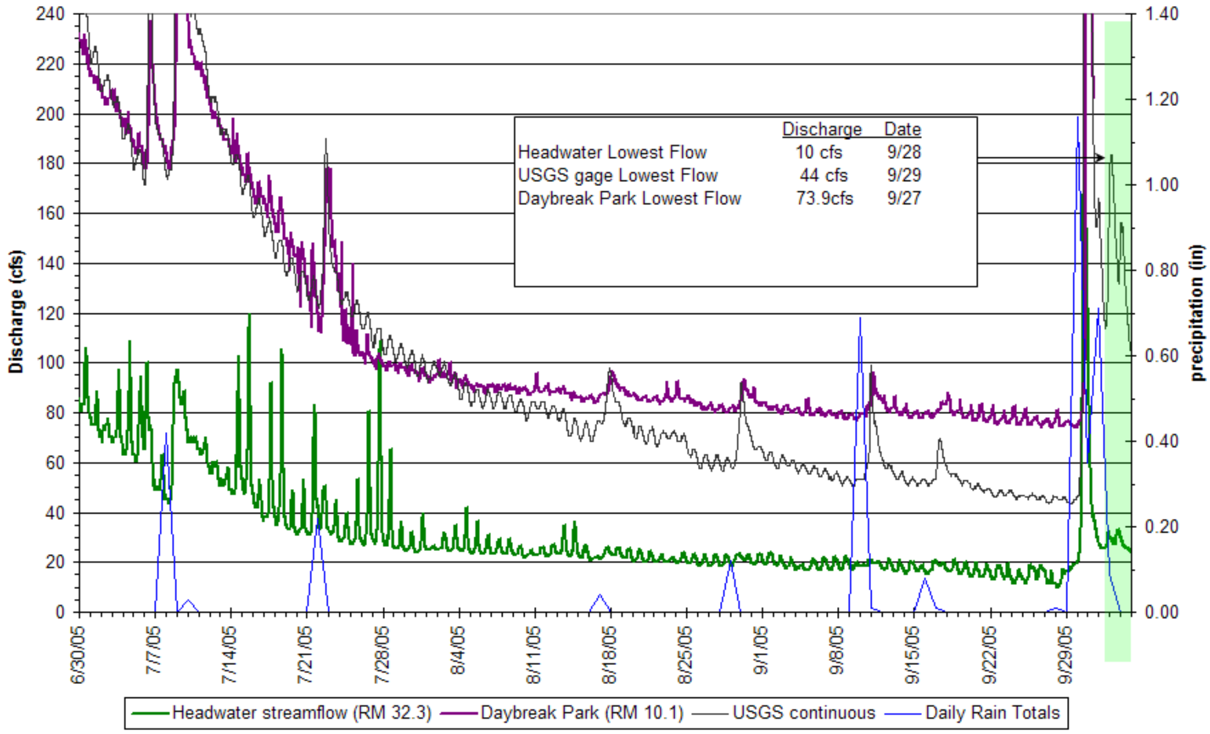
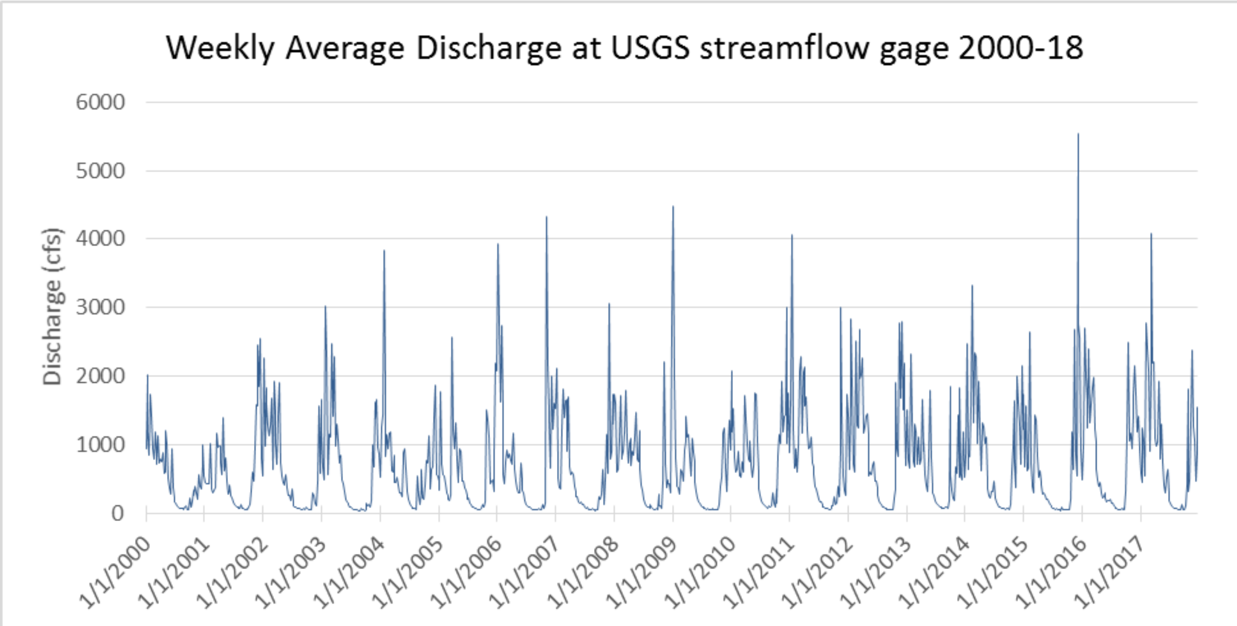


Figure 10. EF Lewis River hydrograph for continuous gages and precipitation data.
The highlighted section (green) shows the lowest flows recorded at the end of September.

A graph of the weekly average discharges (cfs) recorded at the USGS gage from 2000-2018, and the monthly averages of discharge at the USGS gage from 2005-06 compared with the monthly averages from 2000-2018 are shown in Figure 11. Based on these figures, the 2005-06 study period had notable higher than average streamflow in January and November, and lower than average streamflow conditions in February, March, and October. The 2005-06 summer months (June-September) were representative of average streamflow conditions. The overall average streamflow for 2005-06 (683 cfs) was slightly lower than the average annual streamflow from 2000-2018 (723 cfs).



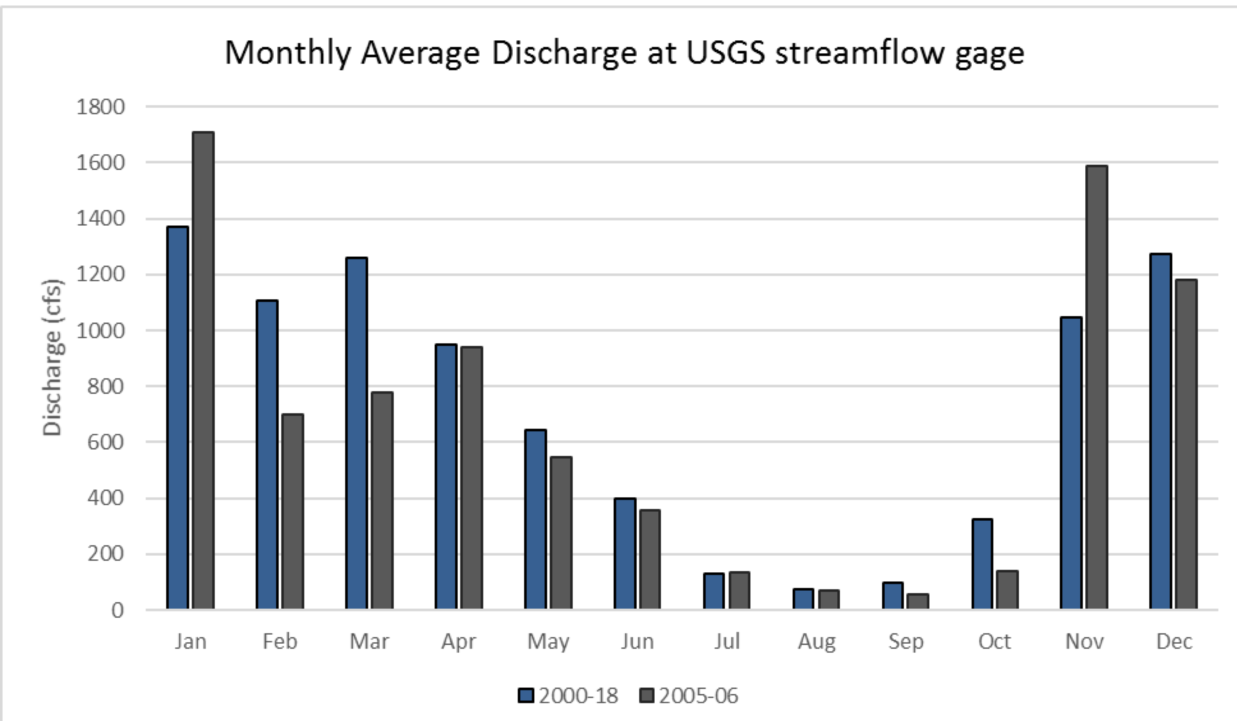


Figure 11. Weekly average discharge at USGS streamflow gage (above) and monthly average discharge at USGS streamflow gage (below).

Surface Water and Groundwater Exchange Study

The report *A Surface Water and Groundwater Exchange along the EF Lewis River* was completed in 2009 (Carey and Bilhimer). This study gathered and interpreted evidence of groundwater inflow and outflow along the mainstem of the river through seepage surveys. It also estimated the areas of groundwater inflows and temperature of groundwater. The surface water and groundwater exchange analysis was completed using data from seepage surveys, vertical hydraulic gradient measurements, and continuous streambed temperature measurements from instream piezometers during 2005.

Groundwater was sampled along the mainstem of the EF Lewis River as part of the original study's field collection from June 2005 through October 2005. Groundwater sampling involved the following three methods:

- Two seepage surveys (surface water discharge balances) in July and August 2005.
- Installation of instream piezometers to measure vertical hydraulic gradient, direction of flow, and temperature.
- Streambed sediment temperature profiling.

The results of the seepage survey, indicating gaining and losing reaches, are shown in Figure 12. Areas with groundwater inflow are considered gaining reaches, and segments with an outflow of streamflow into groundwater are losing reaches. There was a total of 64 cfs streamflow gains and a streamflow loss of 18 cfs (Carey and Bilhimer, 2009). The lower reaches of the river had the largest streamflow gains.

Instream piezometers measured the temperature of the groundwater inflow into the EF Lewis River through continuous streambed temperature monitoring. Hyporheic temperature measurements indicated gaining conditions at four downstream sites. These groundwater temperatures ranged between 10.6-12.5°C. Groundwater temperatures were lower than surface water temperatures, except at the furthest downstream site (RM 1.8). This site is influenced by the incoming warmer tidal water that seeps into groundwater. No groundwater temperatures were recorded for areas in the upper basin because the geology of the area did not allow for the installation of piezometers.

The *Surface Water and Groundwater Exchange* report (Carey and Bilhimer, 2009) contains more details for the field methods, quality assurance for groundwater sampling, and a detailed discussion on the results of the groundwater component of this study.

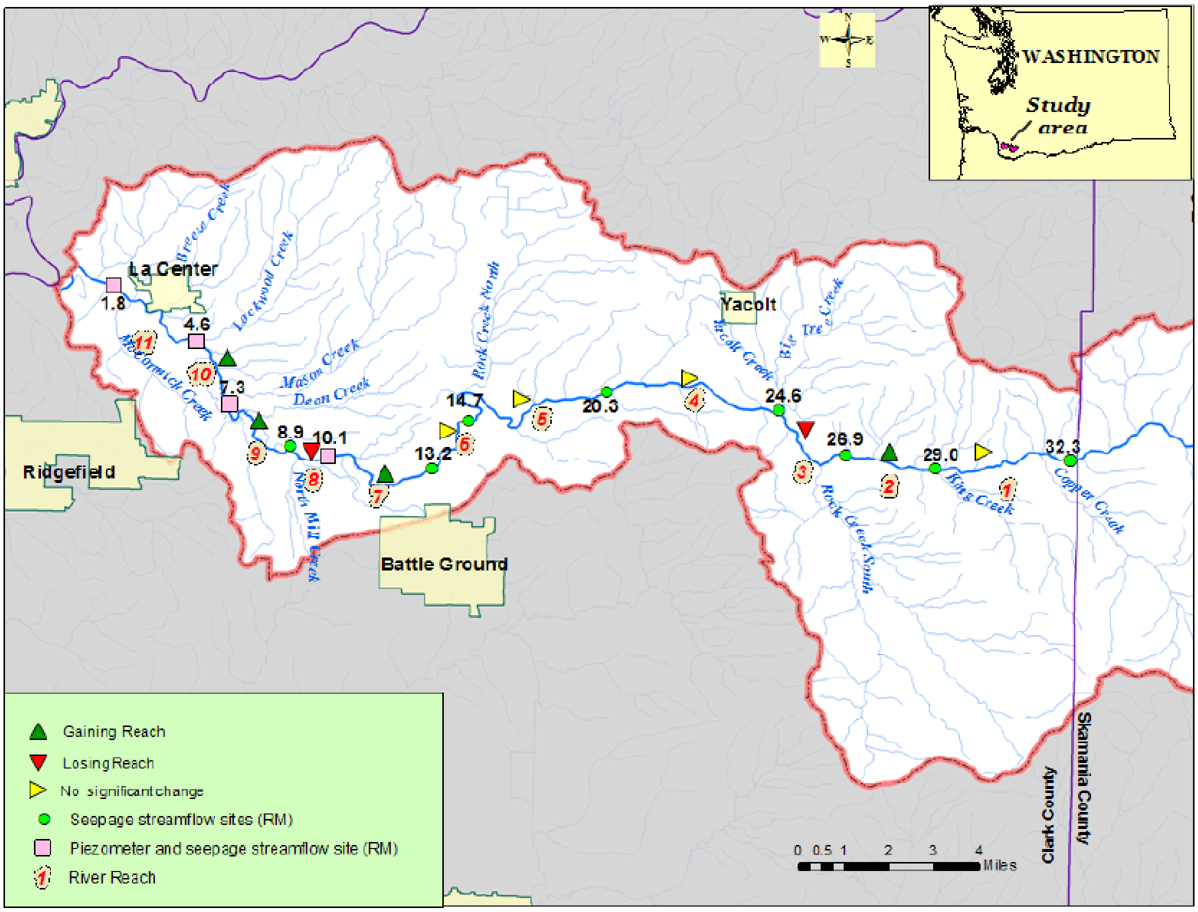


Figure 12. Results of seepage survey showing reaches of gain and loss estimates on the EF Lewis River, August 2005 (Carey and Bilhimer, 2009).

Fishery Resources and Habitat Assessment

The current numbers of native species of salmon and steelhead are significantly fewer than the historic populations (LCFRB East Fork Lewis River Subbasin Plan, 2010). The decline in these fisheries' populations are due to a combination of many factors and threats, including human development and environmental factors.

The EF Lewis River watershed has critical fall Chinook and chum spawning habitat in the lower 10 miles of the mainstem (from Daybreak Park to the mouth). The watershed also provides critical summer steelhead spawning and rearing habitat above Sunset Falls and on Rock Creek South. Table 2 describes the distribution of anadromous fish in the EF Lewis River subbasins (Bilhimer et al., 2005).

Table 2. Anadromous fish distribution in the EF Lewis River subbasins (Bilhimer et al., 2005)

Subbasin - Stream Name	Chum Salmon	Coho Salmon	Fall Chinook	Sea-Run Cutthroat	Summer Steelhead	Winter Steelhead
Big Tree Creek		X		X	X	X
Brezee Creek		X				
Copper Creek					X	X
EF Lewis River	X	X	X	X	X	X
Green Fork				X	X	
King Creek					X	X
Little Creek					X	
Lockwood Creek		X				
Mason Creek		X			X	X
McCormick Creek		X				
McKinley Creek					X	
Poison Creek				X	X	
Rock Creek South		X		X	X	X

A limiting factors analysis considers elevated water temperatures as a critical problem in many tributaries, particularly in the lower EF Lewis River watershed (Wade, 2000). Channel instability, diking, and development within the floodplain are also recognized as factors limiting the amount of rearing habitat during the summer for juvenile salmon and steelhead. Channel modifications over the years have altered natural channel migration and floodplain processes in order to facilitate rural residential development, agricultural land, and gravel mining operations (LCFRB, 2010). Particularly, bank stability is a major concern along portions of the lower 14 miles of the mainstem, particularly in areas with extensive agricultural, residential, and mining development.

The mainstem migration (avulsion) into the abandoned Ridgefield pits has added to the channel instability and led to a significant loss in spawning habitat for fall chinook (Wade, 2000). The avulsion of the EF Lewis River into the gravel pits near RM 9 and the Ridgefield Pits (RM 8) in the mid-1990s caused significant changes in bank and channel stability in the area and in sediment supply both upstream and downstream of the avulsions (Wade, 2000).

Figure 13. Aerial photograph of Ridgefield pits on the EF Lewis River.
Photo adapted from Wade (2000).

The only barriers to anadromous passage within the mainstem EF Lewis River are Lucia Falls (RM 21.5) and other natural falls upstream. Sunset Falls (Gifford Pinchot National Forest Boundary RM 32.7) was notched in 1982, opening up a significant amount of habitat in the upper watershed. Steelhead are the only species that consistently migrate past Lucia Falls. The following tributaries have known access problems for anadromous fish species: McCormick, Brezee, Lockwood, Mason, and Dean Creeks. Details on these identified barriers are described by Wade (2000).

Point Sources

Various point sources discharge to the EF Lewis River under NPDES permits. These include both individual and general permits that were in place during the 2005-06 sampling period and during 2017 and are listed in Table 3.

Table 3. Point source permits in the EF Lewis River watershed, 2005-06 and 2017.

Facility	Permit Number	Type of Discharge
2005-06		
Individual Permits		
La Center Sewage Treatment Plant	WA0023230	Municipal wastewater
Paradise Point State Park	WA0037184A	Municipal wastewater
Larch Correction Center	WA0038687A	Municipal Separate Storm Sewer Systems
Phase I Stormwater Permit (Clark Co.)	WA- 004211-1	Municipal Separate Storm Sewer Systems
General Permits		
Sand and Gravel (4)		Sand and gravel operations process and stormwater
Dairy (3)		All dairy process water and stormwater
Stormwater/Construction (3)		Construction site stormwater
2017		
Individual Permits		
La Center Sewage Treatment Plant	WA0023230	Municipal wastewater
Larch Correction Center	WA0038687	Municipal wastewater
Phase I Stormwater Permit (Clark Co.)	WA0042111	Municipal Separate Storm Sewer Systems
Transportation, WSDOT	WAR043000	Phase 1 Municipal SW
General Permits		
Sand and Gravel (4)		Sand and gravel operations process and stormwater
Stormwater/Construction (18)		Construction SW GP

Land Use

The EF Lewis River watershed is approximately 212 square miles, most of which is located in Clark County. This study focused on the watershed area within Clark County.

The EF Lewis River watershed includes the towns of Yacolt and La Center, and borders the northern boundary of Battle Ground and the eastern boundary of Ridgefield. The majority of the land throughout the watershed is privately owned. Major public land ownership is shown in Figure 14. Data used to produce Figure 14 originated from the Washington State Department of Natural Resources major public lands survey (2000) and the *Lewis River Habitat Assessment* (Johnston et al., 2005). The state owned land and privately managed forests are primarily used for active timber management, and many harvest cuts are visible from the road.

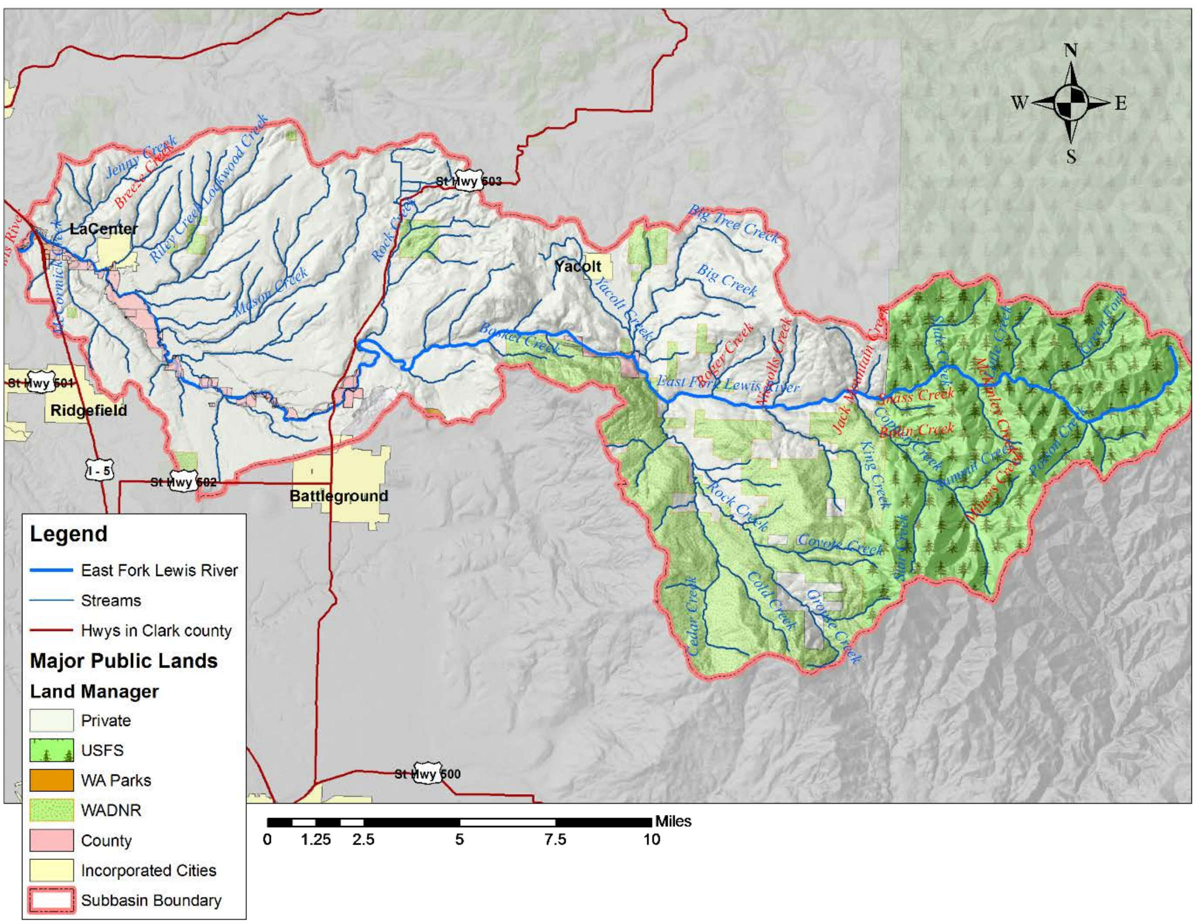


Figure 14. Land ownership in the EF Lewis River watershed (Bilhimer et al., 2005).

The land use types show spatial differences throughout the EF Lewis River watershed (Figure 15). The upper watershed is dominated by forest land, both private and public timber lands. The town of Yacolt is located in the upper watershed and includes mixed-land use including agricultural, residential, and commercial developed areas. As the river progresses downstream, the land use patterns progress from forest dominated land to a more mixed-used landscape. The lower watershed is a combination of agriculture, forest, and developed lands. The EF Lewis River passes along the southern boundary of the town of La Center in the lower watershed before progressing to the river mouth near Interstate-5 (I-5). The park spaces and publicly owned parcels are also seen along the mainstem of the river.

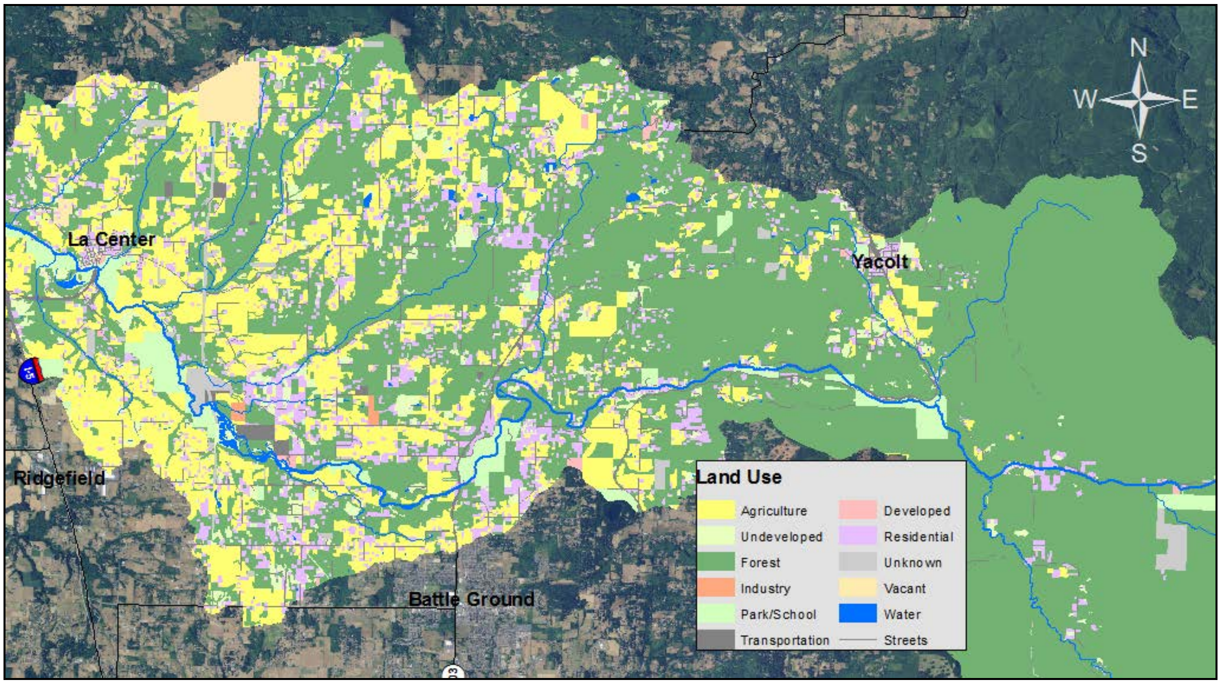


Figure 15. Land use types in the EF Lewis River watershed (Ecology[1], 2010).

Clark County owns different sections of riparian land throughout the lower EF Lewis River watershed. The majority of the land consists of large parcels on the south side of the river where the land is designated as park land. The publicly owned parcels include the following:

- La Center Bottoms Stewardship Site with a walking trail and wildlife viewing.
- Lewisville Park with campgrounds and facilities.
- Daybreak Park with fishing access.
- Lucia Falls Park which prohibits water contact to protect sensitive spawning grounds.
- Moulton Falls Park that offers day use Recreation and water-contact opportunities.

Additionally, the EF Lewis River Greenway, which spans from the river mouth to Daybreak Park, is state-designated priority habitat and has large concentrations of migratory waterfowl, wintering bald eagles, and high-quality riparian habitat.

[1] Land use spatial data developed by Ecology using land parcel data from WA State Dept. of Revenue https://fortress.wa.gov/ecy/gispublic/DataDownload/ECY_CAD_Landuse2010.htm

Land use changes

In order to assess the representativeness of the data collected from the 2005-06 field work as part of this technical analysis, land use changes for the area since 2006 were considered. Clark County published a *Comprehensive Growth Management Plan* in 2016 that included information about land use changes in the county from 2007 to 2014.

Clark County has experienced only relatively minor changes in population, housing, and land use since 2007. There was an approximately 1% population growth in the county, and this growth was almost entirely constrained to areas within incorporated cities, towns, and urban growth areas. Land use has remained relatively consistent, with minor changes occurring in La Center, Yacolt, and other towns in Clark County.

A comparative spatial analysis between the 2007 and 2014 Comprehensive Plan Land Use Maps for Clark County was completed to assess and quantify changes in land use types. There was a 9.5% change in land use type from 2007 to 2014; however, these changes were mostly related to minor, localized changes occurring in incorporated cities and urban growth areas. These changes in their respective cities are presented in Table 4. This table includes only cities and towns in Clark County that lie within or border the EF Lewis River watershed.

Based on this land use analysis, the data collected during 2005-06 in the EF Lewis River watershed are still relevant and representative of current conditions for use in this analysis. These data will continue to be useful for identifying areas for water quality improvement and implementation work. Additionally, the supplemental 2017 FC field sampling will help to better identify more specific changes and problem areas of FC concentrations over time.

Table 4. Land use designation changes (Clark County, 2016).

Area	Land Use Designation Changes between 2007 and 2014
Unincorporated Clark County	Clark County experienced very minor changes to land use designations, with roughly 4,000 acres (a 1% change), some of which could be attributed to mapping discrepancies and annual reviews.
City of Battle Ground	Battle Ground and its UGA experienced a change in roughly 1,200 acres, (a 9% change) mostly within mixed use designations, with lands changing from industrial, parks/open space, and rural-5 designations, to urban residential, mixed use, and employment center designations.
City of La Center	La Center and its UGA experienced a change in roughly 500 acres (a 15% change), most of which is likely attributed to mapping discrepancies from a water designation to urban residential, mixed-use, and industrial. There was likely no real significant reduction to water bodies between 2007 and 2014.
City of Ridgefield	Ridgefield and its UGA experienced a change of roughly 1,000 acres, a 9% change, mostly changes from employment center and office park designations to industrial and light industrial designations.
Town of Yacolt	Yacolt and its UGA experienced a change of roughly 150 acres (an 18% change), mostly from rural designations to parks/open space and industrial designations.

Current Restoration Efforts

After the completion of the water quality sampling from 2005-06, the EF Lewis River water quality exceedance project was put on hold. However, Clark County and other local partners continued implementing water quality improvement activities in the watershed.

Clark County Public Utilities Department received various grants, including a grant from Ecology, to increase stream restoration work in the EF Lewis River watershed. A grant for EF Lewis River improvements was awarded in July 2007 and funded a variety of work projects over a span of five years in the EF Lewis River watershed. These restoration efforts included planting more than 65,000 trees over 35 acres, installing livestock exclusionary fencing, and training landowners on property improvements and maintenance. Partners for this grant-work included Clark County, the AmeriCorps program, Northwest Service Academy, Washington Department of Natural Resources, Washington Department of Corrections, civic organizations, and community volunteers.

Figure 16. Lockwood Creek restoration project (Clark Public Utilities, 2010).

The Centennial Clean Water Program grant was used for the Lockwood Creek riparian restoration project from 2007 through June 2011 (Clark County Coalition, 2011). This project met and exceeded all goals for improvements. The work included stabilizing more than 1,500 feet of eroding streambanks and riparian plantings of more than 47,000 trees and shrubs along 4,150 feet of shoreline and over 23 acres. Outreach and education included teaching more than 3,800 students about the water cycle. Also, more than 24 landowners participated in training.

Clark County's Public Utilities Department provides more information for these restoration projects and others here: https://www.clarkpublicutilities.com/community-environment/environmental-stewardship-programs/watershed-restoration-programs/grant-funded-projects/.

The Friends of the East Fork Lewis River also maintain a record of restoration projects in the watershed that includes projects done in collaboration with Fish First and the Healing Waters Veterans Group at http://www.eastforklewisriver.org/river-restoration/completed-projects/.

The Lower Columbia Fish Recovery Board has a centralized location that maintains records of projects in the Lower Columbia, including those specific to the EF Lewis River watershed. Information can be found at https://www.lcfrb.gen.wa.us/sport.

Study Design

During this source assessment study for FC and temperature exceedances in the EF Lewis River watershed, the technical analysis was completed using both the 2005-06 and 2017 field data.

Field data collection during 2005-06 included the following (Bilhimer et al., 2005):

- FC sampling at a fixed-network.
- Continuous temperature monitoring.
- Discharge measurements.
- Riparian shade estimates.

Supplemental FC sampling at a fixed-network in the EF Lewis River watershed occurred in 2017 (Raunig and McCarthy, 2017).

The FC technical analysis used data from both the 2005-06 study and the 2017 study:

- 2005-06 data were used to determine which sites met the water quality criteria and to investigate potential sources for elevated FC concentrations.
- Loading analysis was performed to identify seasonal loading patterns for 2005-06.
- Statistical rollback analysis was completed to develop target FC concentrations for 2005-06.
- A Seasonal Kendall Trend Test was performed at Ecology's ambient monitoring site (27D090) to identify trends in FC concentrations since 2005.
- Additional FC sampling in 2017 was used to assess current FC concentrations. The 2017 data were compared with the 2005-06 data to confirm areas with high FC concentrations.

The technical analysis for temperature and shade was completed using data from 2005-06:

- The temperature results from 2005-06 were summarized and tributary and river segments with high temperatures were identified.
- Shade analysis was completed to determine current effective shade and system potential shade for the mainstem of the EF Lewis River. This was used to identify areas with large shade deficits to help guide implementation and restoration efforts.

This work also references the key findings from other reports that were completed using the 2005-06 data:

- *Surface Water and Groundwater Exchange along the East Fork Lewis River* (Carey and Bilhimer, 2009).
- *Streamflow Summary for Gaging Stations on the East Fork Lewis River 2005-06* (Springer, 2009).

Methods

For the original study, field sampling began in May 2005 and continued through August 2006. Also, field sampling occurred during a storm event in November 2006. Some parameters were sampled within a subset of this timeframe.

Field parameters sampled or measured include:

- FC (grab samples).
- Continuous temperature.
- Streamflow.
- Groundwater (using piezometers within the mainstem).
- Riparian shade estimates (using hemispherical photography).

Additional FC sampling started in February 2017 and was completed in October 2017. Although originally intended to be completed in January 2018 (Raunig and McCarthy, 2017), the field sampling period ended earlier due to resources and scheduling conflicts.

The Quality Assurance Project Plans (QAPP) provide more details for the field methods (Bilhimer et al., 2005; Raunig and McCarthy, 2017).

The *Streamflow Summary* (Springer, 2009) and the *Surface Water and Groundwater Exchange along the East Fork Lewis River* report (Carey and Bilhimer, 2009) describe field method details for streamflow and groundwater monitoring.

Fecal Coliform Sampling

FC samples were collected twice per month at the 29 fixed-network locations throughout the EF Lewis River watershed from May 2005 through August 2006. These sampling locations included five sampling sites along the EF Lewis River mainstem, two stormwater outfalls, and one site at the La Center Sewage Treatment Plant (STP). The remainder were located at tributaries throughout the watershed. Table 5 presents a summary of the sampling sites, location description, and stream type. Figure 17 shows the sampling locations.

Most FC sites were sampled between 30 and 32 times over the 2005-06 sampling period. MAS0.25 was sampled eight times before being discontinued as a sampling site. MAS4.57 and MAS3.19 were not sampled for a period during both summers due to low-flow conditions. LOC0.1 was added after the initial FC sampling.

Table 5. Fixed-network of FC sampling sites, 2005-06.

Site No.	Site	Site Description	Stream Type	Sampling Size
1	YAC3.60	Yacolt Crk at Chilcote Dr	tributary	31
2	YAC0.90	Yacolt Crk at Railroad Ave	tributary	32
3	RCS3.9	Rock Crk S at Dole Valley Rd	tributary	31
4	BIG0.05	Big Tree Creek at Lucia Falls Rd	tributary	32
5	RCN2.8	Rock Crk N at NE Gabriel Rd	tributary	30
6	RCN0.65	Rock Crk N at Hammond Rd	tributary	31
7	MAS4.57	Mason Crk at 102nd Ave NE	tributary	26
8	MAS3.19	Mason Crk at JR Anderson Rd	tributary	27
9	MAS1.23	Mason Crk at Moore Rd	tributary	32
10	MAS0.25	Mason Creek near mouth	tributary	8
11	LOC3.15	Lockwood Crk off Lester Ave	tributary	32
12	LOC1.25	Lockwood Creek off Lockwood Crk Rd	tributary	32
13	LOC0.1	Lockwood Creek off NE John Storm Ave	tributary	25
14	RIL0.95	Riley Crk off Johnson Rd	tributary	32
15	BRZ14TH	Trib to Brezee Creek	tributary	30
16	BRZ0.5	Brezee Creek off 4th near Stonecreek	tributary	32
17	BRZ0.07	Brezee Creek at mouth	tributary	32
18	BRZSW1	Stormwater Culvert near Cedar and 4th	storm drain	31
19	BRZSW2	Stormwater ditch to Brezee Ck near mouth	storm drain	31
20	MCC3.4	McCormick Crk at NE 289th and Timmen Rd	tributary	32
21	MCC2.0	McCormick Crk at NW Spencer Rd	tributary	32
22	MCC1.18	McCormick Crk at La Center Rd	tributary	32
23	JEN0.35	Jenny Creek at Pacific Hwy crossing	tributary	32
24	STP0.0	La Center Sewage Treatment Plant Effluent	effluent	27
25	EFL24.6	EF Lewis above Big Tree Crk	mainstem	32
26	EFL20.3	EF Lewis at Heisson USGS gage	mainstem	31
27	EFL10.1	EF Lewis at Daybreak (Ecology’s 27D090)	mainstem	32
28	EFL3.15	EF Lewis off La Center Rd	mainstem	32
29	EFL0.75	EF Lewis under I-5 bridge	mainstem	32

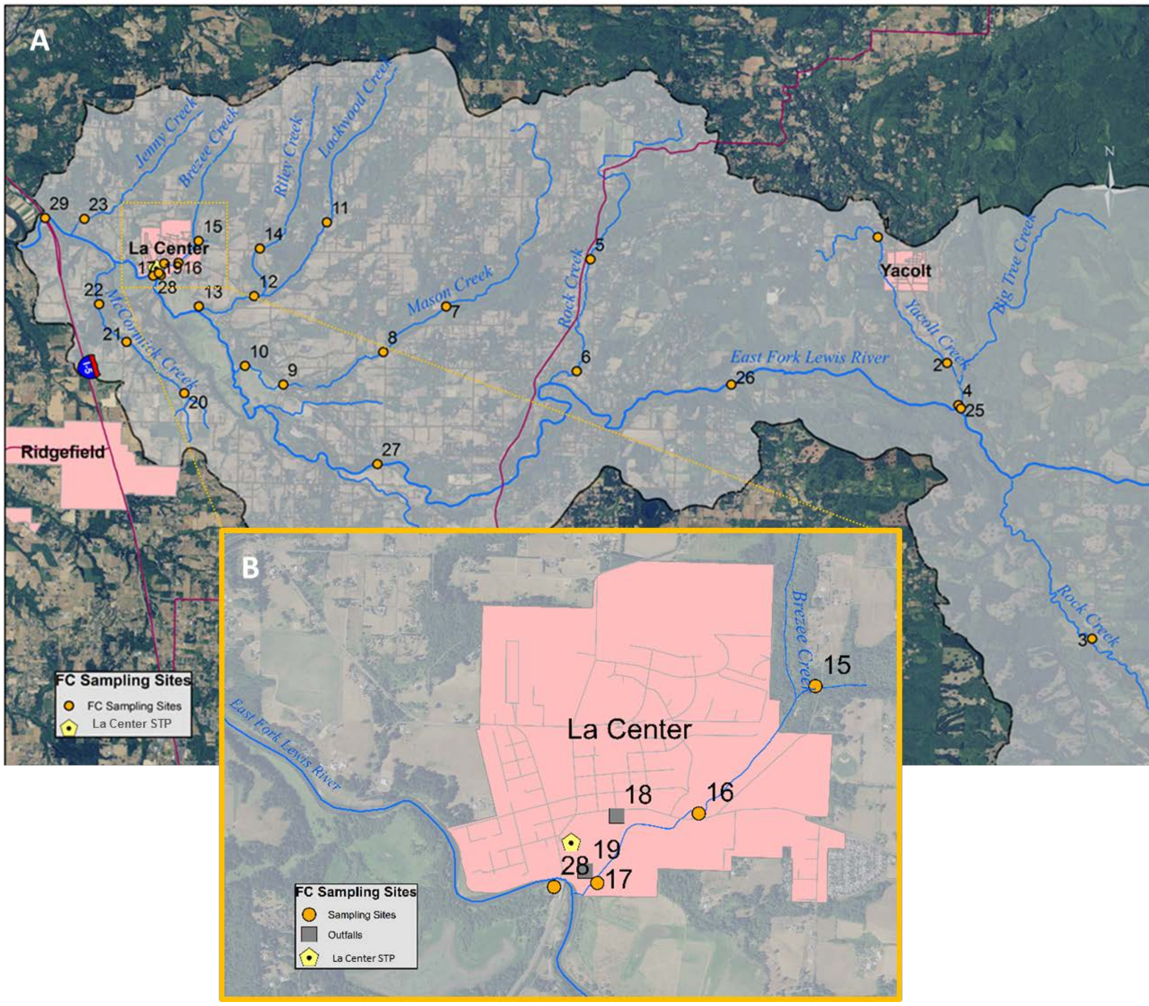


Figure 17. (A) FC sampling sites, 2005-06 and (B) FC sampling sites near La Center.

The 2017 sampling occurred at 17 fixed-network locations. Many of these sampling sites at the fixed-network were consistent with sampling sites used in the 2005-06 field collection, although some sites were moved to a similar location due to access issues with the original sampling sites (RCN2.07, MAS1.11, LOC3.55, JEN1.03, and EFL3.35). These are presented in Table 6 and shown spatially in Figure 18.

Additionally, multiple investigative sites were added and sampled in 2017. These investigative sites were added after the QAPP was published in an attempt to better characterize sources of pollution. All of these investigative sites were located along McCormick Creek and its minor tributaries.

Variability in sampling size during 2017 occurred due to accessibility issues, flooding, and low flow conditions. BRZSW1 and MCCTRIB2 were sampled the least due to low flows during the summer. The EF Lewis River mainstem sites (EFL3.35 and EFL0.75) were sampled less than other sites due to flooding that made these sites inaccessible during the springtime.

All FC samples from 2005-06 and 2017 were analyzed by Manchester Environmental Laboratory (MEL) using the membrane filtration method (MEL, 2012).

Note that the site numbers listed in Tables 5 and 6 are a shortened version of the station ID listed in Ecology's EIM database. Sites were shortened by removing the WRIA number "27", so that 27-EFL-3.15 is referred to as EFL3.15 in this report.

Table 6. FC sampling sites, 2017.

Site No.	Site	Site Description	Site from 2005-06 sampling
1	YAC0.90	Yacolt Creek at Railroad Ave	X
2	RCN2.07	Rock Creek at NE Rock Creek Rd	
3	MAS3.19	Mason Creek at JR Anderson Rd	X
4	MAS1.11	Mason Creek at NE 290th St	
5	LOC3.55	Lockwood Creek at NE Taylor Valley Rd	
6	RIL0.95	Riley Creek off Johnson Road	X
7	BRZ14TH	Tributary to Breeze Creek at 14th	X
8	BRZ0.07	Breeze Creek near mouth	X
9	BRZSW1	Stormwater culvert at Cedar & 14th	X
10	BRZSW2	Stormwater ditch near mouth Breeze Ck	X
11	JEN1.03	Jenny Creek at NW 14th Ave	
12	MCC1.18	McCormick Creek at La Center Rd	X
13	MCC3.4	McCormick Creek at NE 289th St	X
14	MCCTRIB2	Culvert NW 279th St between 10th Ave and 14th Ct	
15	EFL3.35	EF Lewis Boat Ramp at end of NW Pollock Rd	
16	EFL0.75	EF Lewis at I-5 Bridge Left Bank	X

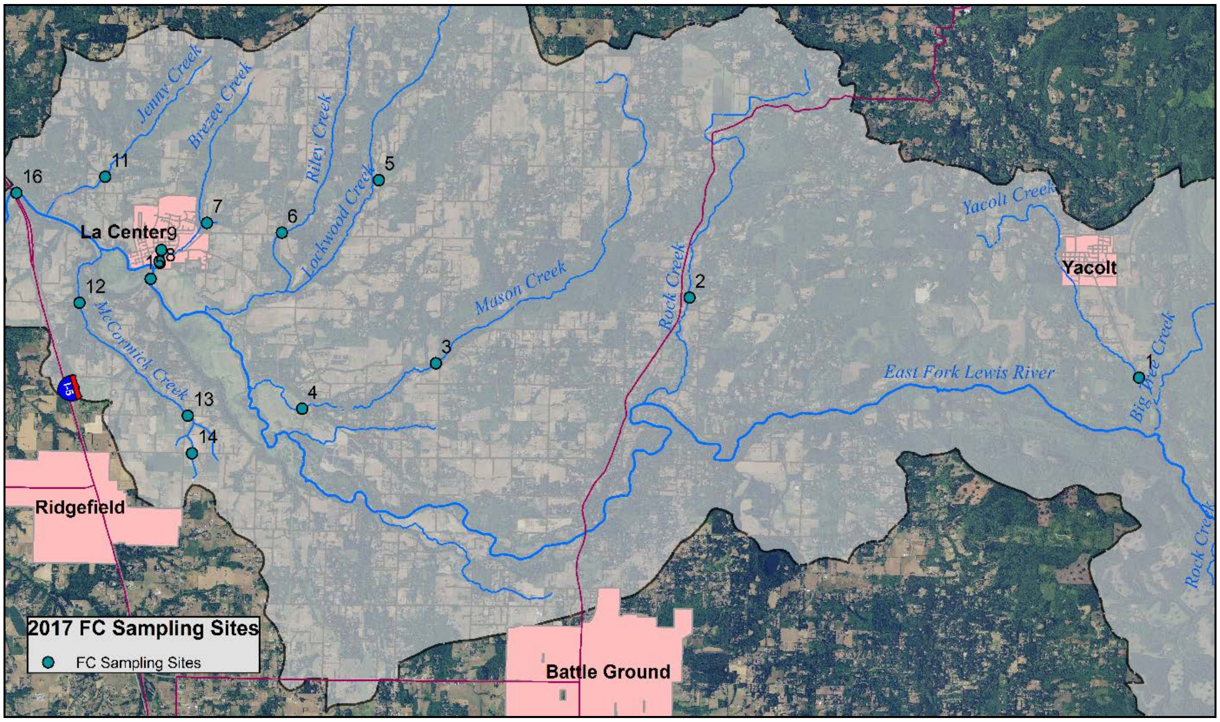


Figure 18. FC fixed-network sampling sites, 2017.

Temperature Sampling

Temperature monitoring occurred from May through mid-October 2005, with some sites collecting temperature data through the winter. Seepage surveys were conducted on July 19 and August 9, 2005. There were 24 instream continuous temperature loggers installed (Table 7 and Figure 19), with 11 of these located along the EF Lewis River mainstem, and the remainder distributed throughout its tributaries (subbasins). Most of the tributary temperature monitoring sites were near the mouth of the stream. Clark County maintains three temperature monitoring sites (RCN050, MAN010, and BRZ010).

Selected sites had both instream and air temperature loggers. The air temperature records were used as a source of comparison for instream temperature monitoring results to check if receding water levels were leaving the temperature loggers exposed to air temperatures.

Table 7. Instream temperature monitoring sites, 2005.

Site No.	Station/Site	Site Description	Temperature Criteria (°C)	Stream Type
1	EFL29.0	EFLR above King Cr	16.0	mainstem
2	KNG00.0	King Cr near mouth	16.0	tributary
3	EFL26.9	EFLR at Dole Valley Rd	16.0	mainstem
4	RCS03.9	Rock Cr S at Dole Valley Rd	16.0	tributary
5	EFL24.6	EFLR above Moulton Falls	16.0	mainstem
6	BIG00.0	Big Tree Cr at Mouth	16.0	tributary
7	EFL20.3	EFLR at the USGS gage	16.0	mainstem
8	RCN050*	Rock Cr North	16.0	tributary
9	RCN00.6	Rock Cr North	16.0	tributary
10	EFL14.7	EFLR at Schultz residence	16.0	mainstem
11	EFL13.2	EFLR at Lewisville Park	16.0	mainstem
12	EFL10.1	EFLR at Daybreak Park	16.0	mainstem
13	MAN010*	Manley Cr	16.0	tributary
14	EFL08.1	EFLR above Ridgefield Pits	16.0	mainstem
15	DEA00.8	Dean Cr at mouth	16.0	tributary
16	DEA00.0	Dean Cr at JA Moore Rd	16.0	tributary
17	EFL07.3	EFLR below Dean Cr	16.0	mainstem
18	MAS00.8	Mason Cr ds of Heitmann Cr	16.0	tributary
19	EFL04.6	EFLR above Lockwood Cr	16.0	mainstem
20	LOC00.0	Lockwood Creek at mouth	16.0	tributary
21	BRZ010*	Brezee Cr	16.0	tributary
22	BRZ00.1	Brezee Cr near mouth	16.0	tributary
23	EFL01.8	EFLR at gage near mouth	16.0	mainstem
24	JEN00.3	Jenny Creek at Pacific Hwy	16.0	tributary

* Sites installed and maintained by Clark County
EFLR = East Fork Lewis River

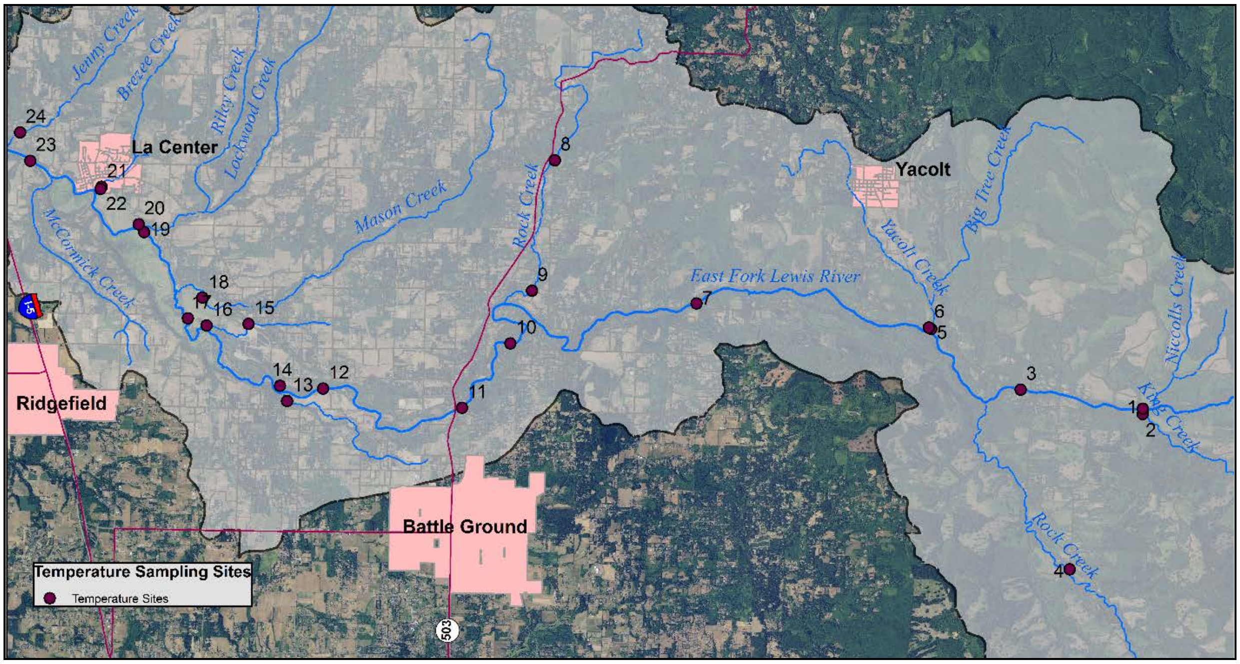


Figure 19. Temperature monitoring sites, 2005-06.

Hemispherical Photographs

Hemispherical photographs were taken at select sites along the mainstem of the EF Lewis River during summer 2005 to estimate riparian shade. Eleven of the hemispherical photography sites were taken at the intersection with the instream temperature logger and the remainder were taken either upstream or downstream of these locations.

Pictures were taken near the center of the stream looking upward to accommodate vegetation canopy using a fish-eye lens and digital camera.

These photographs were then processed and analyzed to calculate effective shade and canopy cover.

Analytical Methods

Information and Data Used

Ecology information and data

The data from the 2005-06 field collection were used to complete the technical analysis for temperature and FC water quality exceedance issues for this pollutant source assessment work in the EF Lewis River watershed. Following the 2005-06 field collection, this data went through quality assurance procedures and were uploaded into Ecology's Environmental Information Management (EIM) database.

The data from the supplemental FC sampling that occurred in 2017 are summarized and used for comparison to 2005-06 conditions and characterization of the current water quality status for the EF Lewis River and selected tributaries.

Data from Ecology's ambient monitoring station on the EF Lewis River (27D090) were used to assess changes to FC levels on the river, particularly focused on trends since the original 2005-06 field collection. Temperature data from 27D090 was also used to assess general temperature patterns and conditions of the EF Lewis River. The temperature data were used to provide context for the seasonal conditions represented in the 2005 sampling period.

Parts of the technical analysis for this water quality exceedance study were started by Ecology staff following the 2005-06 field collection. This information was reviewed, assessed for missing information, and completed for this pollutant source assessment study.

Additional information and data

S.P. Cramer & Associates, Inc. (renamed Cramer Fish Sciences in 2016), along with various other groups and a diverse set of stakeholders, developed the East Fork Lewis River – Habitat Assessment (2005) for the Lower Columbia Fish Recovery Board (Johnston et al., 2005; Keefe et al., 2004). This work included a Level II Habitat Assessment on the EF Lewis River watershed. The study methods used for this product followed the U.S. Forest Service's Level I and II Stream Inventory Protocols for Region 6. The methods used for the habitat assessment are detailed in Kalama, Washougal, and Lewis River Habitat Assessments, Chapter 1 (R2 Resource Consultants, 2004).

The purpose of the habitat assessment was to collect data on habitat conditions, riparian conditions, sediment sources, and hydromodifications for the EF Lewis River.

Data from the S.P. Cramer report were used for this study, particularly GIS data for the riparian habitat analysis. The habitat assessment also included data for sediment counts and percent distributions, riparian vegetation height and canopy density, stream gradients, wetted widths, active channel widths (equivalent to bankfull width), and maximum wetted and active channel depths for each measurement transect.

Fecal Coliform

The analytical methods used to evaluate FC in the EF Lewis River watershed in this study include descriptive summary statistics, rollback analysis, simple loading analysis, and Seasonal Kendall Trend test. These methods were used to help determine FC sources in the EF Lewis River watershed and will be used to guide implementation work.

The annual and seasonal (wet and dry seasons) geometric mean was calculated for sites with more than five samples. Concentrations of FC measured in environmental samples generally follow a log-normal distribution. In Washington State FC water quality exceedance studies, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted to be comparable to the 90th percentile value of the log-normalized values (Cusimano and Giglio, 1995; Fields, 2016; Joy, 2000; Mathieu and James, 2011).

The descriptive summary statistics, rollback analysis, and loading analysis were completed for FC data from the 2005-06 field collection. A data summary was completed for the 2017 supplemental FC sampling. A Seasonal Kendall Trend test was performed from 2005-2016 to assess trends in FC concentrations since the original field collection.

Seasonal Kendall Trend test

A Seasonal Kendall Trend Test is used to detect long-term trends in FC data (Helsel and Hirsch, 2002). This trend test accounts for both seasonal variations in data over time and outliers in data sets and is a recommended statistical test for water quality trend monitoring (Meals et al., 2011). It is a nonparametric test that is used to evaluate a statistically significant trend in a time-series dataset for monotonic trends.

The Seasonal Kendall Trend analysis was completed for the EF Lewis River based on monthly data collected from Ecology's ambient monitoring station (27D090) from 2005-2016 to assess recent water quality trends. FC data were grouped by month to evaluate seasonality.

The Seasonal Kendall Trend test was performed using SYSTAT® Version 13.0.

Simple Loading Analysis

A simple loading analysis was completed to compare measured FC loading sources relative to each other. A loading analysis was completed for annual averages during both wet and dry seasons to illustrate seasonal loading differences. A loading analysis was also performed during a storm event.

A load is defined as the mass of a substance that passes through a particular point of a river or stream (e.g., monitoring site) in a specified amount of time (e.g., daily) (Meals et al., 2013). A load is mathematically defined as the product of water discharge and the concentration of a substance in the water. For this study, FC loads were calculated by multiplying FC concentrations (cfu/100mL) by flow (cfs). These loads were then converted to represent billions of colony forming units per day (billions cfu/day) to allow for an easier comparison of large load numbers.

The loads calculated during the FC loading analysis were not used in determining the level of FC reduction need at sites. Instead, the loading patterns will be used to help understand areas with high seasonal loading patterns and identify potential sources of FC. This information can then be used for directing implementation. Cleaning up high loading sources will benefit downstream sites where the upstream loads are contributing to exceedance of water quality standards.

Rollback Analysis

The statistical rollback method (Ott, 1995) is used to calculate FC reduction targets for EF Lewis River stream segments and selected tributaries. The rollback method compares monitoring data to standards, and the difference is the percentage change needed to meet the standards.

The rollback method has been applied by Ecology in other FC water quality exceedance studies (Coots, 2002; Fields, 2016; Joy, 2006; Joy and Swanson, 2005; Mathieu and James, 2011; Pelletier and Seiders, 2000; Swanson, 2009).

Ideally, at least 20 samples taken throughout the year are needed from a broad range of hydrologic conditions to determine an annual FC distribution. If FC sources vary significantly by season and create distinct critical conditions, seasonal targets may be required. Fewer data provide less confidence in FC reduction targets, but the rollback method is robust enough to provide pollutant allocations and targets for planning implementation measures using smaller data sets. Compliance with the most restrictive of the dual FC standard criteria determines the FC reduction needed at a stream sampling site. The rollback method is applied as follows:

> *The geometric mean (approximate median in a log-normal distribution) and 90th percentile statistics are calculated and compared to the water quality bacteria criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the more restrictive of the two criteria. The 90th percentile criterion is usually the most restrictive.*

The rolled-back geometric mean or 90th percentile FC value then becomes the recommended *target* FC value for the site. The term *target* is used to distinguish these estimated numbers from the actual water quality criteria. The degree to which the distribution of FC counts is *rolled-back* to the target value represents the estimated percent of FC reduction required to meet the FC water quality criteria and standards.

The FC targets are only in place to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is ultimately measured as meeting both parts of the water quality criteria. Any water body with FC targets is expected to:

- Meet both the applicable geometric mean and "percent exceedance" criteria.
- Protect designated uses for the category.

The rollback method assumes that the distribution of the data follows a log-normal distribution. FC concentrations from each of the sites were tested for log-normality prior to the use of the roll-back method. In all instances, the data sets met the log-normality test. The cumulative probability plot of the observed FC data gives an estimate of the geometric mean and 90th percentile which can then be compared to the FC concentration standards.

Vegetation and Effective Shade Analysis

The technical analysis for temperature for the EF Lewis River determined the amount of effective shade along the EF Lewis River mainstem, based on field observations and completing a shade analysis for current effective shade and system potential shade.

For the shade analysis, the following tools were used:

- TTools (Ecology, 2015).
- Ecology's Shade model (Ecology, 2003).

The results of the shade analysis were compared with effective shade calculated from field hemispherical photography.

Current Riparian Vegetation and Effective Shade

Effective shade is the fraction of the total possible solar radiation heat energy that is prevented from reaching the surface of the water. Canopy cover is the percent of sky covered by vegetation and topography at a given point. Effective shade is influenced by canopy cover, but changes during the day depending on the position of the sun both spatially and temporally in relation to the canopy cover. (Kelley and Krueger, 2005).

Current effective shade along the EF Lewis River is influenced by both riparian vegetation cover and river morphology. The current effective shade for the mainstem of the river was found through GIS spatial analysis and hemispherical photography of riparian vegetation and shade modeling.

LiDAR data files obtained from Clark County for bare earth (no vegetation or structures) and vegetation canopy height were used to determine the heights of vegetation along the EF Lewis River. A 10-meter Digital Elevation Model (DEM) was used to determine elevation for the EF Lewis River watershed.

S.P. Cramer developed GIS files that were used as a component of the data for the shade analysis for this study. This GIS data included layers for the stream centerline, and left and right river banks. They also provided GIS files for a 100-foot buffer along the EF Lewis River and selected tributaries and their corresponding riparian vegetation.

GIS coverages of riparian vegetation were extended to a 100-150 meter buffer along the EF Lewis River mainstem. Within this buffer, polygons were created around distinct groups of vegetation. These riparian vegetation categories included distinct characteristics including vegetation type, density, and tree size.

TTools is an ArcView GIS extension that is used to determine physical and vegetation parameters for input for the effective shade analysis (Ecology, 2015). It uses the GIS data on riparian vegetation, topography, and other longitudinal stream-channel characteristics. TTools analyzes stream-channel attributes and samples near-stream topography and vegetation. These inputs are used to determine effective shade using the Shade model.

The TTools analysis sampled elevation, topography, and vegetation type in 50-meter segments along the mainstem of the EF Lewis River. Vegetation was sampled perpendicular to the left and right bank of the river at nine zones that were each six meters apart.

Results of the TTools analysis were used as inputs into the Shade model. This included the following:

- Physical parameters—longitudinal distance, elevation, aspect, wetted width, NSDZ width, riparian zone ground elevations, topographic shade (West, South, East).
- Vegetation parameters—vegetation type, height, density, and overhang.

Ecology's Shade model (Shade) is a tool used for estimating shade from riparian vegetation (Ecology, 2003). It is used to model effective shade based on the GIS data for elevation and riparian vegetation.

Shade was adapted from a program that ODEQ developed as part of Version 6 of its HeatSource model. Shade calculates effective shade using the Chen method (Chen et al., 1998a; 1998b). It quantifies the potential daily solar load and generates percent effective shade. Effective shade is the fraction of shortwave solar radiation that does not reach the stream surface because vegetative cover and topography intercept it. Effective shade is influenced by latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics, such as height, width, overhang, and density.

The shade analysis calculates effective shade based on topography and vegetation for each 50-meter segment along the mainstem of the EF Lewis River. Shade is calculated as percent effective shade, which is the fraction of the total possible solar radiation heat energy that is prevented from reaching the surface of the water.

The shade modeling was completed for July 1, 2005. On the same day, hemispherical photographs were processed to calculate effective shade and canopy cover and to use as a comparison with the modeling results.

Potential Riparian Vegetation and Effective Shade

S.P. Cramer developed system-potential riparian vegetation measurements for the EF Lewis River watershed. System-potential mature riparian vegetation refers to the vegetation that can grow and reach a climax succession at a site without human disturbance, and given climate, elevation, soil properties, plant biology, and hydrologic processes.

System potential conditions for the watershed include mainly mature conifer species in the mid and upper-watersheds and mature deciduous species in the lower reaches of the EF Lewis River (Johnston et al., 2005).

Other studies and reports have estimated similar system-potential vegetation measurements for watersheds near the EF Lewis River. The *Salmon Creek Temperature TMDL and Water Quality Improvement Report* (WQIR) established system-potential mature riparian vegetation for the Salmon Creek watershed, located just south of the EF Lewis River watershed (Stohr et al., 2011). Potential vegetation height was estimated based on DNR soils data. The system-potential vegetation for conifer species (100-year) for Salmon Creek was estimated to have an average height of 45.7 m (150 ft), 85% canopy cover density, and 4.6 m overhang. Burnt Bridge Creek watershed (located south of Salmon Creek) was also estimated to have a 100-year potential tree height of 45.7 m, based on Clark County Soil Survey Geographic Database (SSURGO).

Table 8 displays the measurement values for system-potential vegetation that were used in the Shade model to replace the current riparian vegetation based on information from S.P. Cramer and the Salmon Creek WQIR.

Table 8. System potential riparian vegetation.

Location	Species	Average Tree Height	Canopy Cover (% density)	Overhang
RM 7.0 to headwaters	Conifer	45.7 m	85%	4.6 m
River mouth to RM 7.0	Deciduous	23.0 m	85%	2.3 m

For the potential shade analysis, areas of land that were either developed or would not accommodate vegetation growth (i.e. built, pavement, and water areas) were kept intact. The system-potential vegetation for this study is therefore implied for areas along the EF Lewis River suitable for vegetation growth that are not already paved or developed.

HemiView Analysis

The hemispherical photographs taken in the field at sites with instream temperature loggers were processed using HemiView canopy analysis software (University of Kansas, 1996). The HemiView photos were processed to calculate:

1. Annual average canopy cover.
2. Annual average effective shade.
3. Daily effective shade. HemiView was used to calculate daily effective shade for July 1 for each site. Results for these calculations were used as an approximate comparison with the Shade model results.

More details and information on the HemiView analysis are provided in Appendix I.

Data Quality

The QAPPs (Bilhimer et al., 2005; Raunig and McCarthy, 2017) developed for this study describe the procedures used to collect and analyze field measurements and water quality samples. Ecology assessed all data used in this report for quality.

The overall quality objectives for the FC sampling were to collect and analyze data at the appropriate spatial and temporal scale to characterize pollution in the watershed. Ecology reviewed all data collected to determine if the data met the quality objectives from the QAPPs.

For temperature, data quality was assessed based on the accuracy of a paired comparison between the thermograph and a certified reference thermometer. The representativeness of the temperature data is evaluated by measuring at various locations that account for land practices, flow contribution of tributaries, and seasonal variation of instream and flow temperatures in the watershed. Temperature data were cut at sites EFL01.8 and EFL04.6 due to the influence of tidal water affecting water levels and the placement of the continuous temperature loggers in this segment of the river.

Data collected by Ecology for this work are available in Ecology's Environmental Information Management (EIM) database:

- The user study for the 2005-06 field collection is EFLRTMDL.
- The user study for the supplemental FC sampling in 2017 is EFLewisSA.

Appendix A contains more details about the QA review of the FC and temperature data. More QA information for 2005-06 data relating to study results used in the *Streamflow Summary* (Springer, 2009) and *Surface Water and Groundwater Exchange* study (Carey and Bilhimer, 2009) can be found in their respective reports.

Results

Fecal Coliform Results, 2005-06

FC results, both annual and seasonal, from the 2005-06 field collection in the EF Lewis River watershed are summarized in Table 9. A detailed data summary for FC results from the entire 2005-06 field collection can be found in Appendix B.

Table 9. Summary of FC sampling results, 2005-06.
***Bold** values indicate geometric mean water quality criteria exceedance.*

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	% Exc*	n	Geo Mean	% Exc*	n	Geo Mean	% Exc*
YAC 3.60	31	9	3	16	7	**13**	15	13	7
YAC 0.90	32	13	2	16	14	**13**	16	12	0
RCS 3.90	31	4	0	15	2	0	16	6	0
BIG 0.05	32	15	3	16	9	**13**	16	26	6
RCN 2.8	30	35	**17**	15	14	7	15	86	**27**
RCN 0.65	31	39	**13**	16	35	**13**	15	43	**13**
MAS 4.57	26	29	**12**	16	17	**13**	10	70	10
MAS 3.19	27	34	**15**	16	22	**13**	11	65	**18**
MAS 1.23	32	25	6	16	16	**13**	16	39	0
MAS 0.25	8	90	**13**				8	90	**13**
LOC 3.15	32	99	**31**	16	36	6	16	**271**	**56**
LOC 1.25	32	44	**16**	16	24	**13**	16	80	**19**
LOC 0.1	25	46	8	12	25	0	13	80	**15**
RIL 0.95	32	46	**19**	16	26	**13**	16	79	**25**
BRZ 14TH	30	**166**	**12**	15	95	**33**	15	**288**	**47**
BRZ 0.5	32	**190**	**19**	16	84	**38**	16	**430**	**81**
BRZ 0.07	32	**196**	**19**	16	93	**38**	16	**411**	**81**
BRZ SW1	31	24	**7**	16	55	**31**	15	10	**13**
BRZ SW2	31	**203**	**14**	16	**194**	**38**	15	**214**	**53**
MCC 3.4	32	**333**	**72**	16	**240**	**26**	16	**462**	**88**
MCC 2.0	32	**177**	**47**	16	**164**	**44**	16	**191**	**50**
MCC 1.18	32	**194**	**59**	16	**123**	**38**	16	**307**	**81**
JEN 0.35	32	73	**16**	16	53	**19**	16	101	**13**
STP 0.0G	27	14	7	12	17	8	15	12	7
EFL-24.6	32	6	3	16	3	6	16	12	0
EFL-20.3	31	6	3	15	3	7	16	10	0
EFL-10.3	32	6	6	16	4	**13**	16	10	0
EFL-3.15	32	33	**13**	16	21	**19**	16	51	6
EFL-0.75	32	39	**13**	16	21	**13**	16	69	**13**

*Percentage of samples exceeding 90th percentile water quality criterion.

MCC3.4 had the highest annual FC water quality exceedances. It had the highest geometric means both annually and seasonally. It also had the highest percentage of samples exceeding the 90th percentile criterion both annually and for the dry season. During the wet season, MCC2.0 had the highest percentage of samples exceed the 90th percentile criterion.

Most of the water quality exceedances occurred in the middle and lower watershed, in the tributaries (Brezee, Lockwood, Jenny, Mason, McCormick, and Riley Creeks and Rock Creek North) and the lower EF Lewis River mainstem sites. All sites in the upper watershed (Yacolt Creek, Big Creek, Rock Creek South, and upper EF Lewis River) met both water quality criteria based on the annual and dry season statistics.

During the wet season, four sites along McCormick Creek, as well as site BRZ SW2, exceeded both water quality criteria. All FC sampling sites on Yacolt, Big Tree, Mason, Brezee, and Jenny Creeks had more than 10% of samples exceed the 90th percentile criteria, in addition to the 3 furthest downstream EF Lewis River mainstem sites. There were seven sites that met both water quality criteria for the wet season.

There were more sites that exceeded both water quality criteria during the dry season (eight sites) than during the wet season (four sites). These sites were located on McCormick Creek, Brezee Creek, and Lockwood Creek. Generally, the geometric mean values were higher during the dry season than during the wet season. The average percentage of samples that exceeded the 90th percentile criterion was also higher during the dry season. Although most sites showed higher concentrations of FC during the dry season, there were more sites that met both water quality criterion in the dry season (eleven) than during the wet season (seven).

For the EF Lewis River mainstem, all of the sites met the geometric mean water quality criterion both annually and seasonally, although there were higher geometric means during the dry season than during the wet season. EFL0.75 exceeded the 90th percentile water quality criteria both annually and seasonally. EFL10.3 and EFL3.15 exceeded that water quality criteria during the wet season.

Two stormwater outfalls were sampled (BRZ SW1 and BRZ SW2). BRZ SW2 exceeded both water quality criterion annually and seasonally, and it had high levels of FC concentrations with the second overall highest geometric mean (203 cfu/100 mL). BRZSW1 was the only site to have a notably larger geometric mean during the wet season than during the dry season.

La Center's WWTP (STP0.0G) was sampled 27 times throughout the sampling period. This site met both water quality criteria based on its annual and seasonal statistics.

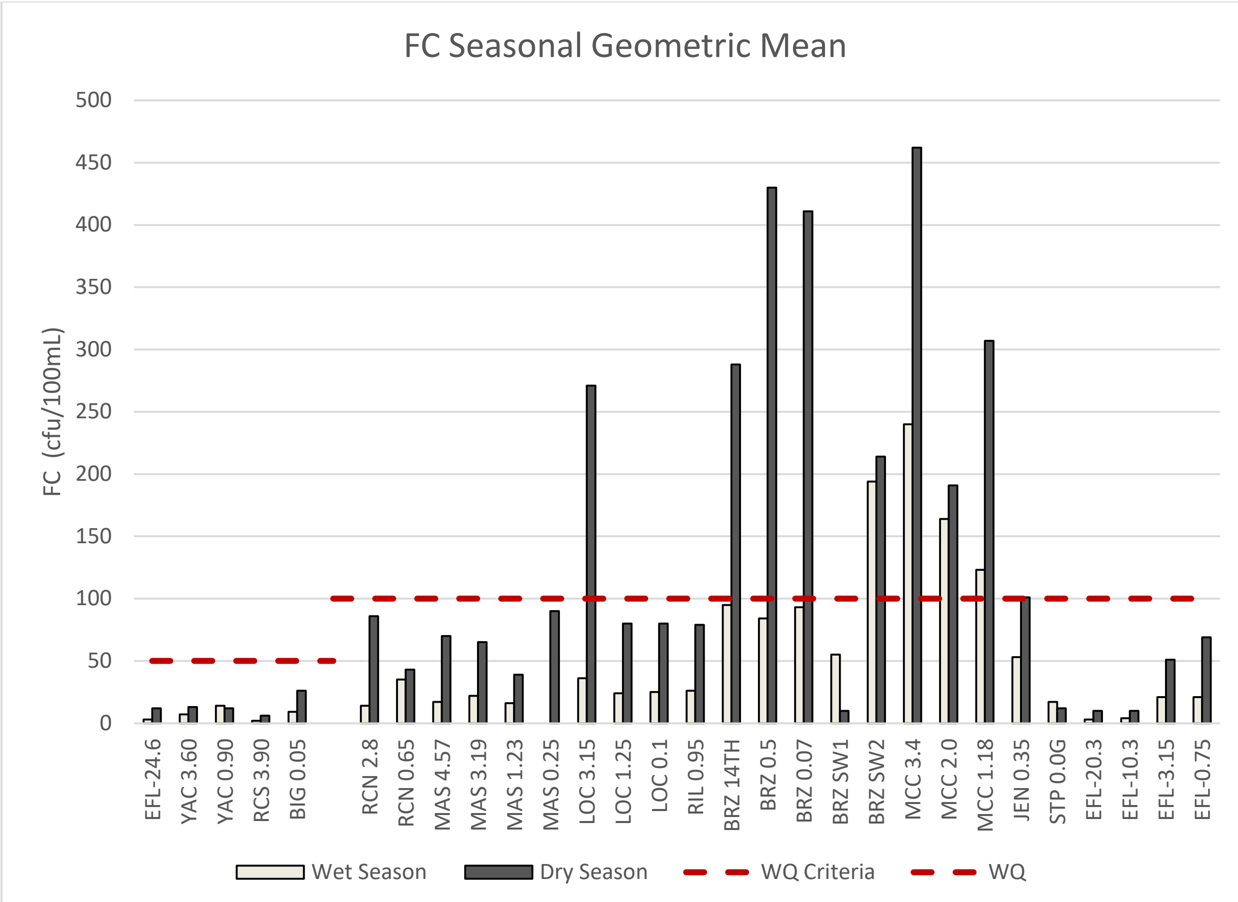
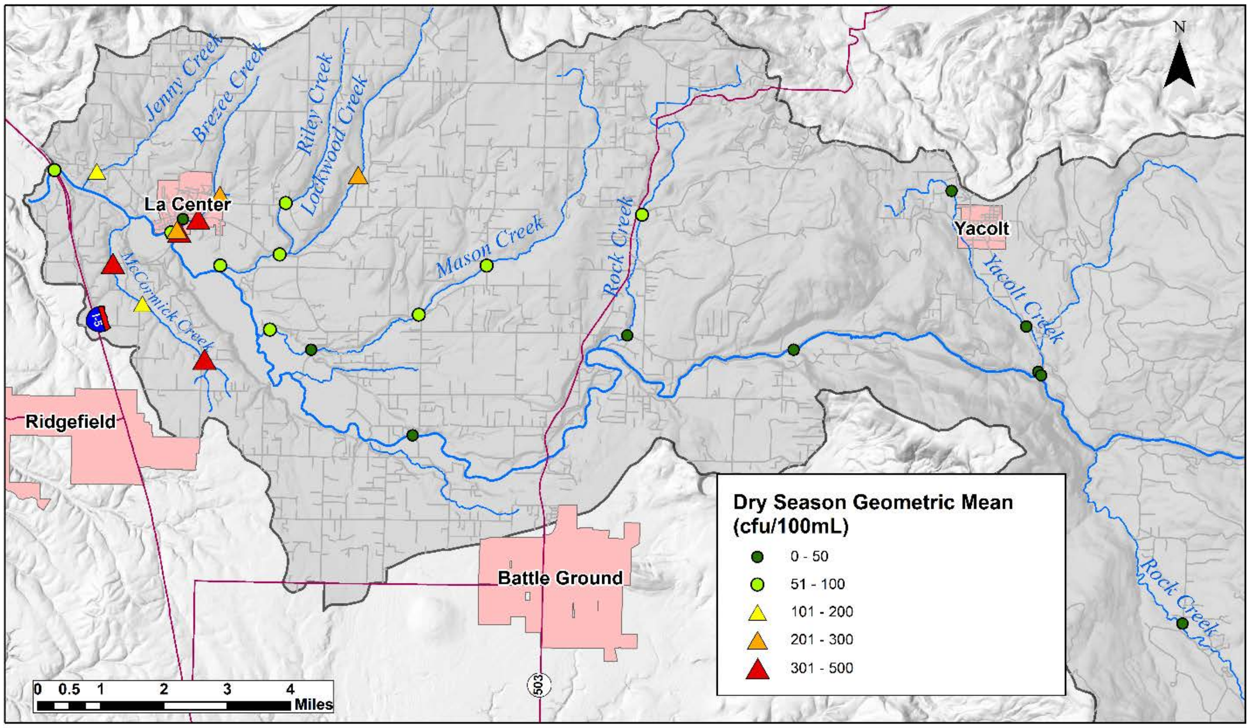


Figure 20. FC seasonal geometric mean, 2005-06.

Figure 21 illustrates the spatial distribution of the annual FC geometric mean for the 2005-06 sampling results. The highest FC geometric means were focused in the lower watershed, on McCormick Creek and on Brezee Creek as it runs through the town of the La Center. The highest geometric mean on the upstream site of McCormick Creek suggests a source of FC in the upper watershed. All tributaries upstream of Lockwood Creek (RM 4.5) and all of the EF Lewis River mainstem sites met the geometric mean water quality criteria during both the wet and dry seasons.

The FC sampling sites showed seasonal differences in FC concentrations and water quality exceedances during the dry season (June-October) and wet season (November-May).



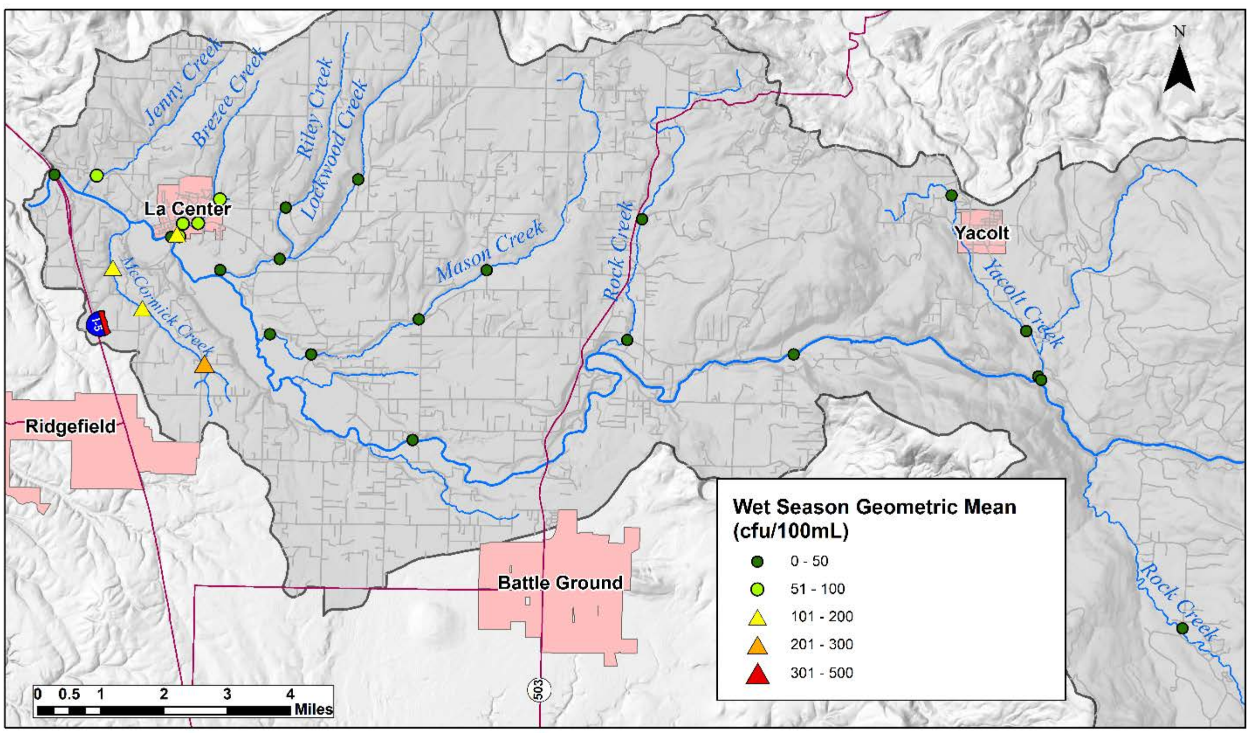


Figure 21. FC geometric mean for dry season (above) and wet season (below).
Triangles indicate water quality exceedance.

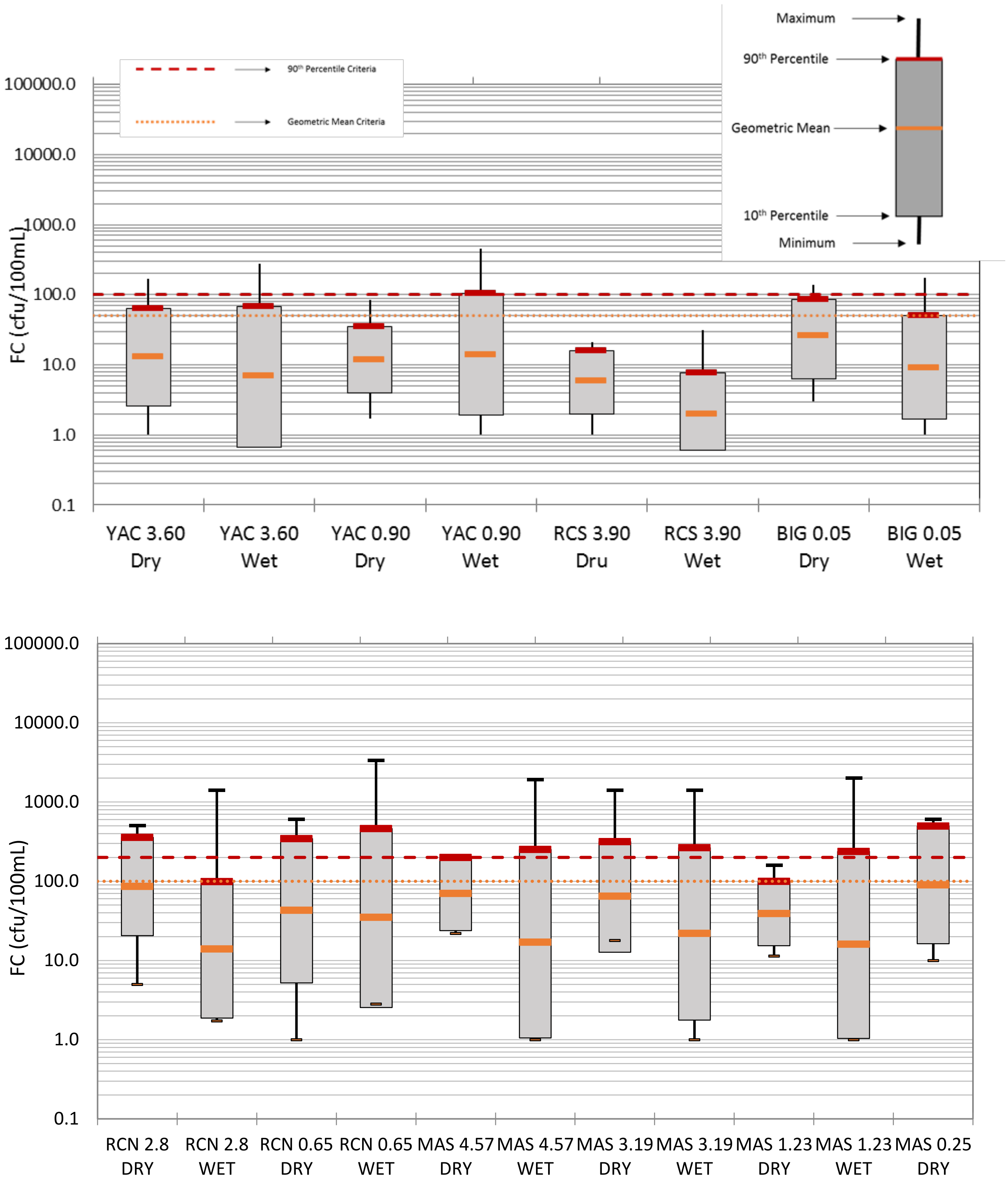


Figure 22. FC seasonal distribution for upper and middle tributaries, 2005-06.

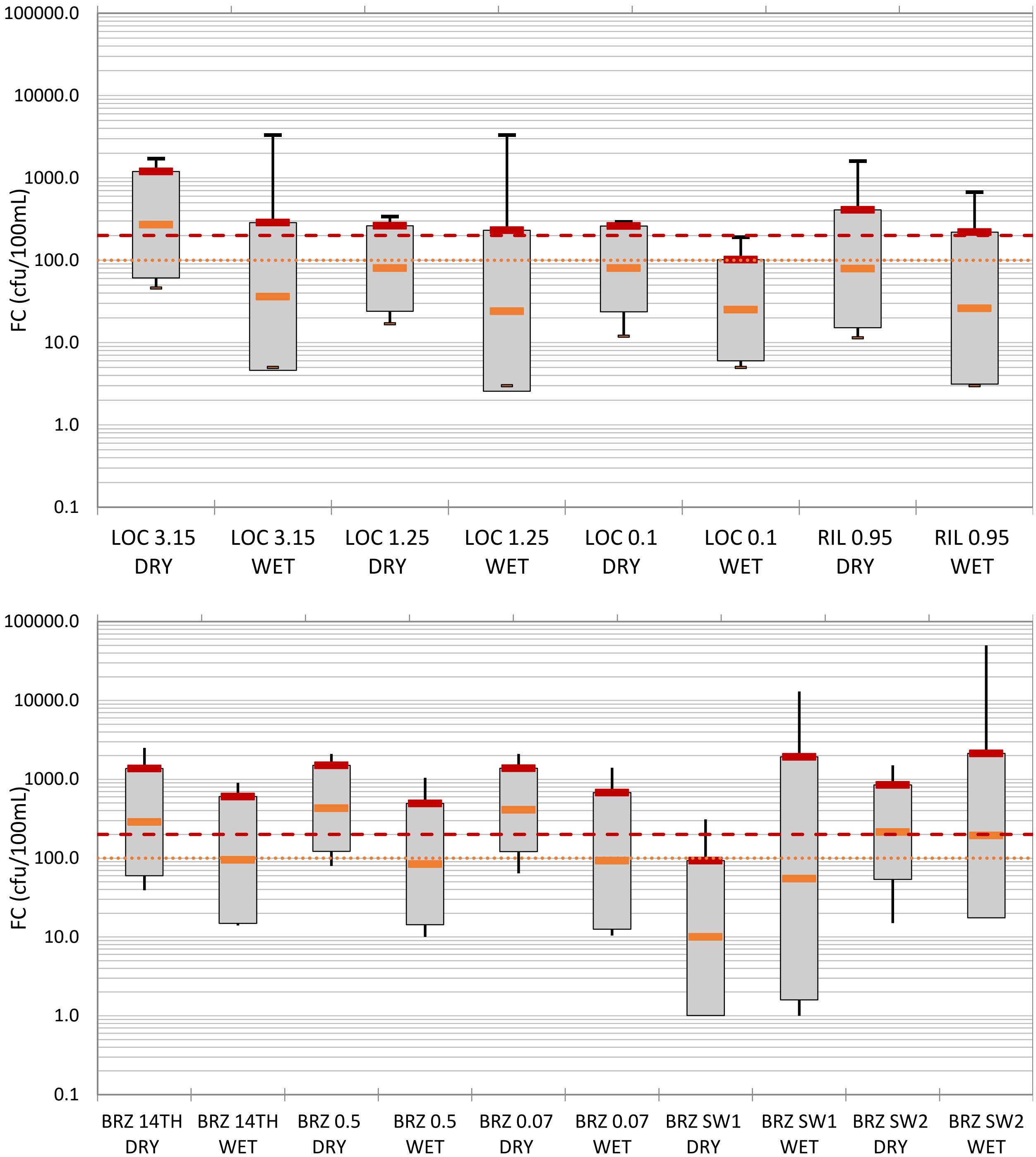
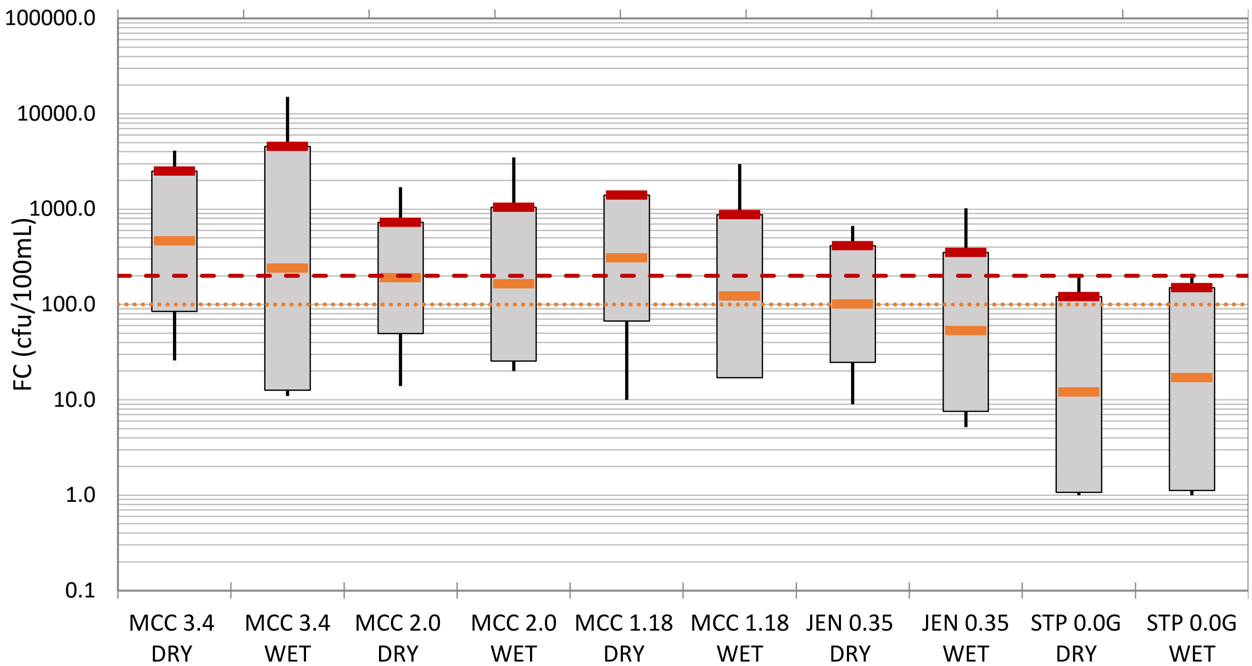


Figure 23. FC seasonal distributions for middle and lower tributaries, 2005-06.



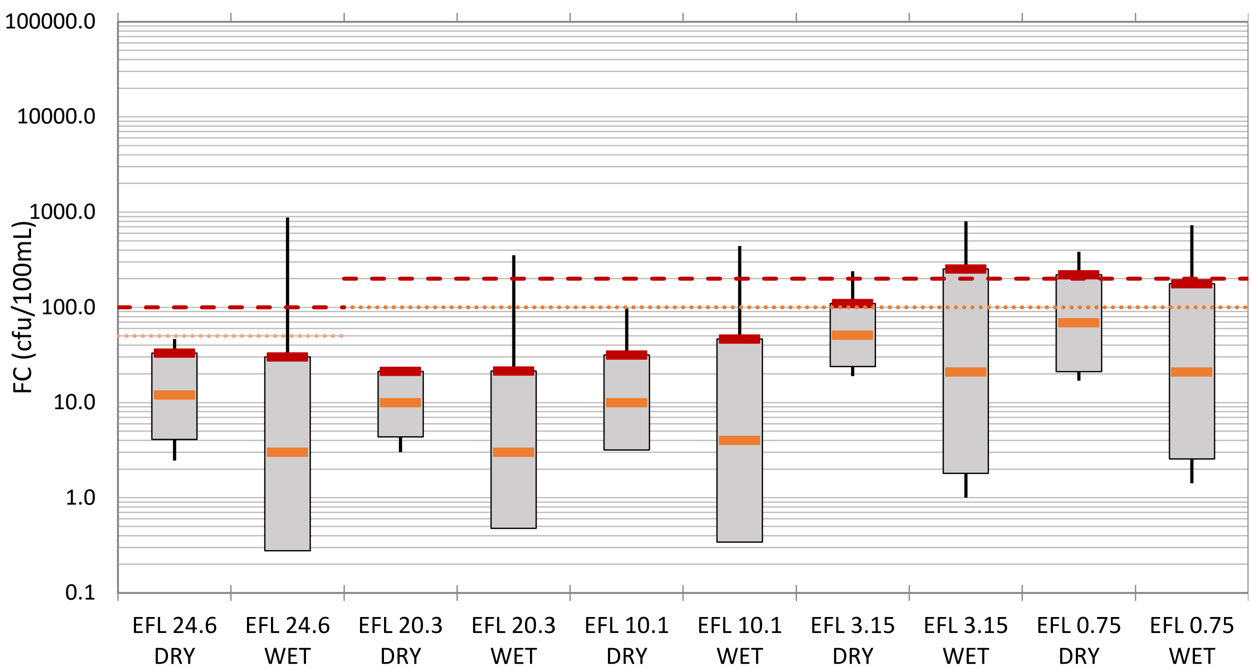


Figure 24. FC seasonal distribution for lower tributaries and mainstem, 2005-06.

Seasonal Kendall Trend Test Results

A Seasonal Kendall Trend test was completed for the EF Lewis River at its ambient monitoring site located near Daybreak Park (27D090) from 2005-2016. This trend test was used to determine any significant trends in FC concentrations since the original field collection period using a significance level of 0.10 (90% confidence).

Results from the Seasonal Kendall Trend test are presented in Table 10. These values indicate a significant increasing trend of FC concentrations at this location from 2005-2016.

Table 10. Seasonal Kendall Trend Test statistics summary.

Tau	0.132
2-sided p-value	0.037
Slope	0.375
Significance level	0.100
Z-value	2.086

Detailed results of the Seasonal Kendall Trend test are documented in Appendix C.

Loading Analysis Results

FC loads are used to represent the amount of FC that enters the EF Lewis River during a defined time. Loads were calculated for the year (annually), storm event, and seasonally (wet and dry seasons excluding storm events). Loads were only calculated at sites along the EF Lewis River's mainstem, tributaries, and outfalls with sufficient flow data.

The only EF Lewis River mainstem sites with sufficient data to calculate loads were EFL20.3 and EFL10.1. Compared to all of the sites with calculated loads, these mainstem sites had the highest annual average FC loads overall (Figure 25). The further downstream site (EFL10.1) has the largest FC load, and this follows typical loading patterns, where loads increase further downstream due to increased flow. Both sites also had the overall highest FC loads during the storm event. The tributary sites with the highest annual average FC loads are found at RCN0.65, MAS3.19, and MAS1.23. FC loads during the storm event were significantly larger than the average annual loads.

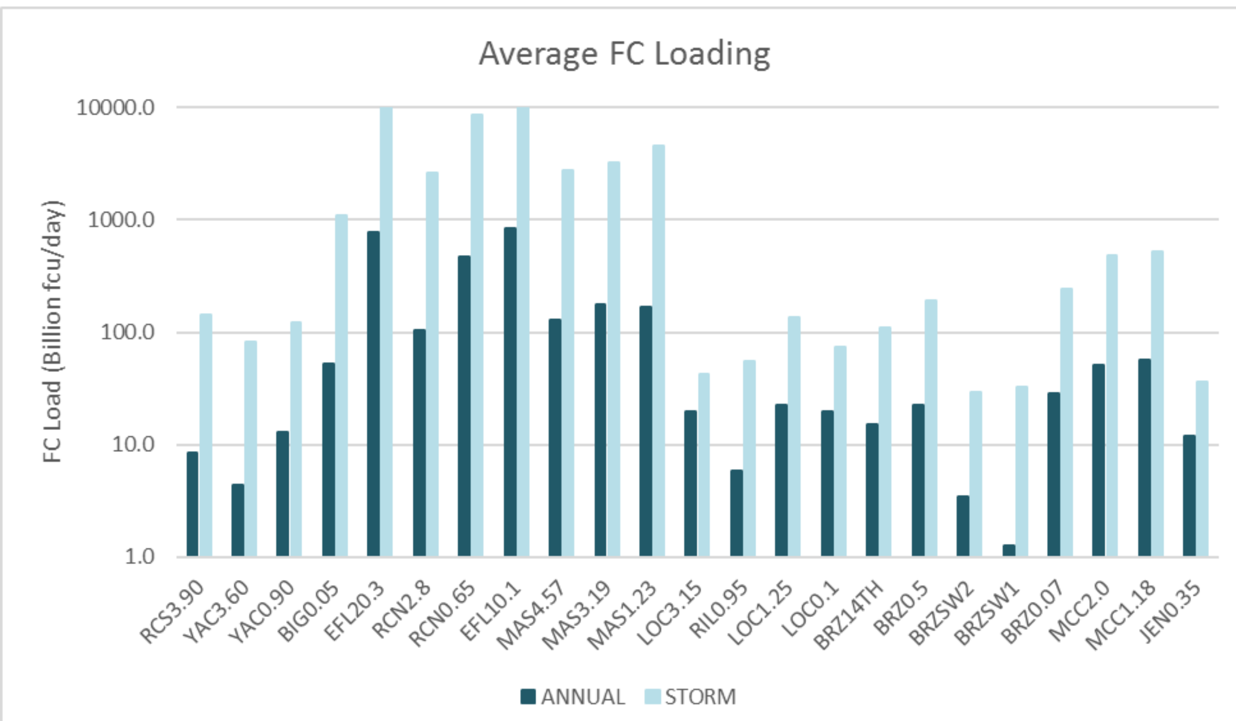


Figure 25. Average annual and storm event FC loading.

Figure 26 shows the average seasonal FC loads for the wet and dry seasons, excluding storm events. Similar to the annual average loading results, EFL10.1 had the highest overall FC load during the dry season (51.8 billion cfu/day) and EFL20.3 had the second largest dry season FC load overall (48.1 billion cfu/day). During the wet season (excluding storm events) however, MCC1.18 and MCC2.0 had the highest overall FC loads (82.7 and 67.1 billion cfu/day, respectively). EFL20.3 and EFL10.1 had the third and fourth highest FC loads during the wet season. These results point to a source of high FC loading upstream of MCC2.0.

Generally, wet season FC loads are higher than the dry season loads due to increased precipitation and runoff. Only three sites (EFL10.1, RCN2.8, and LOC3.15) had higher FC loads during the dry season than during the wet season, but only LOC3.15 was noticeably different. This is an atypical loading pattern, which may suggest there is a strong source of FC upstream in Lockwood Creek during the dry season.

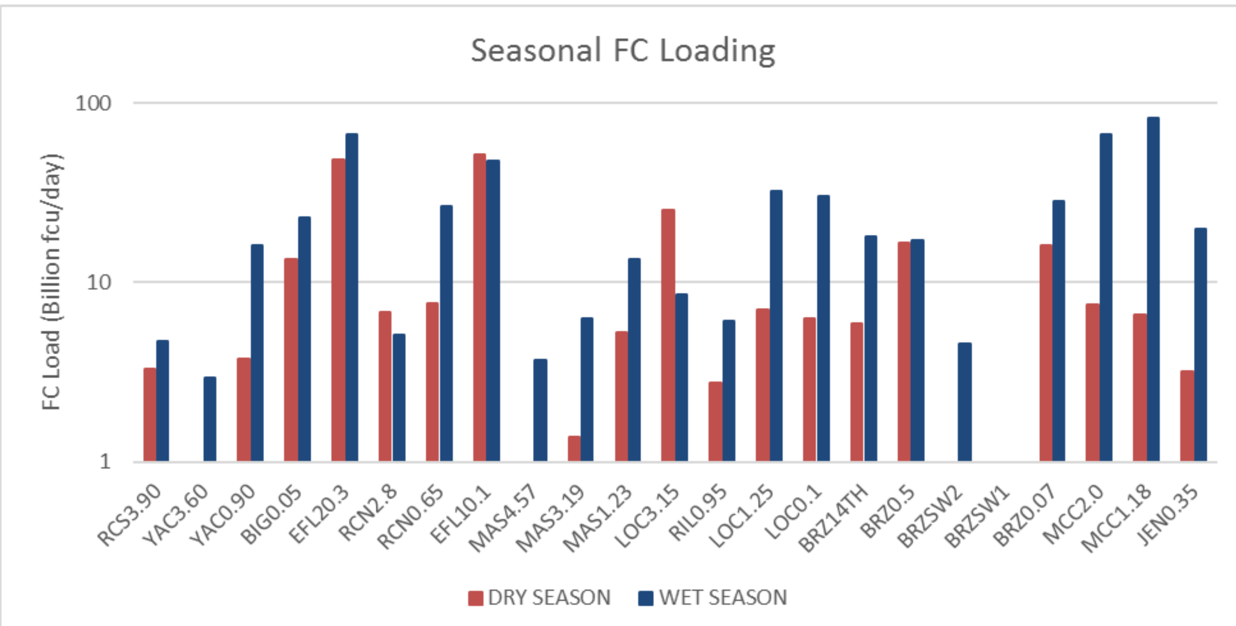


Figure 26. Average seasonal FC loading.

Figure 27 shows seasonal average loading patterns in the EF Lewis River watershed. The dry season map highlights the high loading that is occurring along Brezee Creek, upper Lockwood Creek, and along the mainstem of the EF Lewis River. The upstream sites in Yacolt, Mason, and Riley Creeks had low FC loads during the dry season. The wet season map highlights that loading is significantly higher along most sites. The largest tributary wet season FC loads occurred at lower McCormick, Lockwood, and Brezee Creeks.

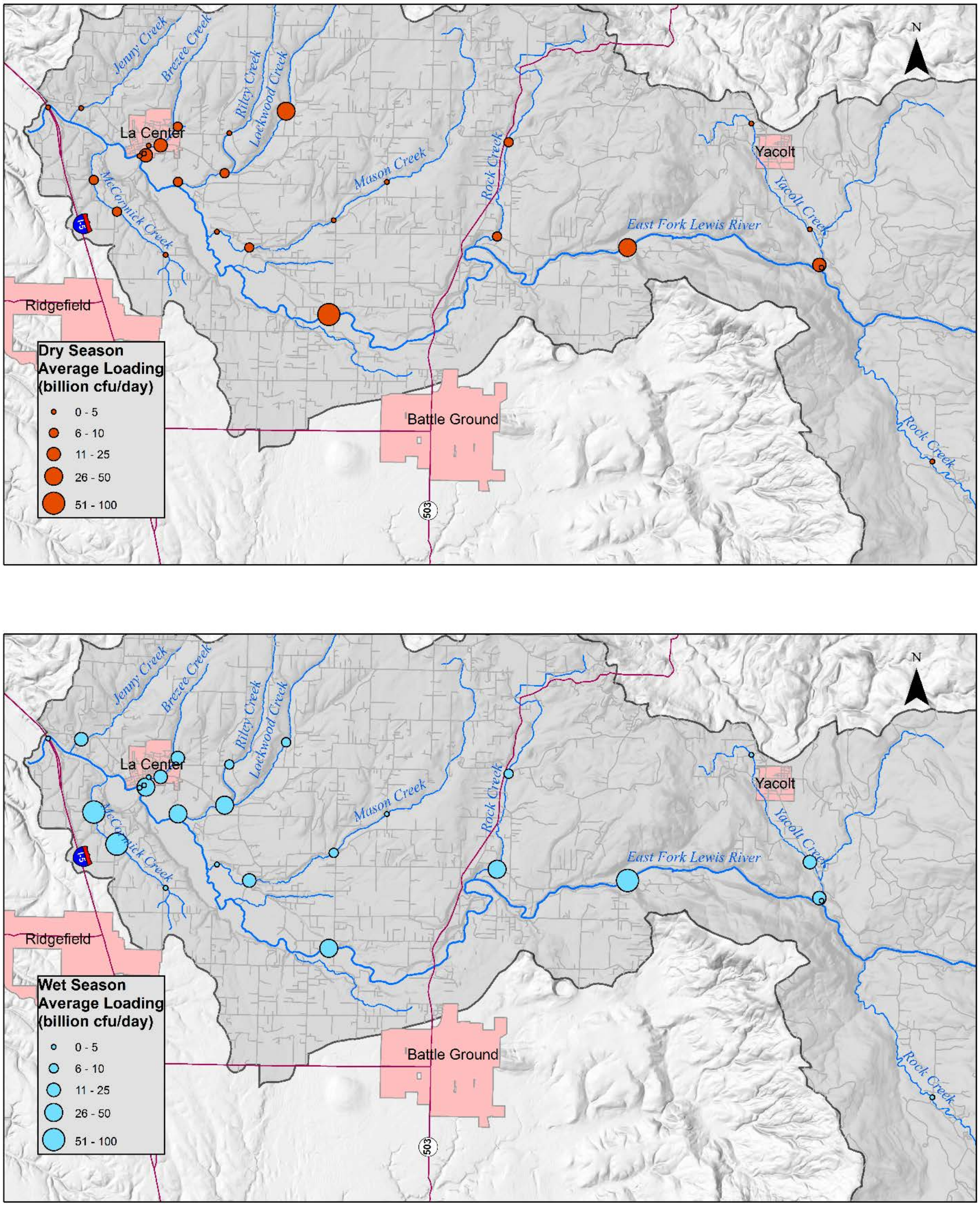


Figure 27. Dry season (top) and wet season (bottom) FC loading patterns.

Figure 28 shows FC loading patterns along the mainstem of EF Lewis River for the sites with calculated loads, EFL20.3 and EFL10.1. Both sites have similar flows during the dry season, and the FC loads slightly increase moving downstream from EFL20.3 to EFL10.1. During the wet season, the sites show typical flow patterns, with flows increasing moving downstream. Despite the lower flow, EFL20.3 has a higher average load during the wet season than the downstream site, EFL10.1.

From RM 20.3 through RM 10.1, the EF Lewis River flows through different land use types, including residential and forest area with some agriculture through RM 15. From RM 15-10.1, the EF Lewis River is surrounded by many parks including Camp Lewisville, a greenway (Lewis River Trail Ranch), and Daybreak Park near RM 10. Many of these parks and public spaces are surrounded by agricultural fields, small farms, residential properties, and forest land.

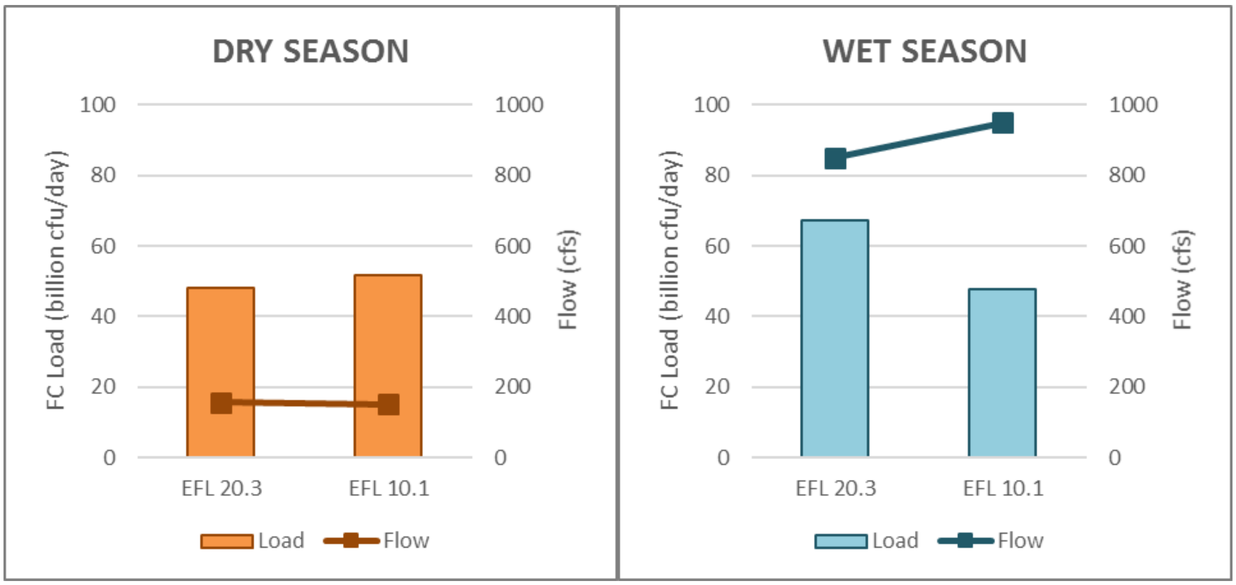


Figure 28. Seasonal FC loads and flow at EF Lewis River sites.

Due to insufficient flow data at EF Lewis River sites located in the lower watershed, a FC load balance was unable to be developed for the lower tributaries and overall watershed.

Fecal Coliform Results, 2017

The summary of 2017 FC results are presented in Table 11. Statistics were calculated only for sites with more than 5 samples.

Table 11. FC results summary, 2017.
***Bold** values indicate geometric mean water quality criteria exceedance.*

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
YAC-0.90	17	25	**18**	8	26	**25**	9	24	**11**
RCN-2.07	15	75	**40**	7	29	**14**	8	**173**	**63**
MAS-3.19	12	39	8	8	38	**13**			
MAS-1.11	17	45	**12**	8	25	**13**	9	75	**11**
LOC-3.55	16	36	**31**	7	8	**14**	9	**120**	**44**
RIL-0.95	17	35	**29**	8	9	**13**	9	**118**	**44**
BRZ-14th	17	**129**	**65**	8	29	**25**	9	**482**	**100**
BRZ-0.07	17	**126**	**65**	8	58	**38**	9	**254**	**89**
BRZ-SW1	9	44	**33**	8	28	**25**			
BRZ-SW2	16	**378**	**81**	8	**238**	**63**	8	**599**	**100**
JEN-1.03	16	**105**	**50**	7	66	**29**	9	**151**	**67**
MCC-1.18	17	**142**	**59**	8	**115**	**50**	9	**172**	**67**
MCC-3.4	15	**547**	**100**	6	**663**	**100**	9	**481**	**100**
MCC-TRIB 2	6	**591**	**67**						
EFL-3.35	13	21	8				9	26	0
EFL-0.75	14	78	**36**	5	40	**20**	9	**113**	**44**

*Percentage of samples exceeding 90th percentile water quality criterion.

Results from the 2017 sampling show that there were FC water quality exceedances at all sites during both the wet and dry seasons, with the exception of EFL3.35 that met both water quality criteria during the dry season. Based on the annual summary, MAS3.19 and EFL3.35 met both water quality criteria.

The highest seasonal geometric mean overall was at MCC3.4 during the wet season (663 cfu/100mL) followed by BRZSW2 during the dry season (599 cfu/100mL). Results from the 2005-06 study are similar to the 2017 results, with MCC3.4 consistently having the highest FC concentrations and BRZSW2 having elevated FC concentrations. MCCTRIB-2 also had a high geometric mean based on the annual summary, and this site was added to the 2017 sampling to help identify FC sources. These results helped to confirm FC exceedances in upper McCormick Creek.

Similar to the 2005-06 results, in general the geometric means were higher during the dry season than during the wet season (Figure 29). The highest geometric and FC exceedances occur in the lower watershed tributaries at McCormick Creek and Brezee Creek as it flows through La Center. Although EFL3.35 showed no FC exceedances in 2017, EFL0.75 had water quality exceedances that were comparable with the 2005-06 results.

Overall, there were no significant differences between FC concentrations from the tributaries and sites sampled in 2005-06 and FC concentrations from supplemental sampling in 2017. This supports using the 2005-06 FC results to help address FC exceedances in the EF Lewis River watershed and help direct implementation efforts.

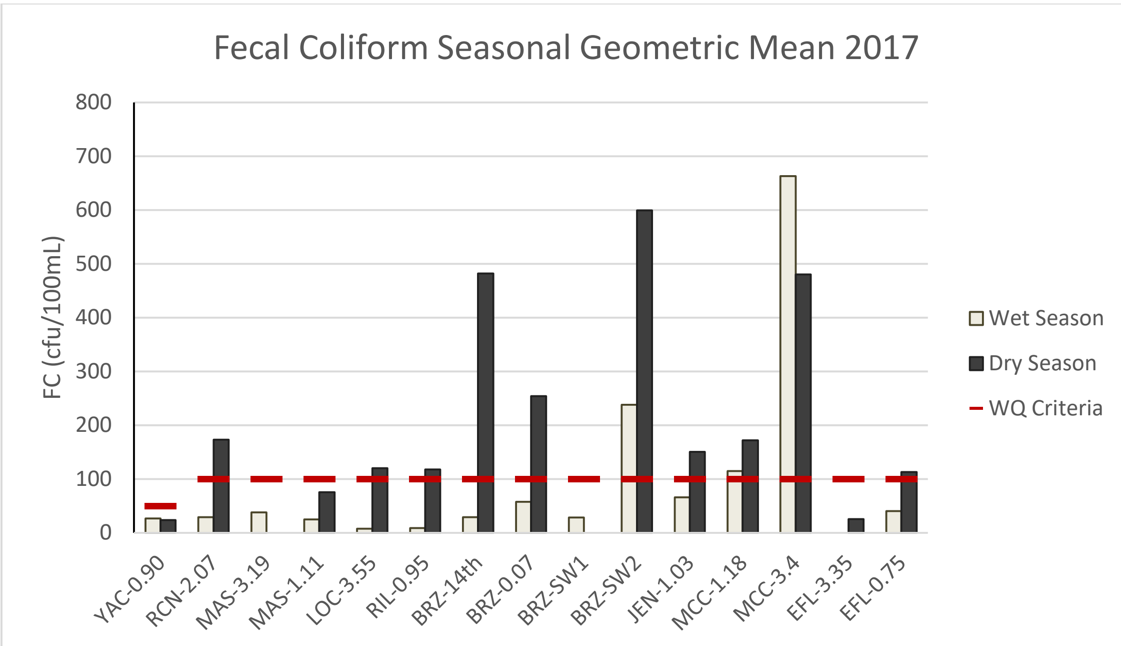


Figure 29. FC results for geometric mean, 2017.

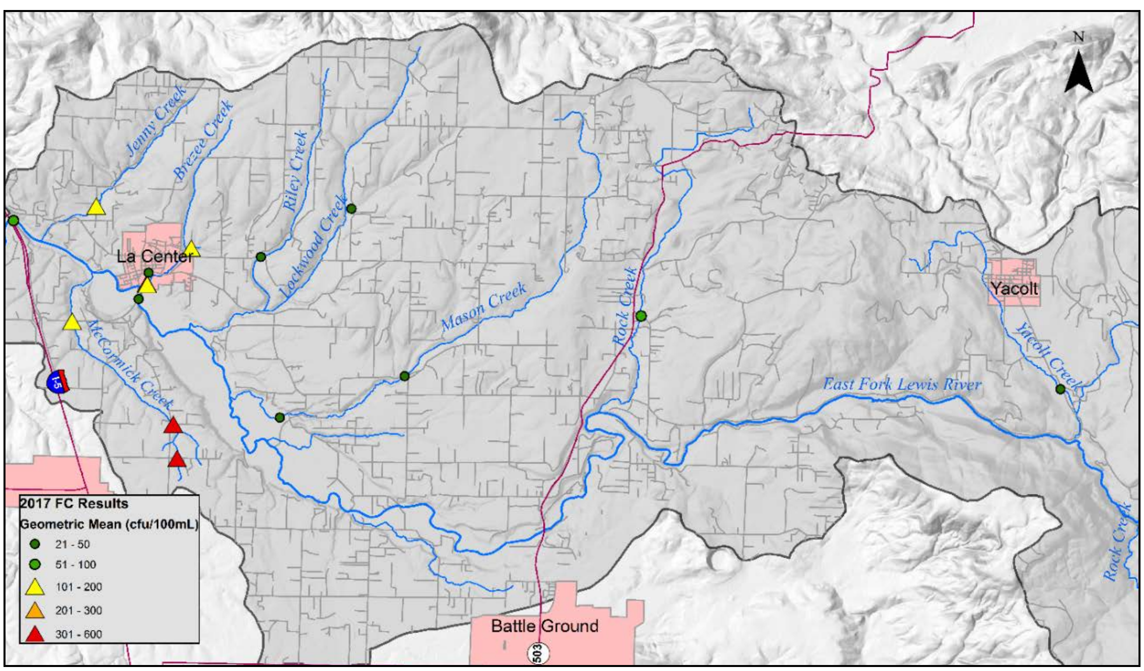


Figure 30. FC results for geometric mean (annual), 2017.

Temperature Results

Table 12 presents a summary of the temperature criteria, average temperature, 1-day maximum temperature (1-DMax), and 7-day average of the daily maximum temperatures (7-DADMax) for each site.

Table 12. Temperature results, 2005-06.

Bold *values indicate water quality exceedance.*

Site	Temperature Criteria (°C)	Total Days Sampled	Average Temp (°C)	1-DMax (°C)	7-DADMax (°C)
EFL29.0	16.0	90	13.8	18.1	**17.2**
KNG00.0	16.0	112	13.9	17.4	**17.0**
EFL26.9	16.0	95	14.6	18.7	**18.4**
RCS03.9	16.0	112	14.2	17.8	**17.4**
EFL24.6	16.0	83	15.2	19.5	**19.0**
BIG00.0	16.0	112	14.6	18.0	**17.6**
EFL20.3	16.0	113	16.0	20.8	**20.0**
RCN050	16.0	131	16.6	22.0	**20.9**
RCN00.6	16.0	91	18.3	24.0	**23.4**
EFL14.7	16.0	75	19.6	23.3	**22.7**
EFL13.2	16.0	90	18.6	23.9	**23.2**
EFL10.1	16.0	120	18.8	24.1	**23.4**
MAN010	16.0	79	18.9	22.4	**21.9**
EFL08.1	16.0	39	20.1	24.5	**23.5**
DEA00.8	16.0	114	18.6	24.6	**23.0**
DEA00.0	16.0	28	24.4	29.4	**26.1**
EFL07.3	16.0	73	19.2	24.0	**23.3**
MAS00.8	16.0	115	15.4	19.3	**18.1**
LOC00.0	16.0	65	17.9	24.0	**22.4**
BRZ010	16.0	131	16.1	20.4	**19.5**
BRZ00.1	16.0	113	16.7	20.4	**19.5**
JEN00.3	16.0	112	16.4	20.8	**20.0**

All temperature monitoring sites in both the EF Lewis River and its tributaries exceeded the 7-DADMax criteria at some point throughout the deployment period.

The site at the mouth of Dean Creek (DEA00.0) was heavily affected by a beaver dam located just upstream of the site that inhibited streamflow and at times caused the creek channel to dry up where the instream temperature logger was located. Although data were cut from this site in mid-July based on a QC analysis (field collection determined the instrument was recording air temperature), early summer temperature measurements may have also been influenced by ponding and dropping stream stage. This would help to explain the source of the high temperatures at the mouth of Dean Creek.

The remainder of the monitoring sites had a range of maximum 7-DADMax temperatures between 17-24°C. Sites in the mid-mainstem section of the EF Lewis River (from RM 7.3-13.2) had maximum 7-DADMax temperatures of 23-24°C and average temperatures between 18-20°C. Sites with the lowest average temperature (14°C) and maximum 7-DADMax (17°C) were located in the upper watershed (EFL29.0, King Creek and Rock Creek South).

The *Surface Water and Groundwater Exchange* study (Carey and Bilhimer, 2009) gathered and interpreted evidence of groundwater inflow and outflow along the EF Lewis River and estimated the temperature of groundwater inputs into the river. Results showed that groundwater temperatures were lower than surface water temperatures and caused cooling of the river in gaining reaches (Figure 31).

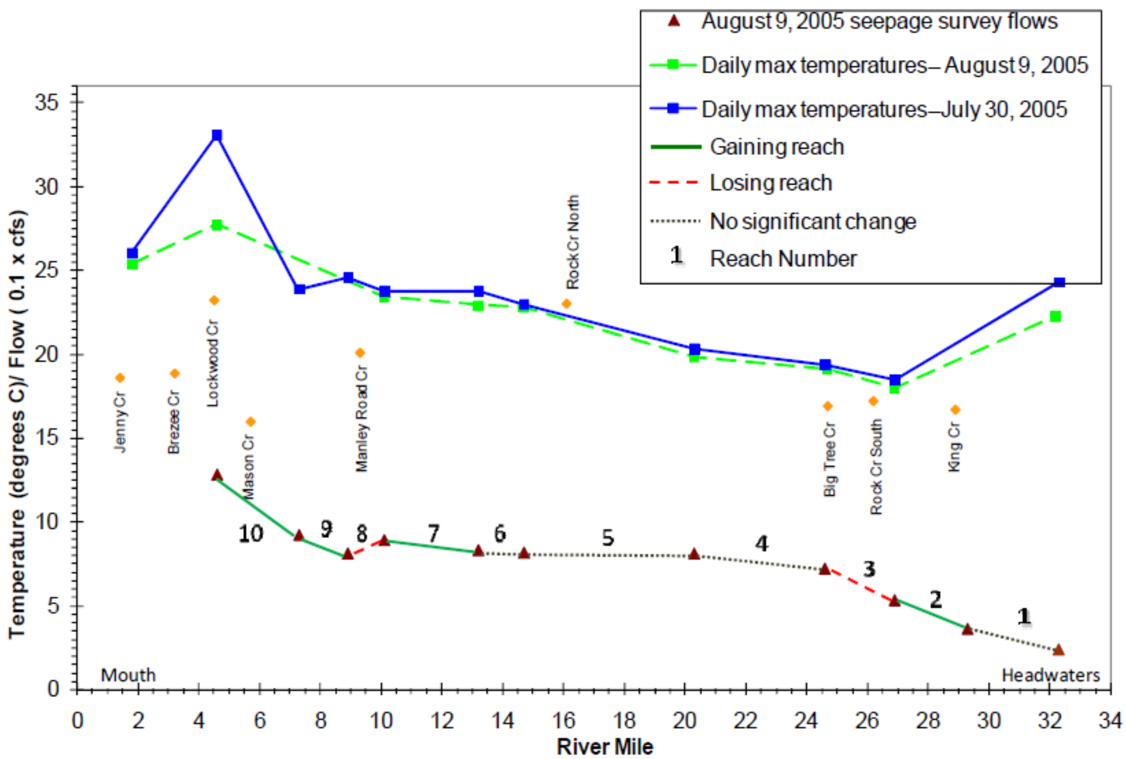


Figure 31. Daily maximum and daily average stream temperature profiles for the EF Lewis River on July 30 and August 9, 2005 and streamflow on August 9-10, 2005 (Carey and Bilhimer, 2009).

A longitudinal temperature profile for the EF Lewis River was created for the critical day (Figure 33). July 31, 2005 is the critical day for the study period, based on having the most occurrences of the seasonal maximum temperature throughout the watershed. The increase in temperature from the river mouth through the Lockwood Creek is caused by tidal backwater. The gaining reaches, those that receive an influx of cool groundwater, show lower rates of heating and are cooling between Daybreak Park and the area above the Ridgefield Pits. The lowest river temperatures are found in the upper EF Lewis River near the headwaters.

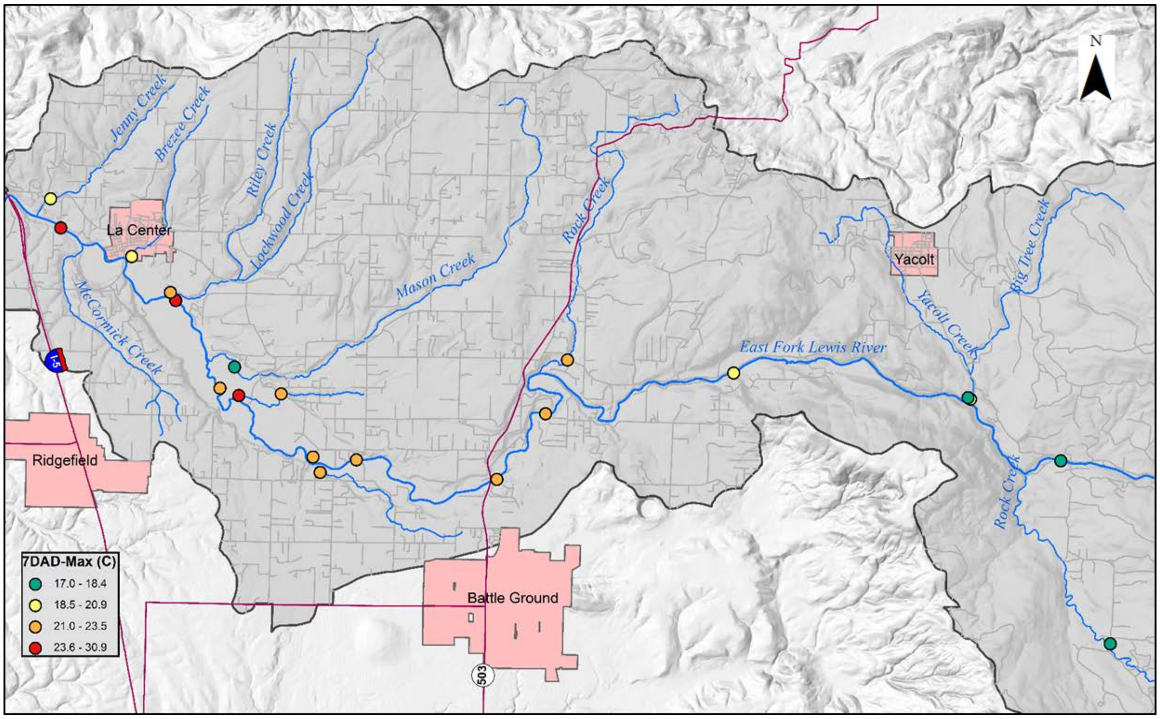


Figure 32. Maximum 7-DADMax temperatures, 2005.

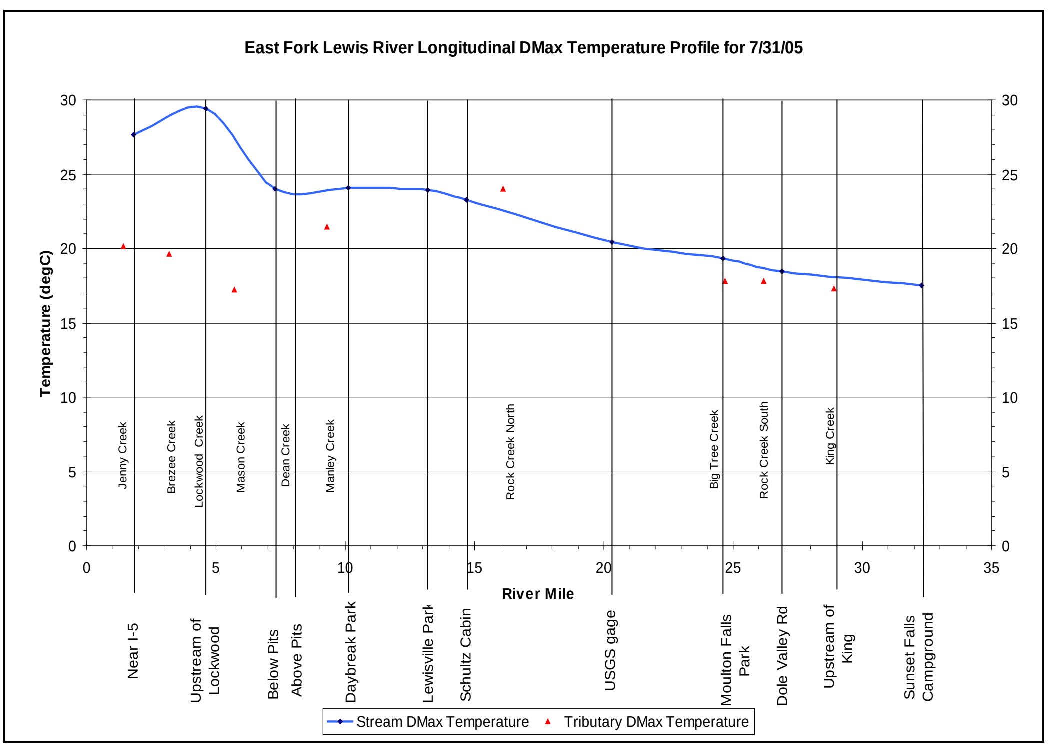


Figure 33. Longitudinal daily maximum temperature profile, 7/31/05.

Temperature Results at Daybreak Park, 2005-2016

As part of Ecology's ambient monitoring program, temperature is measured monthly at the long-term sampling site, 27D090 at Daybreak Park (EFL 10.1). This monitoring has continued since the completion of the 2005-06 field data collection and is used as a comparison for current temperature conditions at the site.

Figure 34 shows the annual maximum temperature and annual average temperature for 27D090 since 2005. During 2005, the year with the continuous temperature logger deployment, both annual maximum and average temperatures were slightly higher than the average over the last 10 years. The range of annual maximum temperatures (17.9-22.5°C) and annual average temperatures (9.1-12.3°C) have been fairly consistent, showing no apparent increase or decrease in temperatures. This suggests that the temperature results collected from 2005 are representative of long-term temperature conditions for this site on the EF Lewis River.

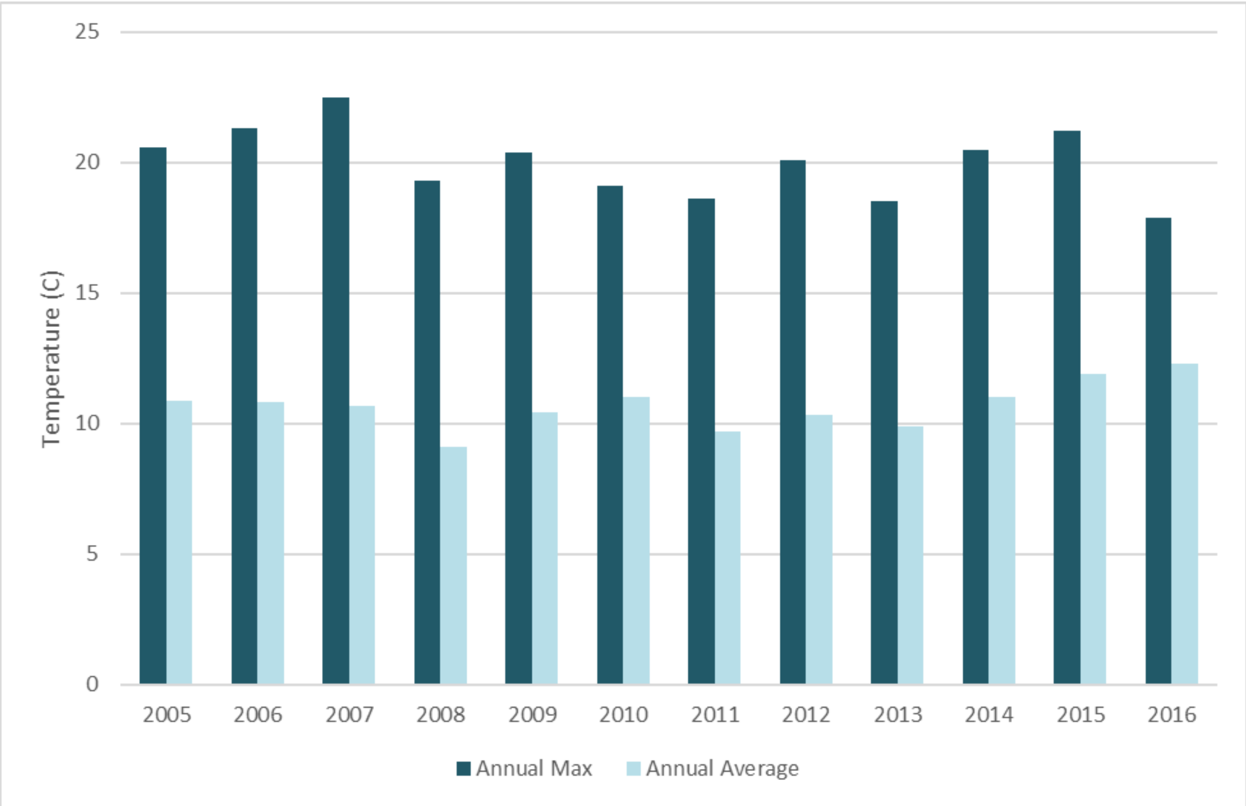


Figure 34. Daybreak Park long-term annual maximum and average temperatures, 2005-16.

Shade Analysis Results

A shade analysis for the EF Lewis River mainstem was completed using a GIS approach (TTools) and Ecology's Shade model to evaluate effective shade and system potential effective shade. Figure 35 shows the results from the modeled effective shade analysis and the results from hemispherical photography (HemiView photos). The results from the Shade modeling analysis were in 50-meter intervals and were then smoothed by calculating a rolling average over 500-meters. The disparities between the HemiView photo and modeled results for effective shade are influenced by the exact location uncertainty of the photos taken in the field and by the fact that the Shade model represents an averaged effective shade value over a reach, rather than at a specific point.

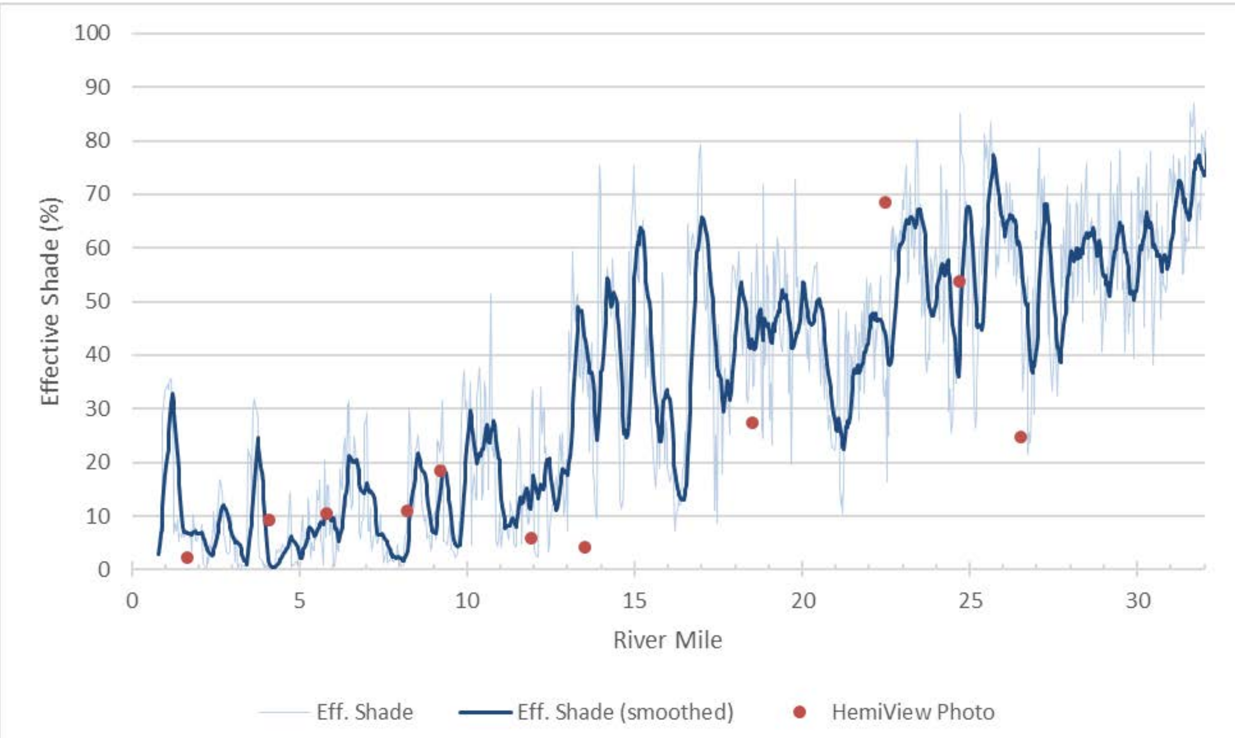


Figure 35. Shade analysis results for effective shade modeling, effective shade over rolling average of 500 meters (smoothed), and HemiView photos as observational points.

Effective shade is highest in the upper watershed, and is consistently high upstream of river mile (RM) 22.0. Effective shade decreases moving from the upper watershed to the lower watershed, with some short fluctuations between high and low effective shade. The sections with the lowest effective shade are between RM 1.0 and 8.0, with almost all effective shade values below 25%. Effective shade essentially reaches 0% near RM 4.2.

The results of the effective shade analysis are consistent with the varying land cover types in the watershed; the upper watershed is primarily dominated by forested land and riparian cover and the lower watershed has more mixed land use, including agricultural and rural areas. As the watershed progresses from forested land to developed and mixed-use, the amount of riparian cover and vegetation decreases causing lower effective shade.

A system potential shade analysis was completed based on system potential mature vegetation height. The system potential shade modeling run accounted for mature vegetation growing on areas that were not already water or developed. The results from the existing effective shade (2005) and system potential effective shade are presented in Figure 36. Most reaches of the EF Lewis River show varying extents of a shade deficit (difference between system potential and current effective shade).

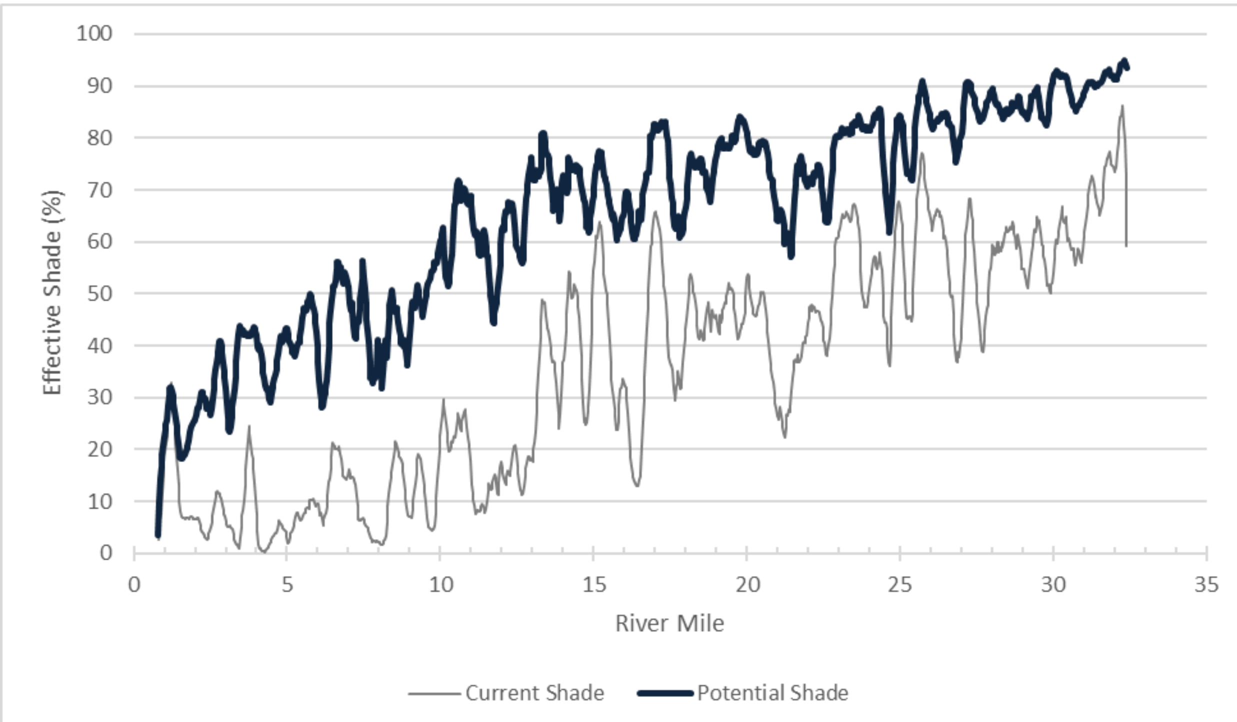


Figure 36. Current effective shade and potential effective shade modeling results.
The area between the current and potential shade represents the shade deficit.

A shade deficit was calculated by taking the difference of system potential shade and current effective shade. The results of this are shown in Figure 37, which is a map displaying the shade deficits along EF Lewis River. This map highlights the highest shade deficits (greater than 50%) are located in the middle watershed, focused around RM 9.0-13.0.

Based on the results from the field photo and HemiView analysis, the results for the average annual effective shade and canopy cover are presented in Figure 38. The sites with both the highest annual average effective shade and canopy cover were all located in the upper watershed (EFL24.6, EFL26.9, and EFL29.0). The sites with the lowest average canopy cover coincided with the lowest effective shade (EFL01.5, EFL07.3).

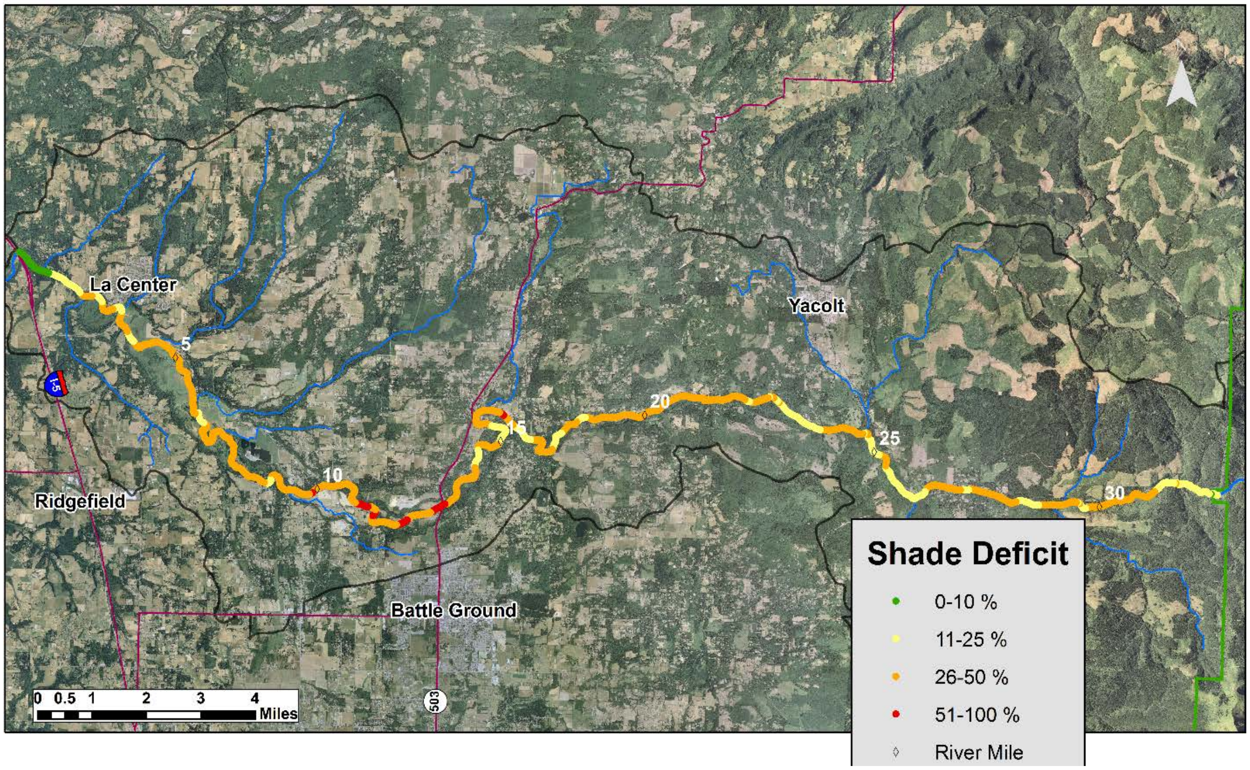


Figure 37. Map of shade deficit based on shade analysis using current effective shade (2005) and system potential effective shade.

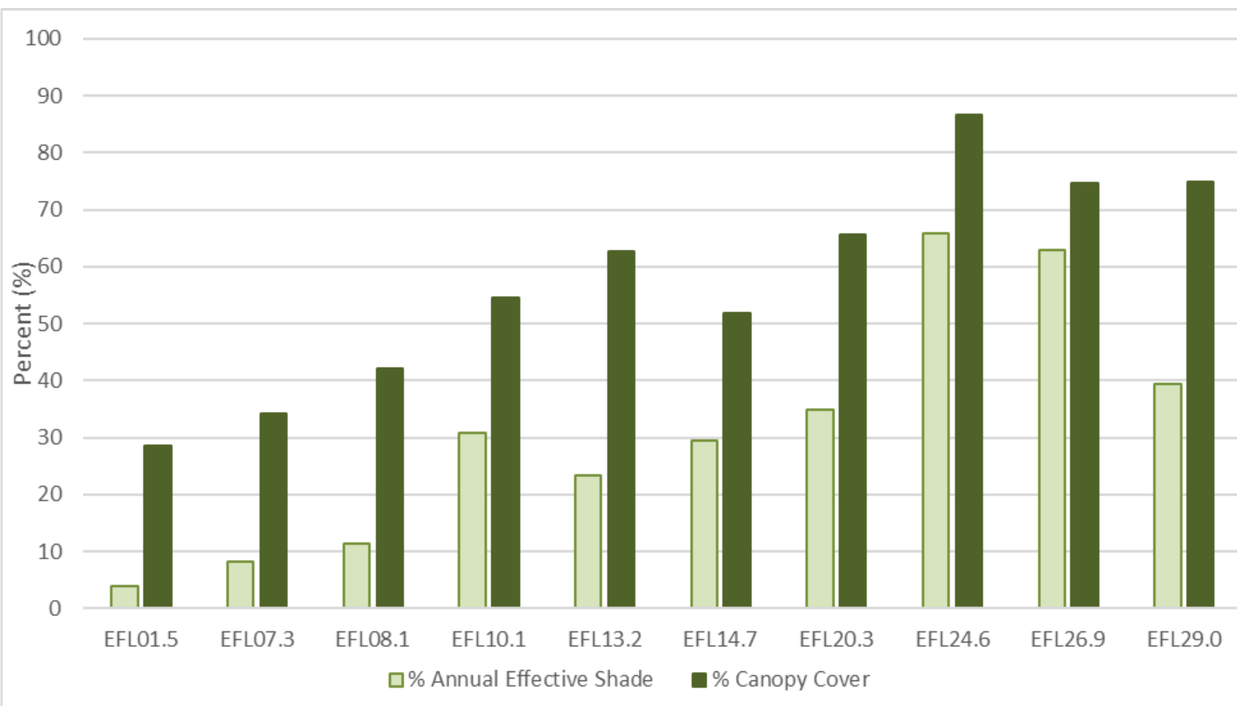


Figure 38. HemiView analysis results for annual effective shade (%) and annual average canopy cover (%).

Subbasin Summaries

The following sections present study results and discussion for the EF Lewis River and its subbasins.

Table 13. Summary results by subbasin.

Subbasin	River/Creek
Upper	EF Lewis River (RM 20.3 – RM32.3) King Creek Yacolt Creek Big Tree Creek Rock Creek South
Middle	EF Lewis River (RM 5.7 – RM 20.3) Rock Creek North Mason Creek Lockwood Creek Riley Creek
Lower	EF Lewis River (river mouth - RM 5.7) Brezee Creek McCormick Creek Jenny Creek

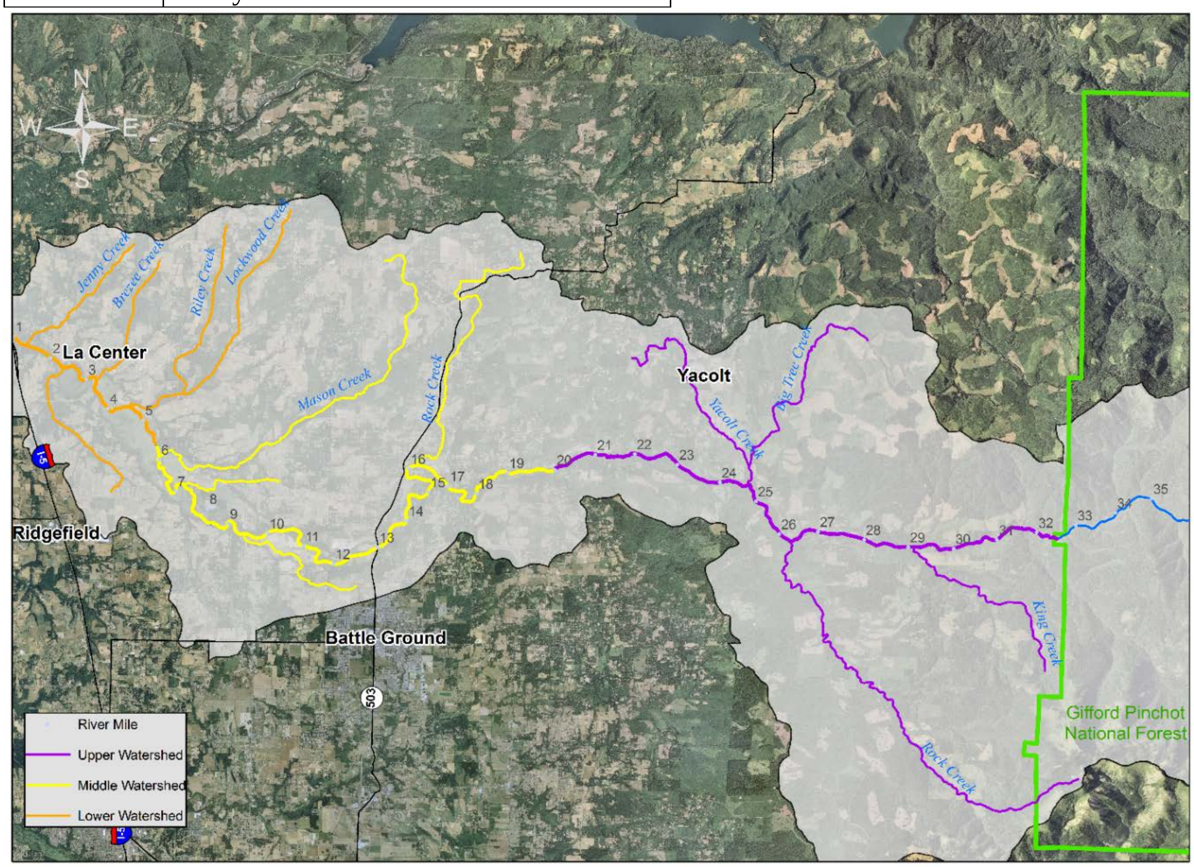


Figure 39. Map of subbasins in the EF Lewis River watershed.

Upper EF Lewis River

The upper EF Lewis River is from RM 20.3 to near the headwaters. This study focused on the section from RM 20.3-RM 32.3 or until the edge of the Gifford Pinchot National Forest. The headwaters of the EF Lewis River originate on the western slope of the Cascade Mountains in the Gifford Pinchot National Forest. Moving downstream from the national forest, land use is dominated by forest land with small pockets of residential and commercial areas. There are both privately and publically owned forest lands where active timber management and forestry practices occur. The forest land south of the mainstem is predominately DNR timber land. This segment of the river passes along the southern boundary of the small town of Yacolt. It also passes through two county-owned regional parks, Moulton Falls and Lucia Falls from RM 21.0-25.0.

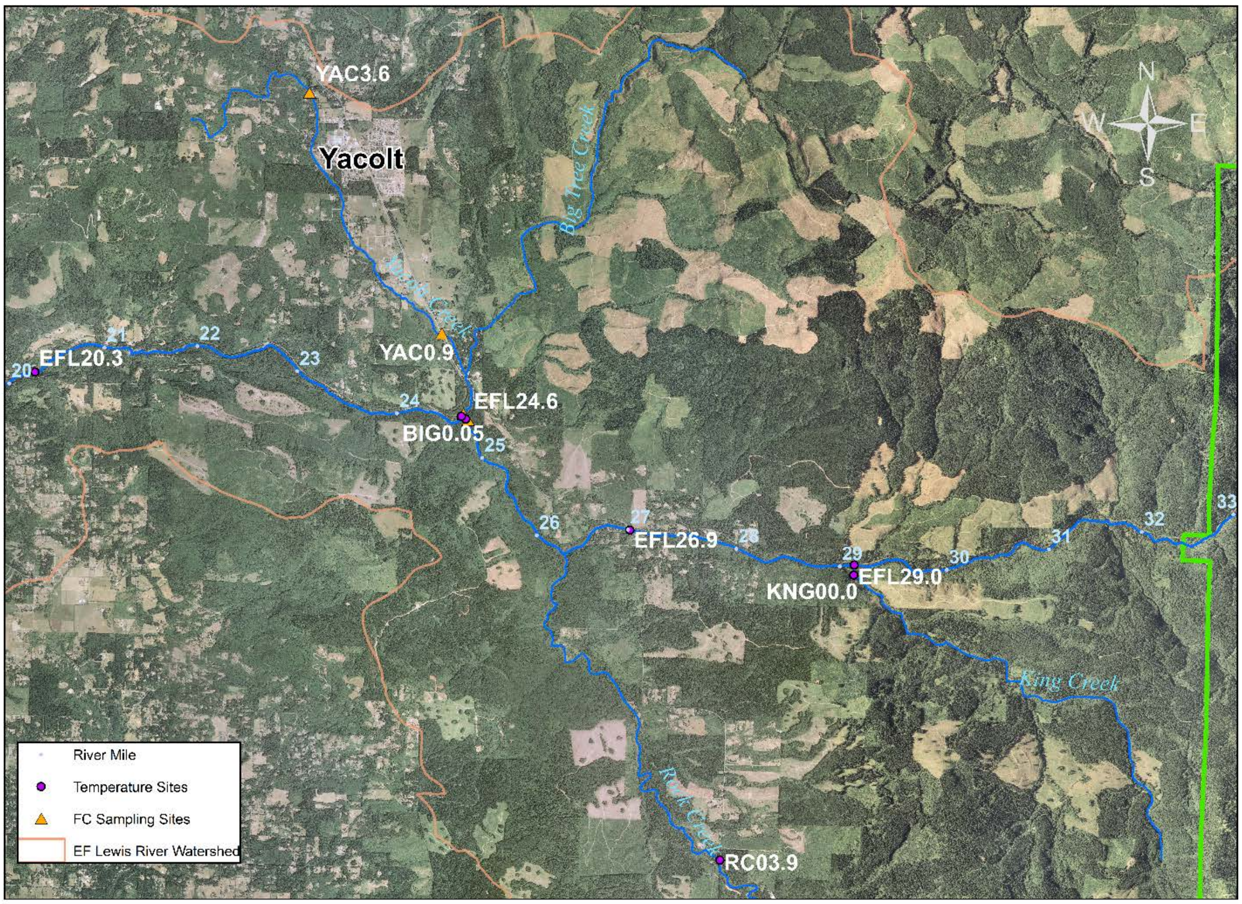


Figure 40. Map of upper EF Lewis River subbasin.

Fecal Coliform

Table 14. FC results for upper EF Lewis River subbasin, 2005-06.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
EFL-24.6	32	6	3	16	3	6	16	12	0
EFL-20.3	31	6	3	15	3	7	16	10	0

*Not more than 10% of samples to exceed water quality criteria for 90th percentile (100 cfu/100mL).

There were two FC sampling sites in the upper EF Lewis River section (EFL24.6 and EFL20.3), and these sites were only sampled in 2005-06. This is an area with designated extraordinary primary contact recreation uses for FC. Both upper EF Lewis River sites met both of the water quality criteria annually and for the wet and dry seasons. These sites did not show any significant FC exceedances.

Temperature and Riparian Cover

Table 15. Temperature results for upper EF Lewis River subbasin.

Station/ Site	Temp Criteria (°C)	Days above 7-DADMax	Total Days	1-DMax (°C)	7-DADMax (°C)	Average Temp (°C)
EFL29.0	16	12	90	18	**17**	14
EFL26.9	16	39	95	19	**18**	15
EFL24.6	16	39	83	20	**19**	15
EFL20.3	16	58	113	21	**20**	16

There were four temperature monitoring locations along this section (Table 15). The aquatic life uses are for core summer habitat and the temperature 7-DADMax criteria is 16.0°C. All of these sites exceeded the 7-DADMax temperature criteria. The site with the lowest number of temperature exceedances was the furthest upstream site, and then the number of days that exceeded the 7-DADMax criteria increased as moving downstream, as did the maximum temperature for 7-DADMax and the average temperature.

The shade analysis showed that the upper EF Lewis River mainstem from RM 20.3 to the boundary with the Gifford Pinchot National Forest (RM 32.4) had an average effective shade of 56%. The average potential shade for this reach is 82%, resulting in a 26% shade deficit. The system potential mature vegetation for this area includes conifer species. Increased riparian plantings of native species may help reduce temperature exceedance issues. Based on the hemispherical photograph analysis for effective shade, this section of the river has an average annual canopy cover of 75%, with the highest canopy cover at the site near RM 24.6.

Upper Tributaries – Rock Creek South and King, Yacolt, and Big Tree Creeks

The tributaries in the upper EF Lewis River subbasin include King Creek, Yacolt Creek, Big Tree Creek, and Rock Creek South. These creeks primarily flow through forest land, with the exception of Yacolt Creek which flows through the town of Yacolt, residential areas, and some agricultural land. Big Tree Creek flows into Yacolt Creek before emptying into the EF Lewis River mainstem. King Creek and Rock Creek South flow through DNR forest land. These creeks have the same water quality criterion for FC and temperature as the upper EF Lewis River watershed.

Fecal Coliform

Table 16. FC results for upper tributaries.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
2005-06									
YAC 3.60	31	9	3	16	7	**13**	15	13	7
YAC 0.90	32	13	2	16	14	**13**	16	12	0
RCS 3.90	31	4	0	15	2	0	16	6	0
BIG 0.05	32	15	3	16	9	**13**	16	26	6
2017									
YAC 0.90	17	25	**18**	8	26	**25**	9	24	**11**

*Not more than 10% of samples to exceed water quality criteria for 90^{th} percentile (100 cfu/100mL).

During 2005-06, all of the upper tributaries with FC sampling sites met both water quality criteria for FC during the dry season and annually. The Yacolt and Big Tree Creek sites had more than 10% of samples exceed the 90^{th} percentile criteria during the wet season. The geometric means were all relatively low (ranging from 2-26 cfu/100 mL), indicating that there are no major FC exceedances in this area of the watershed. Rock Creek South had the lowest overall geometric means and had no samples exceed the WQ criteria throughout the duration of the sampling period.

YAC 0.90 was also sampled during the 2017 sampling period. It had over 10% of samples exceed the 90^{th} percentile criterion during both the wet and dry seasons. The seasonal and non-seasonal geometric means were higher during 2017 than during 2005-06, although they all met the water quality criteria.

Temperature

Table 17. Temperature results for upper tributaries.

Station/ Site	Temp Criteria (°C)	Days above 7-DADMax	Total Days	1-DMax (°C)	7-DADMax (°C)	Average Temp (°C)
KNG00.0	16	25	112	17	**17**	14
RCS03.9	16	34	112	18	**17**	14
BIG00.0	16	36	112	18	**18**	15

Temperature monitoring sites in the upper tributaries were located at the mouth of King Creek, upstream Rock Creek South, and at the mouth of Big Tree Creek (at the confluence with Yacolt Creek). Table 17 presents an overall temperature results summary for these sites. All of the sites exceeded the 7-DADMax temperature criteria. All of the sites were monitored for a total of 112 days, and ranged from 25-36 days above 7-DADMax criteria, with Big Tree Creek having the largest percentage of days exceeded (32%).

Middle EF Lewis River

The middle EF Lewis River section is the reach from RM 20.3 to downstream of Mason Creek (RM 5.7). Moving downstream from the upper watershed, the land use changes from a forest-dominated landscape to one that is mixed-use. The main land use categories for this area include agriculture, forest, and residential and commercial developed areas. This segment of the EF Lewis River includes multiple parks along the mainstem, including Lewisville Regional Park (RM 13.0-14.8), Daybreak Park (RM 10.0-11.2), and a Clark County greenway from approximately RM 5.0-7.0. The city of Battle Ground is located south of this segment of the river. This segment also includes the avulsion of the EF Lewis River into the Ridgefield gravel pits (near RM 8.0).

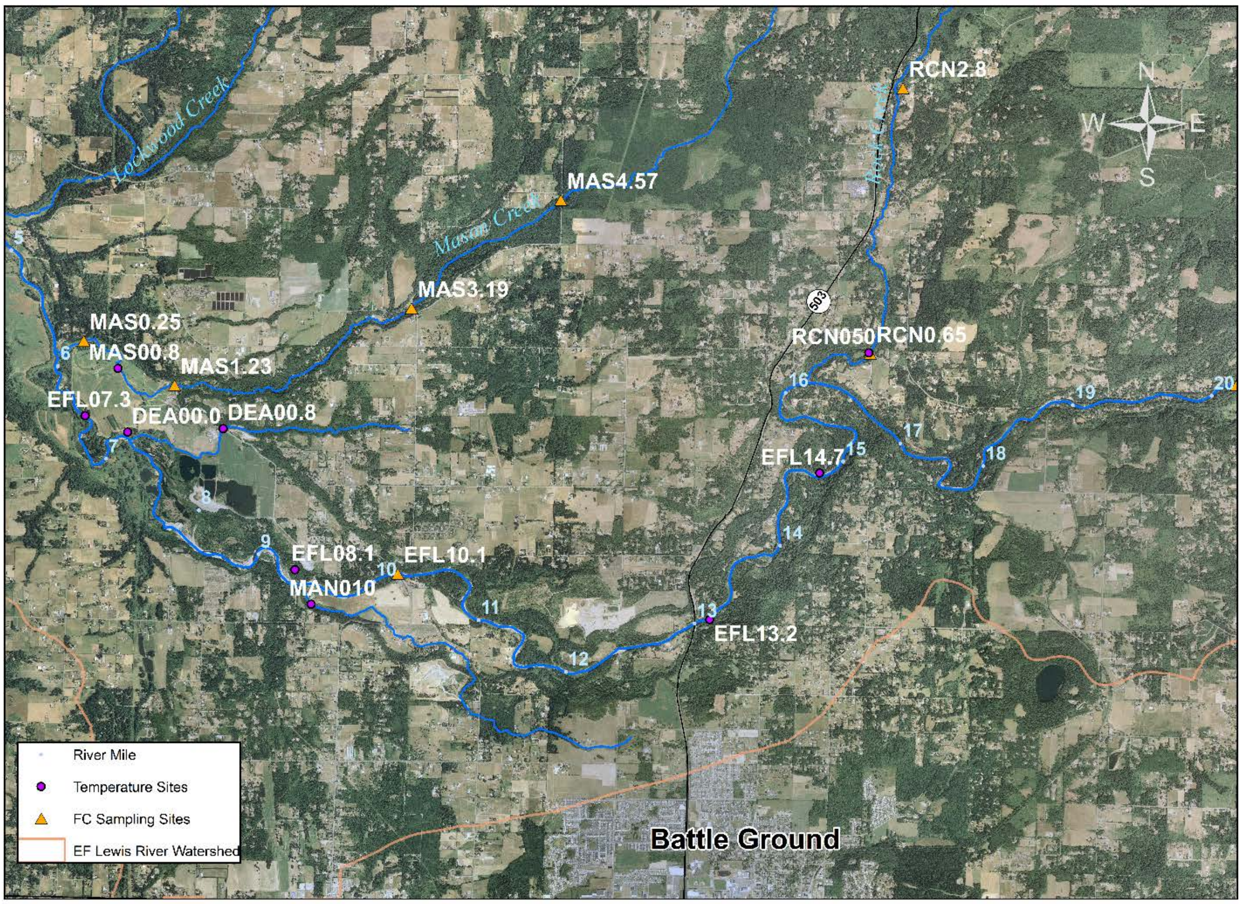


Figure 41. Map of middle EF Lewis River subbasin.

Fecal Coliform

Table 18. FC results for middle EF Lewis River.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
2005-06									
EFL-10.3	32	6	6	16	4	**13**	16	10	0

*Not more than 10% of samples to exceed water quality criteria for 90th percentile (200 cfu/100mL).

There was only one FC sampling site along the middle EF Lewis River, located at RM 10.1, and this site was sampled as part of the fixed-network sampling period during 2005-06. This site is located at Daybreak Park and is part of Ecology's long-term ambient river monitoring program (27D090). It has monthly data collections and was used to assess historical FC trends as part of the Seasonal Kendall Trend Test. The only exceedance of any water quality criteria occurred during the wet season, with two samples exceeding the 90th percentile criterion (resulting in a 13% sample exceedance). EFL10.1 met both water quality criteria during the dry season and annually and had overall low geometric means (4-10 cfu/100mL).

Temperature and Riparian Cover

Table 19. Temperature results for middle EF Lewis River.

Station/ Site	Temp Criteria (°C)	Days above 7-DADMax	Total Days	1-DMax (°C)	7-DADMax (°C)	Average Temp (°C)
EFL14.7	16	62	75	23	**23**	20
EFL13.2	16	60	90	24	**23**	19
EFL10.1	16	92	120	24	**23**	19
EFL08.1	16	33	39	25	**24**	20
EFL07.3	16	49	73	24	**23**	19

There were five temperature monitoring sites located along the Middle EF Lewis River mainstem. All of these sites exceeded the 7-DADMax water quality criteria for temperature. The maximum 7-DADMax for all sites was within 23-24°C and the average temperature was between 19 and 20°C, showing that even the average temperatures exceeded the 7-DADMax criteria and signifying temperature exceedances in this segment. Sites EFL14.7 and EFL8.1 exceeded the water quality criteria 83% and 85% of the total days sampled, respectively.

For riparian shade, this segment of the EF Lewis River had an average of 28% current effective shade. Based on the system potential shade modeling scenario, the average potential shade for this reach is 63%, resulting in a shade deficit of 35%. This was the highest average shade deficit in comparison to both the upper and lower watershed. The average canopy cover, based on the hemispherical photograph analysis, was below 50%. Despite the presence of some parks and forested land along this reach, additional riparian plantings along the greenway and other areas may help mitigate temperature exceedance issues.

Middle Tributaries – Rock Creek North and Manley, Dean, and Mason Creeks

The tributaries in the middle watershed that feed into the middle reach of the EF Lewis River watershed are Rock Creek North as well as Manley, Dean, and Mason Creeks. Similar to the river's mainstem in this part of the watershed, these tributaries flow through a variety of mixed land use areas including forest, agriculture, and residential areas.

Fecal Coliform

Table 20. FC results for middle tributaries.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
2005-06									
RCN 2.8	30	35	**17**	15	14	7	15	86	**27**
RCN 0.65	31	39	**13**	16	35	**13**	15	43	**13**
MAS 4.57	26	29	**12**	16	17	**13**	10	70	10
MAS 3.19	27	34	**15**	16	22	**13**	11	65	**18**
MAS 1.23	32	25	6	16	16	**13**	16	39	0
MAS 0.25	8	90	**13**				8	90	**13**
2017									
RCN-2.07	15	75	**40**	7	29	**14**	8	**173**	**63**
MAS-3.19	12	39	8	8	38	**13**			
MAS-1.11	17	45	**12**	8	25	**13**	9	75	**11**

*Not more than 10% of samples to exceed water quality criteria for 90th percentile (200 cfu/100mL).

FC was monitored along Rock Creek North and Mason Creek during 2005-06 and 2017, although there were fewer sampling sites on these tributaries during 2017. From the 2005-06 sampling period, FC exceedances occurred at all sites during either the dry season or wet season, with RCN0.65 and MAS3.19 having exceedances in both seasons. All sites met the FC geometric mean water quality criterion, with the highest geometric mean FC concentrations occurring during the dry season. The highest FC concentrations based on the geometric means were at MAS0.25 and RCN2.8 during the dry season.

During 2017, two of the sampling sites were slightly moved, with the Rock Creek North site located slightly downstream of the 2005-06 location, similar to the furthest downstream Mason Creek site. MAS3.19 was sampled consistently between the two periods, although it was unable to be sampled during the dry season due to low flow conditions. All of the sites were above the percent sample exceedance criterion (more than 10% of samples having over 200 cfu/100mL). RCN2.07 did not meet the geometric mean criterion during the dry season and had the highest FC concentrations overall. The 2017 FC concentrations were generally higher than during the 2005-06 sampling period.

Figure 42. Mason Creek sampling site (MAS 3.19).

Temperature

Table 21. Temperature results for middle tributaries.

Station/ Site	Temp Criteria (°C)	Days above 7-DADMax	Total Days	1-DMax (°C)	7-DADMax (°C)	Average Temp (°C)
RCN050	16	80	131	22	**21**	17
RCN00.6	16	59	91	24	**23**	18
MAN010	16	62	79	22	**22**	19
DEA00.8	16	91	114	25	**23**	19
DEA00.0	16	22	28	29	**26**	24
MAS00.8	16	47	115	19	**18**	15

Continuous temperature monitoring sites were located at Rock Creek North, Manley Creek, Dean Creek, and Mason Creek. All of the temperature sites exceeded the water quality criteria. The site at the mouth of Dean Creek (DEA00.0) had the overall highest maximum 7-DADMax value (26.0°C), however this site was influenced by the presence of a beaver dam located just upstream, and extremely high temperatures may be attributed to the influence of ponding. The further upstream Dean Creek site (DEA00.8) and Rock Creek North (RCN00.6) had the next highest maximum 7-DADMax (23°C). Both sites along Dean Creek and Manley Creek had approximately 80% of days sampled exceed the temperature water quality criteria. The average temperatures for the creeks varied, with Mason Creek having the lowest overall average (15°C) and Manley and Dean Creek having the highest average temperature (19-24°C).

Lower EF Lewis River

The lower EF Lewis River extends from the river mouth to just below Mason Creek (RM 5.7). Similar to the middle segment of the watershed, this reach flows through areas with mixed land use. This section of the watershed has more agricultural use, although forest land is still significant, and there are more patches of developed and residential areas. The EF Lewis River flows along the southern border of the town of La Center and joins the mainstem of the Lewis River less than a mile west of Interstate-5 (I-5). The EF Lewis River greenway also surrounds segments of the mainstem.

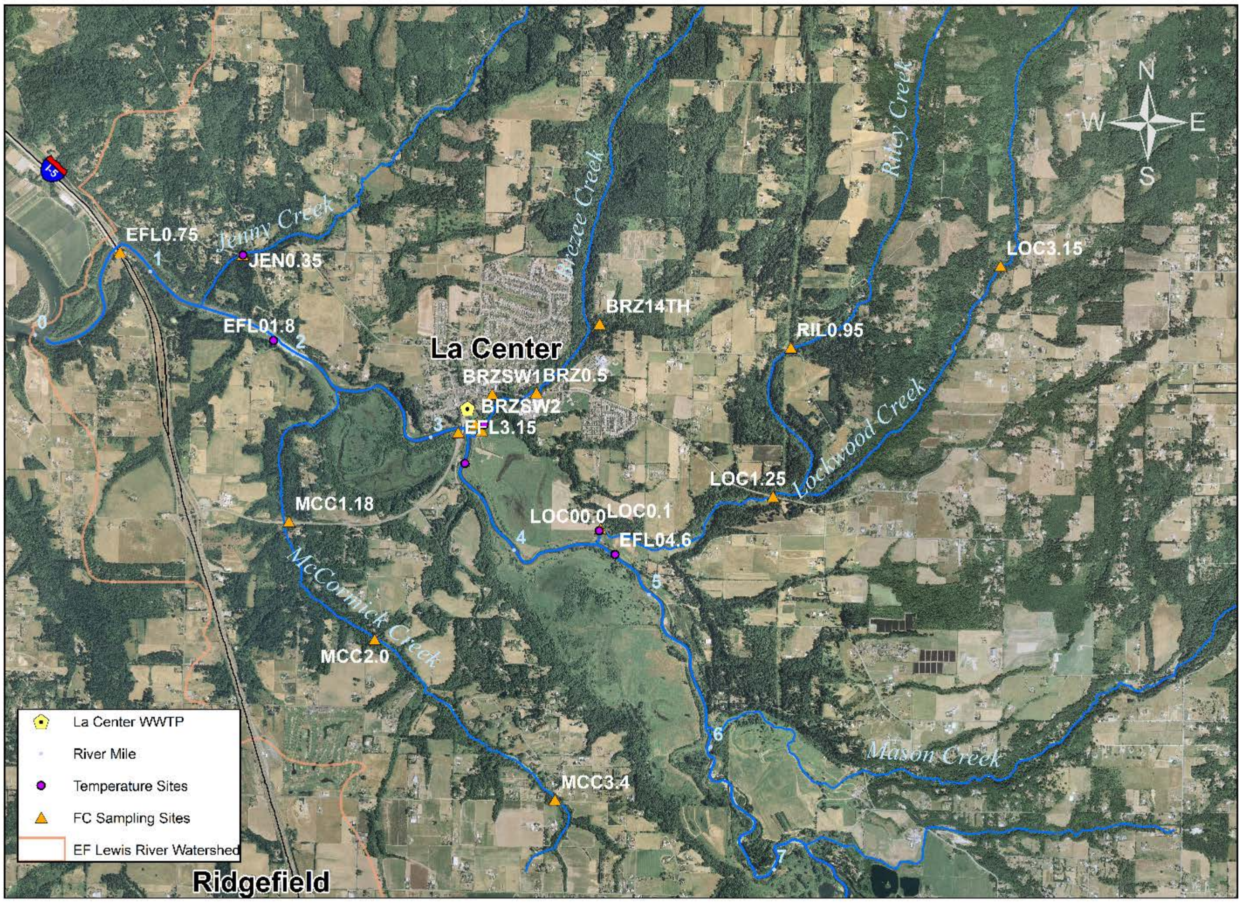


Figure 43. Map of lower EF Lewis River subbasin.

Fecal Coliform

Table 22. FC results for lower EF Lewis River.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
2005-06									
EFL-3.15	32	33	**13**	16	21	**19**	16	51	6
EFL-0.75	32	39	**13**	16	21	**13**	16	69	**13**
2017									
EFL-3.35	13	21	8				9	26	0
EFL-0.75	14	78	**36**	5	40	**20**	9	**113**	**44**

*Not more than 10% of samples to exceed water quality criteria for 90th percentile (200 cfu/100mL).

There were two mainstem FC sampling sites in this section of the watershed, and these sites were sampled in both sampling periods, although EFL3.15 was moved slightly upstream in 2017. During 2005-06, both sites exceeded water quality criteria for FC during the wet season, and EFL 0.75 also exceeded standards in the dry season. These were the only mainstem EF Lewis River sites to exceed any annual FC criteria, although they both met the water quality criteria for geometric mean during both seasons. Both sites had similar FC concentrations during the wet season, although concentrations were higher at the further downstream site (EFL 0.75) during the dry season. EFL0.75 is located at Paradise Point State Park, where the river is used for recreational activities, including swimming, particularly during the summer months (Figure 44).

Figure 44. EF Lewis River sampling site at Paradise Point State Park (EFL0.75)

Temperature and Riparian Cover

Two sites monitored temperature along the lower mainstem (EFL01.8 and EFL04.6). However, both of these sites are influenced by tidal water which increases water temperature in this segment of the river. These sites were also left exposed to air or in shallow water during periods of time where tidal water influenced water levels in this portion of the river. Due to this, the temperature data from these sites were not used for the temperature analysis.

Results from the shade analysis showed that the average current effective shade for the lower mainstem is only 8%. The average for the system potential shade analysis was 35%, which demonstrates that there is still a shade deficit that could be improved for this area. The average annual canopy cover for this reach segment, based on the hemispherical photograph analysis near RM 1.5, is 29%. Due to the expanse of the greenway along most of the mainstem in this reach, there are opportunities for increased riparian vegetation plantings and cover to help with temperature exceedances.

Lower Tributaries – Lockwood, Riley, Brezee, McCormick, and Jenny Creeks

The lower tributaries that feed into the EF Lewis River mainstem below Mason Creek through the mouth include Lockwood, Riley, Brezee, McCormick, and Jenny Creeks. These tributaries flow mainly through forest land and agricultural areas, along with some residential and other developed areas. Before flowing into the mainstem, most of these tributaries flow through a section of park or the EF Lewis River Greenway. Brezee Creek flows along the town of La Center before its confluence with the EF Lewis River.

Fecal Coliform

Table 23. FC results for lower tributaries.

Station/ Site	Annual			Wet Season			Dry Season		
	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*	n	Geo Mean	%Exc*
2005-06									
LOC 3.15	32	99	**31**	16	36	6	16	**271**	**56**
LOC 1.25	32	44	**16**	16	24	**13**	16	80	**19**
LOC 0.1	25	46	8	12	25	0	13	80	**15**
RIL 0.95	32	46	**19**	16	26	**13**	16	79	**25**
BRZ 14TH	30	**166**	**12**	15	95	**33**	15	**288**	**47**
BRZ 0.5	32	**190**	**19**	16	84	**38**	16	**430**	**81**
BRZ 0.07	32	**196**	**19**	16	93	**38**	16	**411**	**81**
BRZ SW1	31	24	**7**	16	55	**31**	15	10	**13**
BRZ SW2	31	**203**	**14**	16	**194**	**38**	15	**214**	**53**
MCC 3.4	32	**333**	**72**	16	**240**	**26**	16	**462**	**88**
MCC 2.0	32	**177**	**47**	16	**164**	**44**	16	**191**	**50**
MCC 1.18	32	**194**	**59**	16	**123**	**38**	16	**307**	**81**
JEN 0.35	32	73	**16**	16	53	**19**	16	101	**13**
STP 0.0G	27	14	7	12	17	8	15	12	7
2017									
LOC-3.55	16	36	**31**	7	8	**14**	9	**120**	**44**
RIL-0.95	17	35	**29**	8	9	**13**	9	**118**	**44**
BRZ-14th	17	**129**	**65**	8	29	**25**	9	**482**	**100**
BRZ-0.07	17	**126**	**65**	8	58	**38**	9	**254**	**89**
BRZ-SW1	9	44	**33**	8	28	**25**			
BRZ-SW2	16	**378**	**81**	8	**238**	**63**	8	**599**	**100**
JEN-1.03	16	**105**	**50**	7	66	**29**	9	**151**	**67**
MCC-1.18	17	**142**	**59**	8	**115**	**50**	9	**172**	**67**
MCC-3.4	15	**547**	**100**	6	**663**	**100**	9	**481**	**100**
MCC-TRIB 2	6	**591**	**67**						

*Not more than 10% of samples to exceed water quality criteria for 90th percentile (200 cfu/100mL).

The lower tributaries had the greatest number of sites during both data collection periods. Sites that were sampled consistently during both of these data collection periods include the Riley Creek site, all Brezee Creek sites, and two of the McCormick Creek sites (MCC3.4, MCC1.18). During 2017 sampling, the Lockwood and Jenny Creek sites were moved slightly upstream, and MCC-TRIB2 was added as an investigative site to help identify FC sources.

This group of sampling sites had the highest FC exceedances out of all the areas during 2005-06. All sites except for one (La Center Sewage Treatment Plant, STP0.0G) exceed at least one water quality criteria during the dry season. During the wet season, all sites except for LOC3.15, LOC0.1, and STP0.0G exceeded at least one criteria as well. FC concentrations were generally higher during the dry season than during the wet season, with only BRZSW1 having a higher wet season geometric mean than during the dry season. The highest FC concentrations occurred along McCormick and Brezee Creeks, with MCC3.4 having the highest geometric mean overall.

During 2017, similar results showed that the lower tributaries continued to have the highest FC water quality exceedances, with all sites exceeding both criteria during the wet season and exceeding at least one criteria during the dry season. Similar to 2005-06, MCC3.4 had the highest geometric mean concentrations overall, followed by sites along Brezee Creek. All sites had higher FC concentrations during the dry season, with the exception of MCC3.4.

These results help to confirm that there is a FC source upstream of MCC3.4. The water sampled at MCC3.4 was typically slow moving, and flow was further inhibited by aquatic vegetation growth during the dry season (Figure 45). MCCTRIB2 was added as an investigative site to help identify FC sources, and although it was unable to be evaluated seasonally due to the low number of samples collected, it had very high FC concentrations and out of the six samples taken, four were above the 90th percentile criterion (200 cfu/100mL). McCormick Creek is located in a mainly agricultural area with some residential properties.

Figure 45. McCormick Creek (MCC3.4) photos during the dry season (left) and wet season (right).

The consistently high FC levels along Brezee Creek, including from one of the stormwater outfalls (BRZSW2) during both sampling periods, confirms a source of FC in this area. Brezee Creek runs through the town of La Center and then through a waterfront park (including BRZ0.07) before discharging into the EF Lewis River. The drainage area that flows through the second outfall (BRZSW2) should be further investigated to better identify the FC sources.

Figure 46. Brezee Creek stormwater outfall (BRZSW2) field photo.

Based on the 2005-06 loading analysis, McCormick, Brezee, and Lockwood Creeks had high FC loads that were generally higher during the wet season than during the dry season. An exception to this was LOC3.15, which had noticeably higher dry season loads. These results show that there may be a source of FC present during the dry season, and should be further investigated. Upper Lockwood Creek has a mixed land-use of forest, agriculture, and undeveloped areas.

Temperature

Table 24. Temperature results for lower tributaries.

Station/ Site	Temp Criteria (°C)	Days above 7-DADMax	Total Days	1-DMax (°C)	7-DADMax (°C)	Average Temp (°C)
LOC00.0	16	32	65	24	**22**	18
BRZ010	16	45	131	20	**20**	16
BRZ00.1	16	53	113	20	**20**	17
JEN00.3	16	50	112	21	**20**	16

Temperature sampling sites were placed on Lockwood, Brezee, and Jenny Creeks. All of these sites exceeded the 7-DADMax water quality criteria for temperature. The average temperatures for these streams were between 16 and 18°C. The maximum 7-DADMax occurred at Lockwood Creek (22°C). Since the 2005-06 temperature monitoring, a restoration project was implemented along Lockwood Creek that included riparian plantings and restoring riparian areas. This restoration work will help with shade cover and temperature for the creek, particularly as it enters EF Lewis River.

Conclusions

Fecal Coliform Bacteria

- A seasonal trend analysis showed that FC concentrations have increased from 2005-2016 based on long-term ambient monitoring data from the East Fork (EF) Lewis River at RM 10.1 (site 27D090).
- The 2005-06 data showed that the highest FC concentrations and water quality criteria exceedances occurred during the dry season. The sites with the highest FC levels were along McCormick Creek and Brezee Creek, including a stormwater outfall on Brezee Creek (site BRZSW2).
- FC loads were generally higher during the wet season than during the dry season, particularly at McCormick, Brezee, and Lockwood Creeks. One site on Lockwood Creek had a noticeably higher dry season FC load, which signifies a source of FC during the dry season that should be further investigated.
- The 2017 supplemental study confirmed areas with high FC levels. Similar to the 2005-06 results, the highest FC water quality exceedances occurred along McCormick and Brezee Creeks. An investigative site was added to an upstream tributary leading to McCormick Creek (MCCTRIB2) in an agricultural area that also had high FC concentrations.
- The EF Lewis River mainstem sites generally did not exceed (met) FC water quality criteria, with the exception of some sites in the lower watershed. These patterns were consistent between the 2005-06 and 2017 data collection.

Temperature

- Long-term temperature monitoring at Ecology's ambient site (27D090 at RM 10.1) on the EF Lewis River has displayed similar temperature conditions since the 2005-06 sampling.
- Temperature monitoring data from 2005-06 were summarized and showed that all temperature monitoring sites exceeded the 7-DADMax temperature water quality criterion at some point during the sampling period.
- The upper EF Lewis River and tributaries had the lowest overall temperatures, and temperatures tended to increase moving from the upper to lower watershed. The monitoring sites in the lower EF Lewis River (EFL01.8 and EFL04.6) were influenced by tidal water that increased temperatures.
- A shade analysis compared the current effective shade (2005) with system potential effective shade by calculating a shade deficit along the EF Lewis River mainstem. The segments of the river with the highest shade deficits were located between RM 9 and 13. The temperature monitoring sites near this area (EFL10.1 and EFL08.1) had some of the highest temperature exceedances overall.
- The results of the shade analysis can help guide restoration efforts and activities to improve temperature conditions in the watershed. These activities are recommended for the middle watershed along waterfront parks and greenways.

Recommendations

Reduce Fecal Coliform Bacteria and Improve Water Quality

The results of the statistical rollback analysis include target FC concentrations and recommended reductions to meet these targets. Results from the statistical rollback analysis are presented as FC reductions, or the percentage necessary for FC concentrations to be “rolled back” in order to meet water quality criteria. These FC reductions were calculated for sites that exceeded (did not meet) either the geometric mean or 10% exceedance water quality criteria. In Table 25, FC reduction values are highlighted by order of magnitude. FC load reduction targets are set for geographic areas upstream of each study site.

Table 25. Recommendations for seasonal (wet and dry) and non-seasonal (annual) FC reductions.

	Wet Season					
Site	Sample Size	FC (cfu/100mL)		FC Reduction	FC Target (cfu/100mL)	
		GeoMean	90th %tile		GeoMean	90th%ile
YAC 0.90	16	14	**105**	5%	14	14
RCN 0.65	16	35	**467**	57%	22	200
MAS 1.23	16	16	**238**	16%	14	200
BRZ SW1	16	55	**1923**	90%	17	200
BRZ SW2	16	**194**	**2144**	91%	38	200
MCC 3.4	16	**240**	**4543**	96%	31	200
MCC 2.0	16	**164**	**1047**	81%	49	200
EFL-3.15	16	21	**252**	21%	19	200
	Dry Season					
Site	Sample Size	FC (cfu/100mL)		FC Reduction	FC Target (cfu/100mL)	
		GeoMean	90th %tile		GeoMean	90th%ile
RCN 2.8	15	86	**359**	44%	55	200
MAS 0.25	8	90	**496**	60%	47	200
LOC 3.15	16	**271**	**1194**	83%	66	200
LOC 0.1	13	80	**268**	25%	64	200
RIL 0.95	16	79	**411**	51%	47	200
BRZ 14TH	15	**288**	**1386**	86%	63	200
BRZ 0.5	16	**430**	**1508**	87%	81	200
BRZ 0.07	16	**411**	**1394**	86%	82	200
MCC 1.18	16	**307**	**1403**	86%	66	200
JEN 0.35	16	**101**	**413**	52%	58	200
	Non-Seasonal (Annual)					
Site	Sample Size	FC (cfu/100mL)		FC Reduction	FC Target (cfu/100mL)	
		GeoMean	90th %tile		GeoMean	90th%ile
MAS 4.57	26	29	**315**	36%	22	200
MAS 3.19	27	34	**325**	38%	25	200
LOC 1.25	32	44	**306**	35%	33	200
EFL-0.75	32	39	**240**	17%	34	200

During the wet season, site MCC3.4 has the highest exceedances for both criteria and has the highest overall recommended FC reduction (96%). The next site downstream on McCormick Creek (MCC2.0) also had high geometric mean and 90th percentile FC concentrations, with a recommended 81% reduction to meet target FC concentrations. However, improving FC levels at MCC3.4 may help to reduce FC exceedances in McCormick Creek downstream. Other sites with high geometric mean and 90th percentile concentrations for FC during the wet season include both Brezee Creek stormwater sites (BRZ SW1, BRZ SW2). The Department of Ecology (Ecology) recommends a 90% to 91% FC reduction at these sites, respectively. Ecology recommends further investigation of the sources that drain into these outfalls in order to better understand sources of FC.

During the dry season (June-October), the highest FC water quality exceedances occurred along the Brezee Creek sites (BRZ14TH, BRZ0.5, BRZ0.07) and McCormick Creek (MCC 1.18). Ecology recommends FC reductions of 86-87% at these sites, although targeting FC exceedances upstream may also help with the overall water quality of Brezee Creek.

At MAS0.25, fewer than the recommended number of samples were taken (< 10 samples). With fewer samples, there is less confidence in FC target results. However, MAS0.25 was included to provide a general target for planning implementation measures and for understanding FC concentrations along Mason Creek.

For the EF Lewis River mainstem sites, the highest FC water quality exceedances occurred during the wet season at EFL3.15. Ecology recommends a 21% FC reduction at this site. EFL0.75 has a non-seasonal recommended FC reduction of 17%.

The spatial distribution of the FC reductions is shown in Figure 47, where the smallest recommended reductions are in the upper watershed (Yacolt Creek) and the largest recommended reductions are in the lower watersheds. The middle tributaries (Mason Creek and Rock Creek North) have moderate FC reductions and do not show a strong seasonal difference.

Generally, McCormick Creek sites and Brezee Creek stormwater sites have the highest recommended FC reductions during the wet season, and Brezee Creek and Lockwood Creek sites have the highest recommended FC reductions during the dry seasons. These sites are all found in the lower watershed. The results of the FC rollback analysis can be used to help guide seasonal and general restoration work in the EF Lewis River watershed. By focusing on restoration activities on reducing FC inputs upstream, water quality conditions downstream should improve.

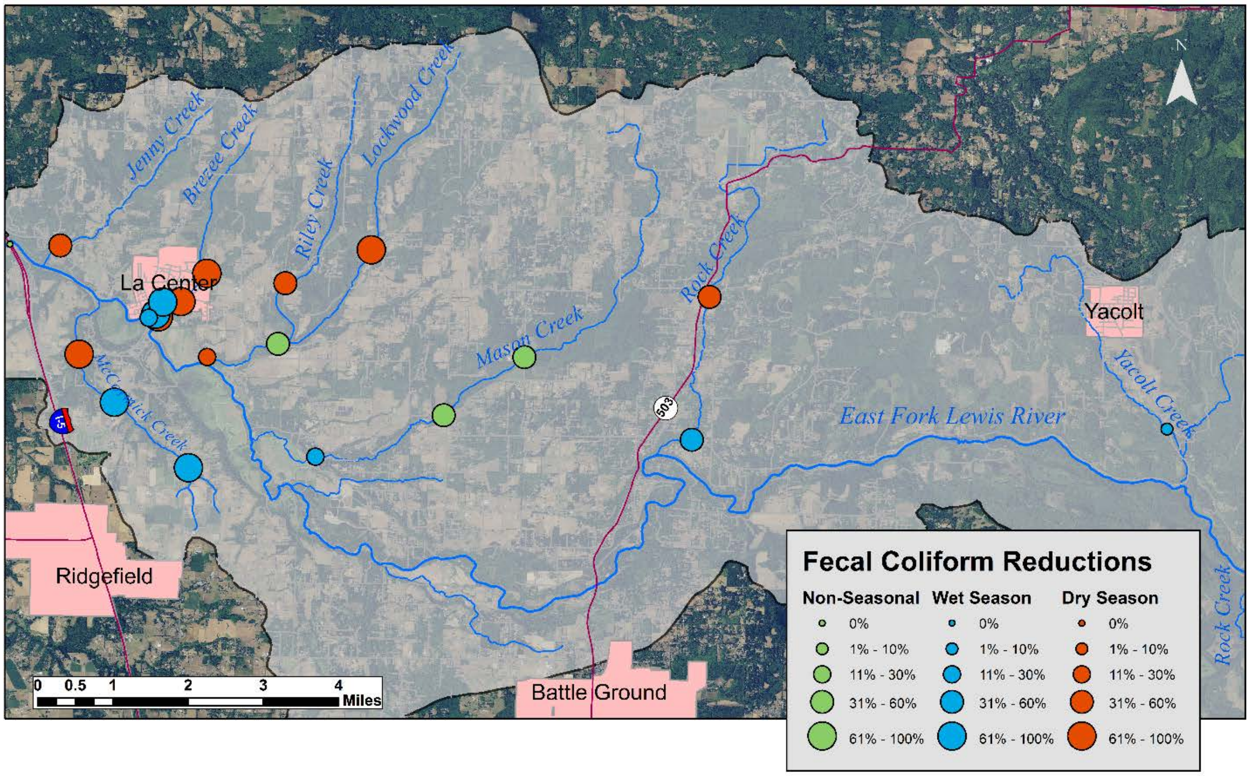


Figure 47. Map of recommendations for FC reductions for wet season (November-May), dry season (June-October), and non-seasonal (annual).

Based on the 2005-06 and 2017 data, general recommendations from Ecology to decrease FC concentrations and improve water quality in the EF Lewis River include the following:

- Implement best management practices (BMPs) to reduce FC loading from agricultural land into waters. This is needed for sites that showed high FC concentrations that were located in agricultural areas including at Rock Creek North, Mason Creek and McCormick Creek.
- Continue management of stormwater through appropriate BMPs to reduce water quality impacts at Brezee Creek stormwater outfalls, particularly during the wet season.
- Continue education and outreach work in the watershed community about the effects of nonpoint pollution to water quality and human health. This includes nonpoint pollution from pet waste and recreational activities at parks and greenways on the waterfront of the EF Lewis River and its tributaries.
- Conduct investigative stream walks along tributaries to identify and sample unknown or unmapped outfalls (e.g., pipes and culverts), including stormwater outfalls. Investigative stream walks should be conducted at sites along McCormick Creek and Brezee Creek with high FC levels in both the wet and dry seasons. Upstream Lockwood Creek should also be further investigated based on high dry season FC loads.

- Fix failing Onsite Septic Systems (OSS). Continue to maintain inventory and records of OSS, educate homeowners on operation and maintenance inspections, and enforce OSS owner permit requirements by Clark County (CCC 24-17-060).

Restore Riparian and Stream Habitat

In order to address high temperatures in the EF Lewis River watershed, Ecology recommends the following:

- Restore and protect wetlands in areas that will benefit the stream and enhance habitat.
- Continue to increase native vegetation plantings on stream banks to increase riparian shade. Focus these restoration activities in areas with large shade deficits in the middle watershed, as determined through the shade analysis.
- Continue river and stream restoration projects that enhance channel complexity.
- Protect and restore natural flood plains, riparian habitats, and microclimate enhancements that increase the number of cold water refuges available and improve the overall habitat quality for salmonids and other fish species.
- Continue restoration and conservation projects and activities led by Clark County, LCFRB, and other local stakeholders and groups to improve salmon recovery efforts and overall water quality in the watershed. Restoration activities include planting native trees and vegetation, installing livestock exclusionary fencing, and training landowners on property improvements and maintenance.

These recommendations are in addition to those stated in the *Groundwater and Surface Water Exchange Report* (Carey and Bilhimer, 2009). Ecology recommends that decision makers use information about the effects of current and future withdrawals (groundwater and surface water) on the EF Lewis River when making water rights decisions in the basin.

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Appendices

Appendix A. Data Quality

This appendix contains information regarding the data quality for fecal coliform bacteria (FC) results collected during 2005-06 and the supplemental 2017 sampling. It also contains an overview of the data quality for temperature results.

The *Surface Water and Groundwater Exchange Report* provides more data quality information for the continuous temperature measurements and equipment accuracy (Carey and Bilhimer, 2009).

The *Streamflow Summary Report* for the East Fork (EF) Lewis River contains more detailed QA information for the streamflow measurements (Springer, 2009). It provides information for both the instream discharge measurements and stage height records produced by the dataloggers.

Fecal Coliform Bacteria

All FC samples were analyzed in the Manchester Environmental Laboratory (MEL) for both the 2005-06 and 2017 sampling. All sampling procedures and protocols for FC complied with the procedures from the QAPPs (Bilhimer et al., 2005; Raunig and McCarthy, 2017).

Following the 2005-06 field collection, the FC results were reviewed and finalized before being uploaded into Ecology's EIM. The data were validated in reference to the measurement quality objectives outlined in the QAPP (2005). Any data qualifiers for the results were also included.

Ecology staff started the analysis for the FC results following the 2005-06 sampling. This work used the 2005-06 FC results to complete an analysis for water quality exceedances in the EF Lewis River watershed. All FC data used for this report and analyses were the values reported in EIM that were reviewed and finalized based on quality assurance procedures.

Additionally, field and technical notes, correspondence with Ecology staff, and other related documents were used as supplemental information to help understand data gaps, missing information, and the current status of this project. Data without supporting quality assurance information were omitted from this analysis.

For the 2017 FC sampling, all FC samples were analyzed except for 1 sample due to the container leaking during transportation. Luckily, there was a replicate sample for this site, so the replicate was analyzed for FC instead (BRZSW2 on 2/21/17). The FC sampling sites that were included in the annual statistics had a minimum of 5 distinct samples collected. Due to the short duration for field collection and the large number of sites that dried during the summer, seasonal statistics were not computed for the 2017 results. However, these supplemental FC sampling results still met the overall project objective of confirming areas with FC exceedances similar to the 2005-06 results.

Precision for Field Replicates

Total precision for field sampling and laboratory analysis was assessed by collecting replicate samples, which are two samples taken from the environment at the same time and place using the same protocols. Precision for field replicates is expressed as percent relative standard deviation (%RSD). The RSD, also known as the coefficient of variation (CV), is computed as the standard deviation of two values divided by their average. The value is then converted to percent (by multiplying by 100) and referred to as the percent (%) RSD.

The 2005 QAPP did not set specific measurement quality objectives (MQOs) for FC results and instead suggested that the precision target should not exceed 50%RSD (CV). The 2005-06 results were assessed based on newly recommended MQOs for FC that were specified in the 2017 QAPP, where at least 50% of replicate pairs are less than 20% RSD and at least 90% of replicate pairs are less than 50% RSD. These precision targets were also used for the 2017 FC results. Results for the field replicates precision are in Table B-1. Based on these results, both field sampling results met the MQOs for precision.

Table B-1. FC data quality results.

Field Sampling Period	MQO Criteria	% Samples Meeting MQO	Meets MQO Criteria?
2005-06	50% of replicate pairs <20%RSD	63%	YES
	90% of replicate pairs <50%RSD	97%	YES
2017	50% of replicate pairs <20%RSD	72%	YES
	90% of replicate pairs <50%RSD	98%	YES

Precision for Laboratory Duplicates

Precision for laboratory analysis is measured through analyzing duplicate samples. Duplicate laboratory analysis refers to analyzing duplicate aliquots in the lab taken from a single sample container. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. The results for laboratory duplicates provide an estimate of lab analytical precision, including the homogeneity of the sample matrix (MEL, 2008). The measurement quality objective (MQO) is 40% average relative percent difference (RPD).

Overall, the laboratory duplicate results with FC concentrations greater than 20 cfu/100mL for the 2005-06 sampling met the MQO and were within 40% RPD. Any of the samples that did not meet the MQO for lab duplicates were qualified as estimates.

For the 2017 results, the average RPD was 16%, meeting the MQO (40% RPD). For samples greater than 20 cfu/100mL, the average RPD was 17%. Only one sample exceeded the MQO for laboratory duplicates.

Temperature

Onset StowAway Tidbits were used for continuous temperature measurements throughout the study. Three instruments mentioned in the 2005 QAPP (Bilhimer et al., 2005) were either stolen or lost and no data was collected (sites at Copper Creek, mouth of McCormick Creek, and EF Lewis River at RM03.4).

Most of Ecology's continuous temperature loggers were installed between 6/7/05-7/13/05 and were removed by 10/12/05, with a few instruments kept in place through the fall and winter. The Clark County temperature monitoring locations (BRZ010, MAN010, and RCN050) recorded measurements from 6/2/05-10/5/05.

Selected sites had both instream and air temperate loggers. To check for data ranges, continuous temperature monitoring data were validated as real water temperatures by comparison with the paired air temperature logger at (or near) each site. Pre- and post-study accuracy checks were completed to identify any instruments that were not measuring within their manufacturer-specified accuracy range.

The QA/QC analysis showed problems during the comparison with the instream temperature measurements and air temperature measurements. The following issues were reported when collecting temperature data throughout the study period:

- EFL1.8: Temperature logger was cut for a period of time during the summer. Following this, a comparison of air and instream water temperatures showed that site was affected by tidal influence on water levels and data were not used for the technical analysis.
- EFL4.6: The temperature record showed a wide daily temperature range similar to the air record during time periods with wide swings. This site was compared with the stage record from EFL1.8 to check for tidal influence, and data were not used for the technical analysis.
- DEA00.0: This site was heavily affected by a beaver dam approximately 50 feet upstream that dried up the creek channel, inhibiting streamflow, where the instream temperature logger was located. The instream data QC showed that the instrument began closely tracking the air temperature during the day of 7/18/05; this resulted from the instrument being out of the water. The data were cut to end on 7/17/05. The data recorded before 7/18/05 may have been influenced by ponding and dropping stream stage.

There are some breaks in instream temperature monitoring due to external influences where data were unable to be recovered due to instrument loss, failure, or theft. Data were cut from these sites:

- EFL29.0 data were cut from 7/18/05-8/10/05 due to the instrument being pulled out and left on a stream bank. Additionally, after redeployment, there was a problem with the optic shuttle rendering the data unusable.
- EFL14.7 data were cut from 9/25/05-10/12/05 due to the instrument being pulled out of the water and later found on a streambank.
- EFL10.1 data were cut from 9/27/05-10/1/05 due to the instrument being left out of the water.

- EFL08.1 data were cut from 7/31/05-8/8/05 due to the instrument being pulled out of the river and left on the streambank. The newly deployed temperature logger was unable to be recovered and data after August was lost.
- EFL07.3 data were cut from 8/8/05-8/22/05 due to a problems with the optic shutter.
- LOC00.0 instrument was stolen in either July or early August and was not recovered. A new temperature logger was deployed in August and started recording after 8/8/05.

The *Surface Water and Groundwater Exchange Report* contains more QA information for the temperature results, including the instrument calibration results (Carey and Bilhimer, 2009).

Appendix B. Fecal Coliform Data (2005-06)

Table B-1. FC data 2005-06.

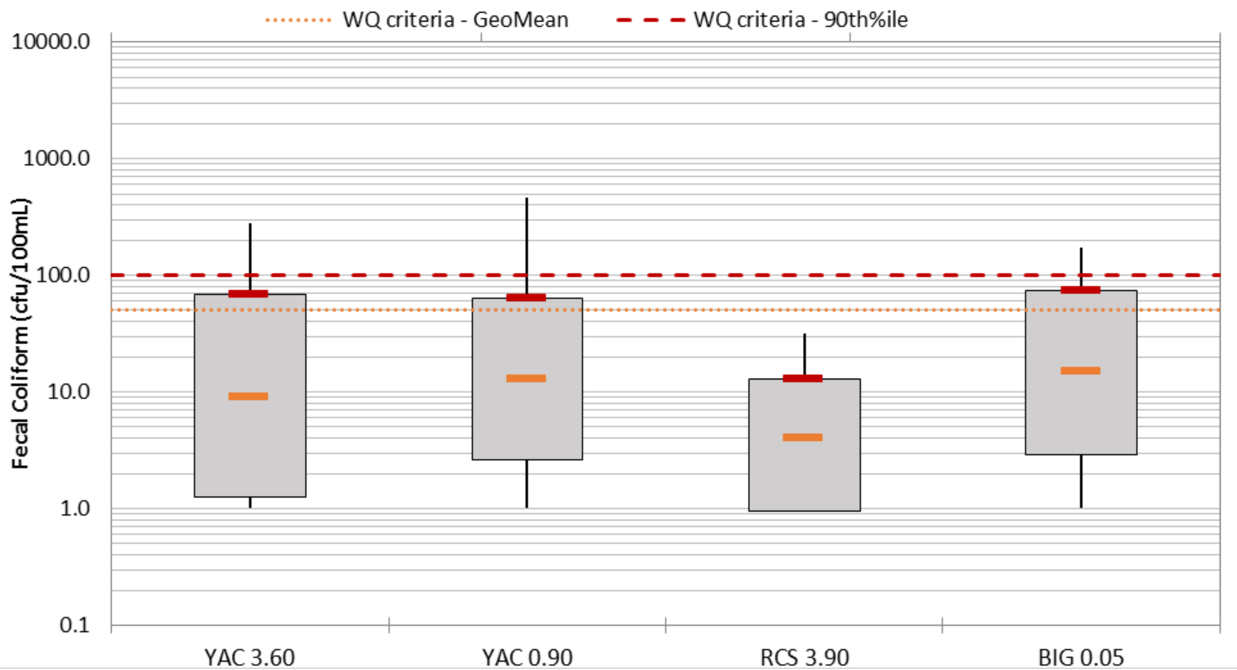
Bold *values indicate geometric mean water quality criteria exceedance.*

	YAC 3.60	YAC 0.90	RCS 3.9	BIG 0.05	RCN 2.8	RCN 0.65	MAS 4.57	MAS 3.19	MAS 1.23	MAS 0.25	EFL 24.6	EFL 20.3	EFL 10.1
5/24/05	7	44	7	7	18	29	21	26	24		2	2	2
6/7/05	45	84	3	36	54	71	41	26	76		12	15	7
6/21/05	3	8	1	12	61	61	22	48	84		14	6	9
7/5/05	7	12	5		46	47	36	30	33	10	4	3	7
7/6/05				15									
7/19/05	21	19	6	**140**	32	98	160	69	60	110	12	13	15
8/2/05	31	24	5	54	56	11	89	20	28	150	13	13	24
8/16/05	10	10	11	45	**265**	**600**			12	180	26	20	9
9/6/05	10	10	5	74	118	5			76	**600**	8	10	5
9/26/05	5	12	2	13	**260**	1			36	71	3	5	7
10/4/05	**170**	11	12	23	71	160	200	**215**	17	190	26	25	26
10/24/05	4	2	2	5	5	26	120	19	21	18	7	5	4
11/1/05	**280**	**210**	32	**175**	**1400**	**2300**	**1900**	**1400**	**1300**		**880**	**355**	**283**
11/20/05	26	8	5	4	7	8	9	13	17		2	4	3
12/5/05	8	5	4	7	9	14	17	12	12		2	2	2
12/18/05	4	15	1	7	10	23	4	9	2		1	3	4
1/9/06	28	33	4	17	19	23	17	24	25		5	3	12
1/23/06	8	12	1	5	5	9	11	11	9		2	6	1
2/13/06	1	10	1	4	11	15	3	22	5		1	1	2
2/27/06	1	18	1	8	20	65	21	48	14		3	5	3
3/13/06	1	2	1	2	2	4	1	3	1		1	1	1
3/27/06	1	4	2	1	2	3	2	1	1		1	1	1
4/10/06	2	1	1	8	7	130	8	10	12		1	5	8
4/24/06	3	16	1	15	18	10	3	2	5		1	1	1
5/15/06	7	14	2	8	17	42	110	46	12		1	1	1
5/30/06	6	13	2	17	50	100	38	59	52		7	6	3
6/12/06	20	33	21	68	79	**300**	34	**1400**	18		47	23	11
6/26/06	15	6	7	15	**265**	130	36	96	41		4	9	26
7/10/06	23	8	15	9	87	39	200	46	88		16	6	4
7/24/06	28	22	8	31	140	60		67	160		16	13	98
8/7/06	1	6	5	18	**530**	11			37		41	9	9
8/28/06		9	11	34					22		10	15	4
11/6/06							**1100**	**1200**	**2000**				
11/8/06	**280**	**460**		**140**		**3400**					43		**440**

	LOC 3.15	LOC 1.25	LOC 0.1	RIL 0.95	BRZ 14TH	BRZ 0.5	BRZ 0.07	BRZ SW1	BRZ SW2
5/25/05	47	28		22		140	**460**	140	88
6/8/05	100	31		17		**300**	**290**	6	120
6/22/05	**900**	**340**		**180**	**270**	**1300**	**2100**	**250**	**650**
7/6/05	**280**	65		43	180	**260**	**310**	60	180
7/20/05	120	190	145	35	180	160	**630**	4	**550**
8/3/05	**300**	110	69	94	140	**480**	**415**	1	15
8/17/05	**1700**	200	**210**	**1600**	**2200**	**2100**	**1300**	**310**	
9/7/05	**670**	**210**	40	85	170	**1100**	**970**	6	**250**
9/27/05	46	19	29	19	**1300**	**410**	**390**	2	**1500**
10/5/05	200	31	36	27	71	81	85	32	**210**
10/25/05	51	17	13	12	40	100	64	8	100
11/1/05					**900**	**760**	**880**	**2000**	**1400**
11/2/05	120	**220**	100	**490**					
11/21/05	20	13	10	3	14	20	16	1	100
12/6/05	5	7	11	12	14	10	15	130	40
12/19/05	66	24	14	42	87	**205**	100	**280**	**250**
1/10/06	61	55		62	48	40	48	**500**	190
1/24/06	5	5		6	22	18	11	6	**220**
2/14/06	9	10	8	21	63	26	29	12	69
2/28/06	52	77	190	55	**690**	**320**	**370**	**620**	**1300**
3/14/06	27	7	18	10	140	48	31	54	77
3/28/06	8	3	5	21	26	40	31	34	26
4/11/06	59	9	22	3	29	36	42	17	24
4/25/06	8	5	42	3	110	72	84	1	**220**
5/16/06	97	41	66	120	**350**	**240**	**370**	1	110
5/31/06	48	45	43	49	**220**	200	**350**	84	150
6/13/06	**1650**	51	130	40	160	**260**	180	6	140
6/27/06	85	180	**250**	**320**	**2500**	**230**	**255**	2	130
7/11/06	**880**	40	100	96	**700**	**425**	**315**	3	96
7/25/06	180	130	**290**	96	**350**	**2000**	**1400**	25	**270**
8/8/06	168	120	120	**210**	92	**700**	**500**	2	**350**
8/28/06	**480**	88	45	**260**					
8/29/06					**520**	**655**	**500**		**580**
11/6/06	**3300**	**3300**		**670**	**770**	**1050**	**1400**	**13000**	**50000**

	MCC 3.4	**MCC 2.0**	**MCC 1.18**	**JEN 0.35**	**STP 0.0-G**	**EFL 3.15**	**EFL 0.75**
5/25/05	**500**	135	120	22	**2604**	30	17
6/8/05	**560**	92	155	18	18	19	17
6/22/05	**2500**	**380**	**490**	180		78	47
7/5/05					15		
7/6/05	**560**	**630**	**290**	92	4	69	32
7/19/05			**910**				
7/20/05	**1000**	**335**		140	40	45	41
8/3/05	**300**	**210**	**370**	170		**240**	34
8/17/05	**260**	**220**	**240**	190	120	77	**363**
9/7/05	**2100**	120	210	9	155	55	50
9/27/05	**2000**	101	620	95	36	48	**470**
10/5/05	**430**	83	62	36	1	60	64
10/25/05	**4100**	14	10	49	34	19	120
11/2/05	**12000**	**3500**	**3000**	**305**	3	**430**	**295**
11/21/05	37	23	17	16	**210**	1	7
12/6/05	55	65	58	14		**390**	45
12/19/05	**430**	**320**	**310**	180	140	6	15
1/10/06	**1100**	**420**	**330**	103	97	54	160
1/24/06	11	20	20	6	3	3	5
2/14/06	13	**350**	63	20	4	3	3
2/28/06	**3400**	**370**	**390**	**230**		58	55
3/14/06	15	50	84	59	4	7	14
3/28/06	40	170	42	6		17	2
4/11/06	87	29	28	16		7	10
4/25/06	**520**	155	22	71	4	6	17
5/16/06	**290**	79	120	110	1	16	10
5/31/06	**360**	**230**	**400**	114	13	35	24
6/13/06	**250**	180	**410**	140	**205**	28	43
6/27/06	26	190	**830**	**670**	3	48	22
7/11/06	77	**220**	**450**	58	2	43	88
7/25/06	**250**	**400**	**260**	**440**	2	53	80
8/8/06	**330**	**1700**	**890**	150	2	63	96
8/29/06	**230**	130	**1200**	165	13	45	190
11/6/06	**15000**	**1600**	**1500**	**1050**	8	**800**	**730**

The following figures show the annual distributions of the 2005-06 FC results.



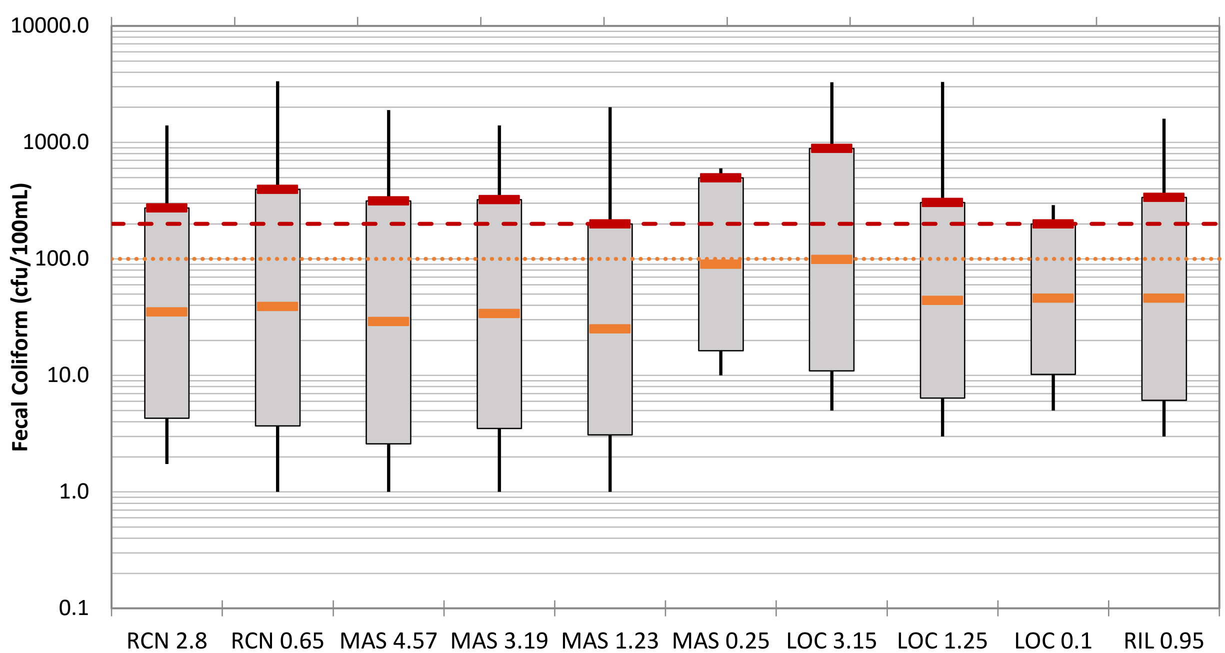


Figure B-1. Annual distribution of 2005-06 FC results.

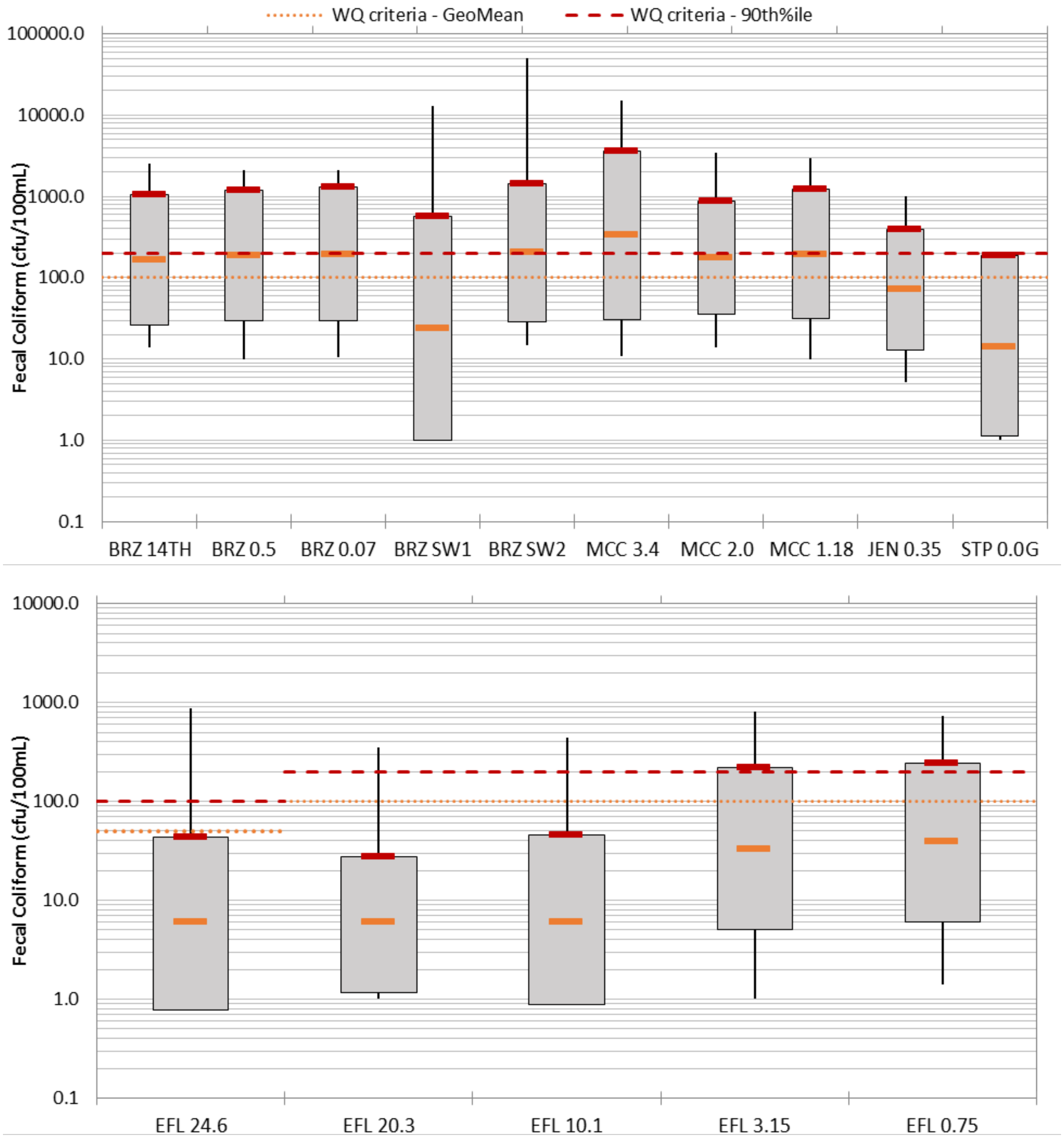


Figure B-2 (continued). Annual distribution of 2005-06 FC results.

Appendix C. Seasonal Kendall Trend Test Results

The purpose of the Seasonal Kendall Trend test is to determine monotonic (increasing or decreasing) trends in data over a period of time (Hirsch et al., 1982; Gilbert, 1987; Helsel and Hirsch, 1995). This trend test is used to calculate the probability of a relationship between FC and time and discounts seasonal variability by only comparing sample results from the same month. A nonparametric, two-tailed Seasonal Kendall Trend test was performed for EF Lewis River using data from Ecology's ambient monitoring site at 27D090 from 2005-2016.

This trend test used a significance of 0.10 (90% confidence). By using a significance of 0.10, the critical Z-value is 1.64. Thus, results of the Seasonal Kendall Trend test with a Z-value greater than 1.64 indicates a significant increasing trend and a Z-value less than -1.64 indicates a significant decreasing trend. A separate test (Sen) calculates the slope of the trend, where a negative slope indicates a decreasing trend, while a positive slopes indicates an increasing trend. The greater or lesser the slope, the larger the rate of change over time.

Results of the Seasonal Kendall Trend test for EF Lewis River show a significant increasing trend of FC levels from 2005-2016 (Z-value 2.086).

Table C-1. Summary tables of results from Seasonal Kendall Trend test.

Tau	0.132
2-sided p-value	0.037
Slope	0.375
Significance	0.100
Z-value	2.086

Seasonal Kendall Trend Test (2005-2016)				
Month	**n**	**Statistic**	**ASE**	**Tau**
October	12	0	14.58	0
November	12	3	14.48	0.045
December	12	13	14.48	0.197
January	12	19	13.97	0.288
February	12	-1	13.58	-0.015
March	12	2	14.42	0.03
April	12	25	14.48	0.379
May	11	11	12.85	0.2
June	12	18	14.58	0.273
July	11	-2	12.81	-0.036
August	12	-3	14.48	-0.045
September	12	17	14.48	0.258

n = number of samples

Statistic = test statistic used to compare subsequent time period values where a positive value indicates increasing trend and a negative value indicates decreasing value.

ASE (Asymptotic Standard Error) = standard deviation of each parameter.

Tau = Kendall's tau coefficient is a statistic used to measure the association between two measured quantities.

Appendix D. Loading Analysis Results

Table D-1. FC loads (billion cfu/day) calculated for annual, storm event, dry season, and wet season (excluding storm event).

Site	Annual	Storm	Dry	Wet
RCS3.90	8.5	145	3.3	4.7
YAC3.60	4.3	81	0.5	2.9
YAC0.90	13.1	121	3.8	16.0
BIG0.05	52.1	1081	13.5	22.8
EFL20.3	767	22077	48.1	67.1
RCN2.8	104	2641	6.8	5.1
RCN0.65	471	8678	7.6	26.5
EFL10.1	844	24674	51.8	47.6
MAS4.57	128	2753	1.0	3.7
MAS3.19	175	3255	1.4	6.3
MAS1.23	166	4548	5.3	13.5
LOC3.15	19.5	43	25.5	8.6
RIL0.95	5.9	55	2.7	6.1
LOC1.25	22.7	136	7.0	32.4
LOC0.1	19.6	74	6.3	30.3
BRZ14TH	15.3	111	5.9	18.0
BRZ0.5	22.5	191	16.7	17.1
BRZSW2	3.4	29	0.3	4.5
BRZSW1	1.2	33	0.0	0.3
BRZ0.07	28.6	245	16.0	28.5
MCC2.0	51.3	486	7.6	67.1
MCC1.18	57.5	520	6.6	82.7
JEN0.35	11.8	36	3.2	19.9

Appendix E. Fecal Coliform Data (2017)

Table E-1. FC data 2017. ***Bold*** *values indicate geometric mean water quality criteria exceedance.*

Date	YAC 0.90	RCN 2.07	MAS 3.19	MAS 1.11	LOC 3.55	RIL 0.95	MCC 3.4	MCC 1.18	MCC TRIB2
2/7/2017	8.5		68	44		8		**325**	
2/21/2017	52	55	48	45	7	11		**190**	
3/7/2017	**150**	94	41	36	33	37	**760**	**215**	
3/21/2017	14.5	15	28	14	8	4	**980**	83	
4/4/2017	11.5	5	5	5	1	3	**730**	16	
4/18/2017	8	6	33	8	4	3	**320**	60	**2700**
5/2/2017	6	18	18	9	1	2	**150**	53	**1500**
5/16/2017	**430**	**430**	**360**	**380**	**230**	**140**	**3250**	**530**	**8250**
6/6/2017	14	40	65	47	24	18	**530**	**110**	4.5
6/20/2017	74	**300**	61	63	76	84	**275**	**145**	**5800**
7/5/2017	14	**160**	77	78	71	**160**	**720**	75	
7/19/2017	11	**700**	11	100	80	91	**240**	82	49
8/1/2017	36	48		59	49	44	**420**	**235**	
8/15/2017	35	**160**		41	**190**	**470**	**190**	**160**	
9/6/2017	11			92	**160**	**130**	**885**	**395**	
9/19/2017	**360**	**800**		**360**	**1400**	**840**	**2300**	**1150**	
10/3/2017	3	96		43	**240**	87	**360**	78	

Date	BRZ 14th	BRZ 0.07	BRZ SW2	BRZ SW1	JEN 1.03	EFL 0.75	EFL 3.35
2/7/2017	9	14	**210**	41		80	
2/21/2017	20	10	29	65	32	19	
3/7/2017	**160**	**190**	**640**	**400**	84	44	17
3/21/2017	14	26	42	19	13		
4/4/2017	8	68	**1040**	2	33		
4/18/2017	32	**420**	99.5	2	**240**		7
5/2/2017	32	17	**295**	3	59	8	1
5/16/2017	**160**	**360**	**2050**	**1700**	**320**	**190**	**220**
6/6/2017	**450**	**240**	**160**		64	40	7
6/20/2017	**295**	**260**	**720**		**190**	47	28
7/5/2017	**290**	**210**	**830**		83	**600**	33
7/19/2017	**435**	**120**	**515**		**140**	**390**	43
8/1/2017	**450**	96	**705**		**130**	**200**	11
8/15/2017	**325**	**230**	**995**		68	43	17
9/6/2017	**560**	**390**			**140**	59	65
9/19/2017	**1300**	**1400**	**2050**	**1500**	**1900**	**210**	100
10/3/2017	**785**	**230**	**235**		**120**	64	14

Appendix F. Temperature Data

Table F-1. Summary of temperature results data.

Site	Criteria (°C)	Days above 7DADMax	Total Days	% Days WQ Standard Exceeded	Max - 1DayMax (°C)	Max - 7DADMax (°C)	Mean (°C)	10th%ile (°C)	90th%ile (°C)	Minimum (°C)
EFL29.0	16	12	90	13	18	17	14	11	17	10
KNG00.0	16	25	112	22	17	17	14	10	17	9
EFL26.9	16	39	95	41	19	18	15	11	18	9
RCS03.9	16	34	112	30	18	17	14	11	17	10
EFL24.6	16	39	83	47	20	19	15	11	19	10
BIG00.0	16	36	112	32	18	18	15	11	17	10
EFL20.3	16	58	113	51	21	20	16	11	20	11
RCN050	16	80	131	61	22	21	17	12	20	11
RCN00.6	16	59	91	65	24	23	18	13	23	12
EFL14.7	16	62	75	83	23	23	20	15	23	12
EFL13.2	16	60	90	67	24	23	19	13	23	11
EFL10.1	16	92	120	77	24	23	19	14	23	12
MAN010	16	62	79	78	22	22	19	15	22	13
EFL08.1	16	33	39	85	25	24	20	17	24	15
DEA00.8	16	91	114	80	25	23	19	14	23	12
DEA00.0	16	22	28	79	29	26	24	21	28	20
EFL07.3	16	49	73	67	24	23	19	13	23	12
MAS00.8	16	47	115	41	19	18	15	13	18	12
EFL04.6	16	97	189	51	35	31	18	7	29	4
LOC00.0	16	32	65	49	24	22	18	13	22	12
BRZ010	16	45	131	34	20	20	16	13	19	11
BRZ00.1	16	53	113	47	20	20	17	13	19	12
EFL01.8	16	100	127	79	31	27	21	15	25	13
JEN00.3	16	50	112	45	21	20	16	12	20	10

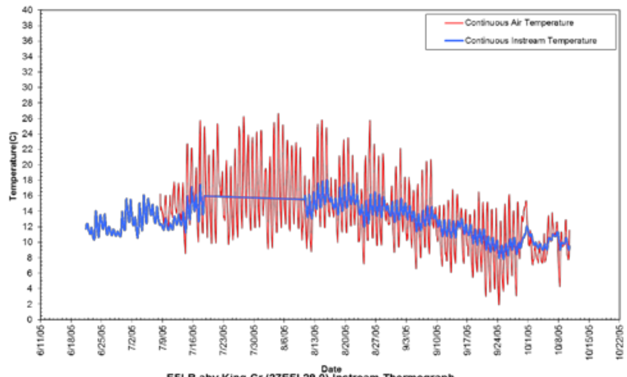
Appendix G. Temperature Thermographs

The temperature monitoring sites along the EF Lewis River and its tributaries measured both instream water temperatures and air temperature.

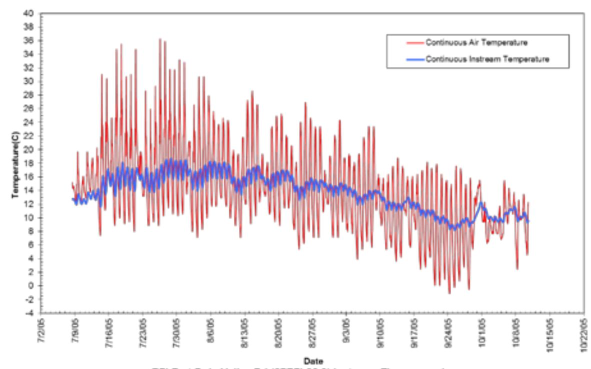
This appendix includes charts from the temperature monitoring sites that show (1) combined instream and air thermograph and (2) instream thermograph. The graphs with the instream thermograph data show the continuous temperature for the study period, 7-DADMax temperature, and 7-DAD-Min temperature. They also contain data points for field checks using thermometers. The combination charts show the recorded continuous temperature measurements with continuous air temperature. Unless otherwise noted, these air temperature measurements were recorded near the instream temperature logger site.

These thermographs serve as a visual comparison for air and water temperature.

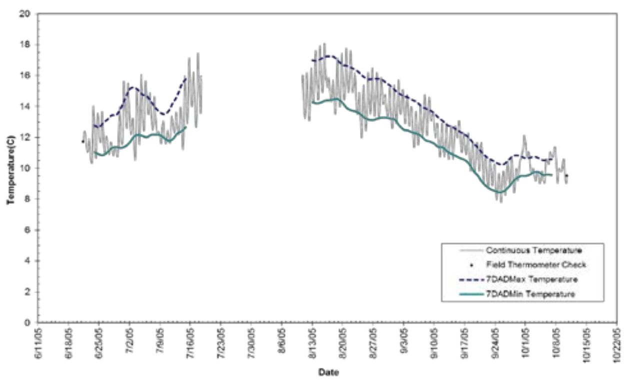
EFLR abv King Cr (27EFL29.0) Combined Instream and Air Thermograph.



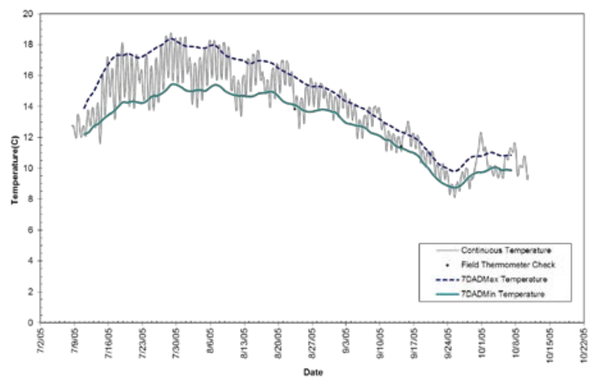
EFLR at Dole Valley Rd (27EFL26.9) Combined Instream and Air Thermograph.



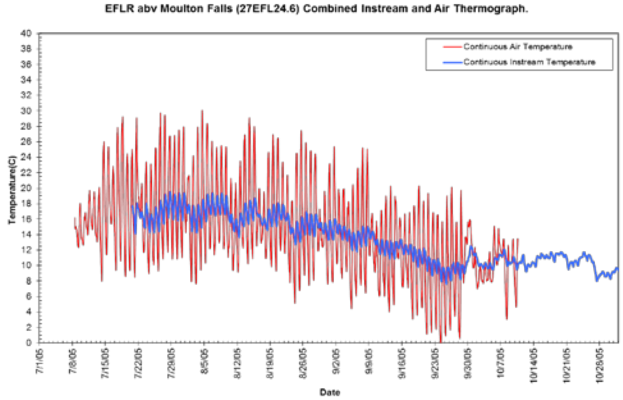
EFLR abv King Cr (27EFL29.0) Instream Thermograph.



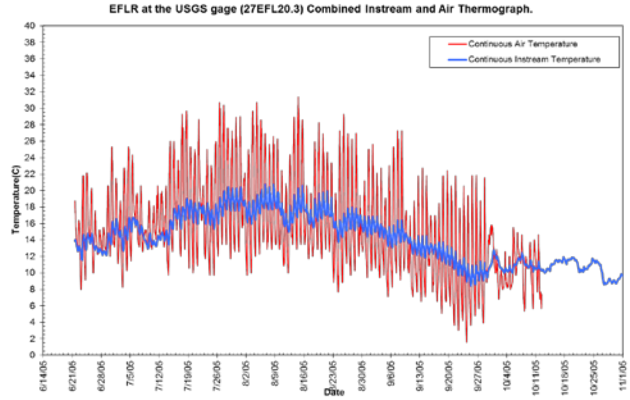
EFLR at Dole Valley Rd (27EFL26.9) Instream Thermograph.



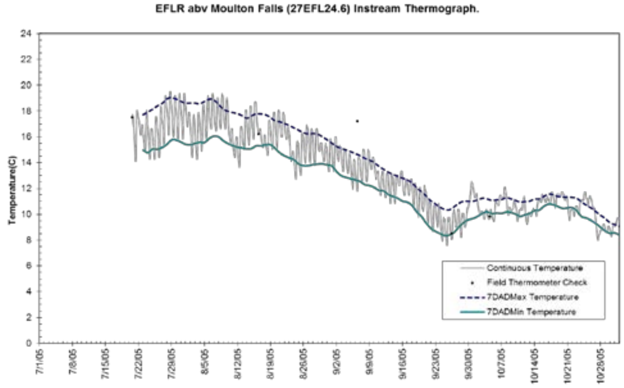
EFLR abv Moulton Falls (27EFL24.6) Combined Instream and Air Thermograph.



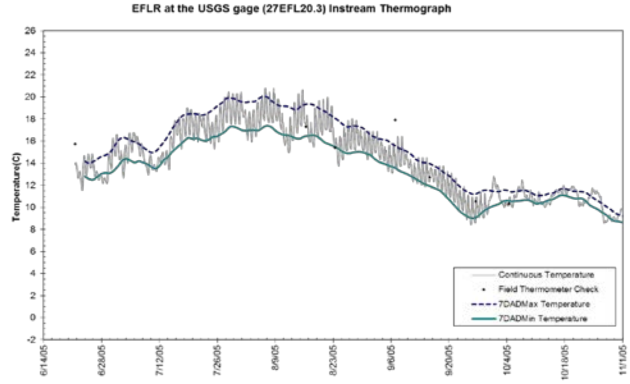
EFLR at the USGS gage (27EFL20.3) Combined Instream and Air Thermograph.



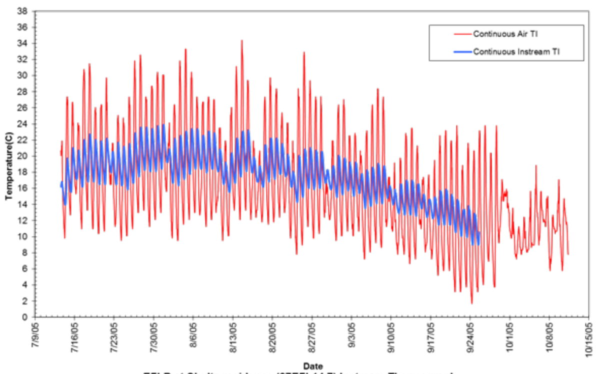
EFLR abv Moulton Falls (27EFL24.6) Instream Thermograph.



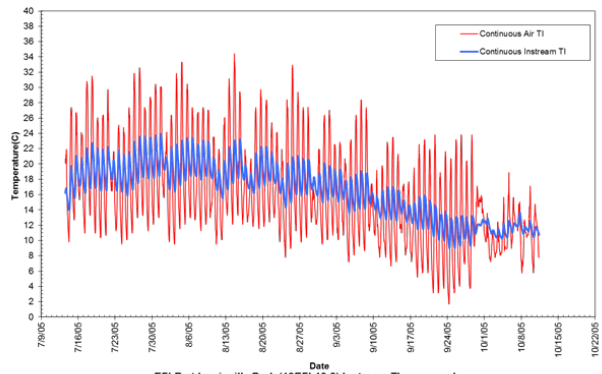
EFLR at the USGS gage (27EFL20.3) Instream Thermograph



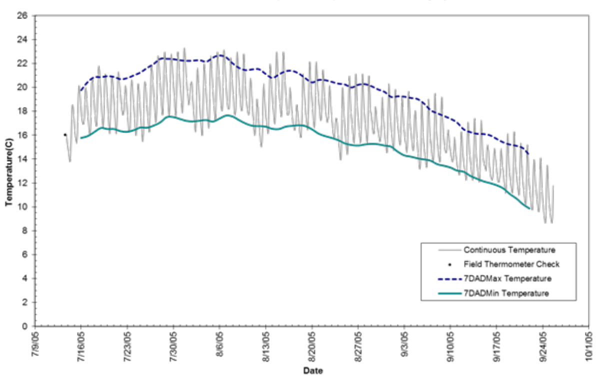
EFLR at Shultz Residence (27EFL14.7) Combined Instream and Air Thermograph (27EFL13.2).



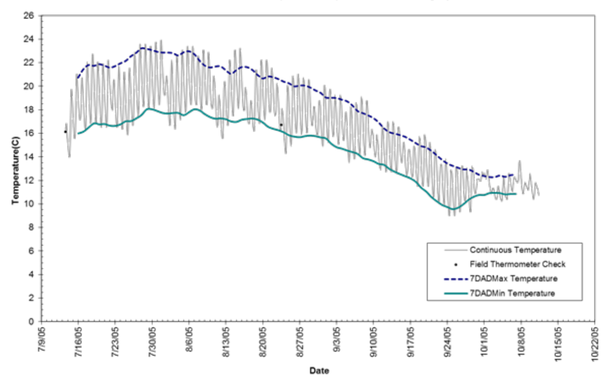
EFLR at Lewisville Park (13EFL13.2) Combined Instream and Air Thermograph.



EFLR at Shultz residence (27EFL14.7) Instream Thermograph.



EFLR at Lewisville Park (13EFL13.2) Instream Thermograph.



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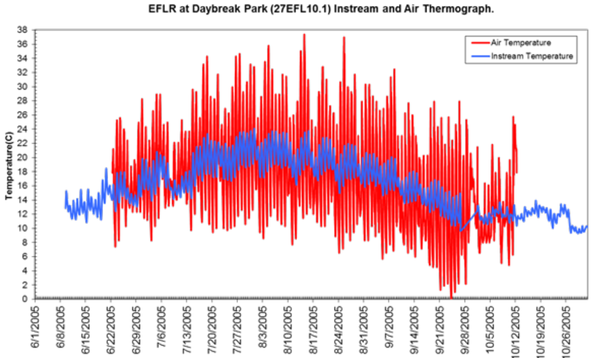

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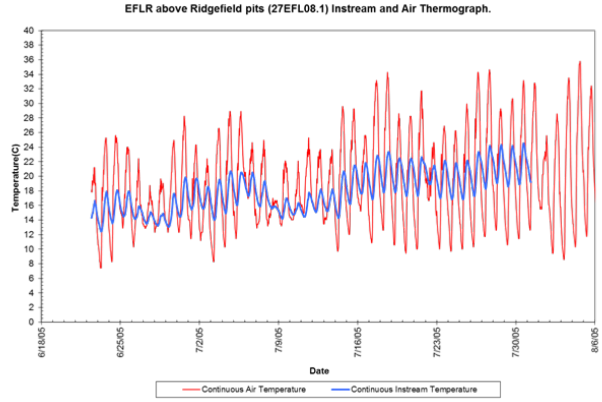

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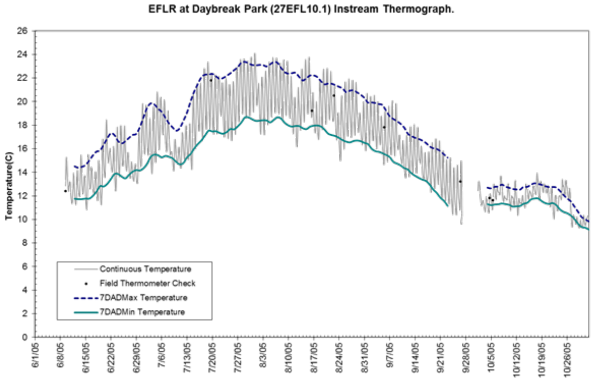

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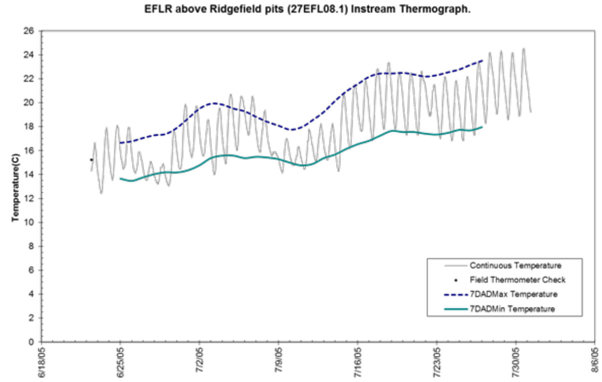
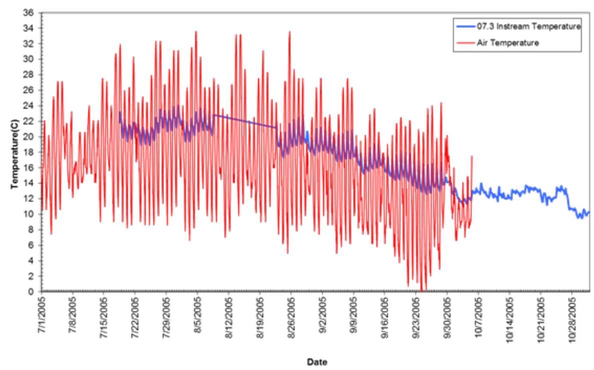


East Fork Lewis River Continuous Instream Thermograph.



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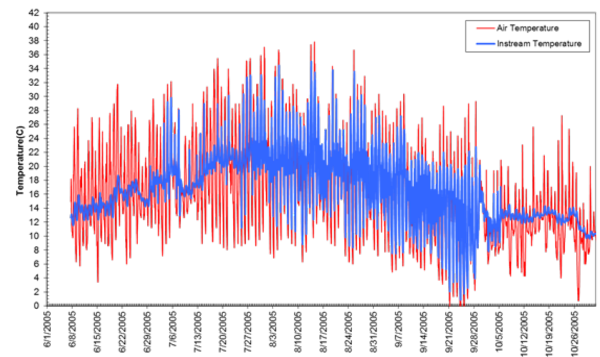

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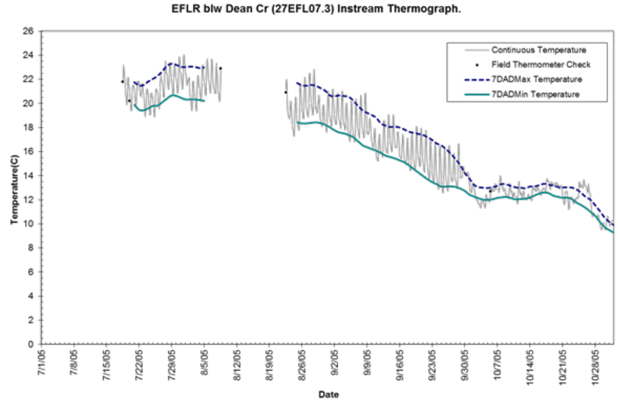

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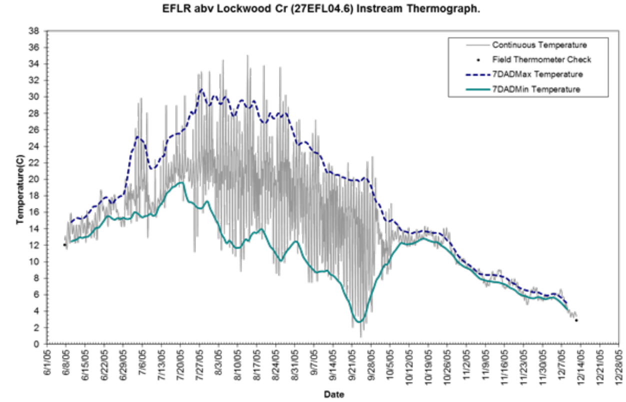

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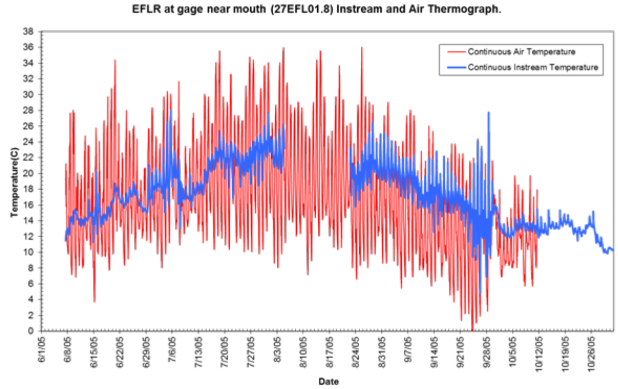

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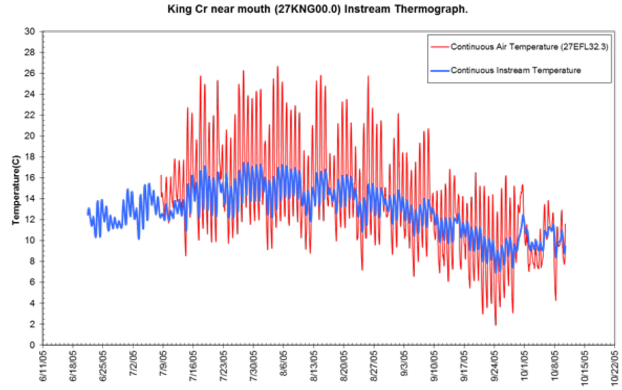

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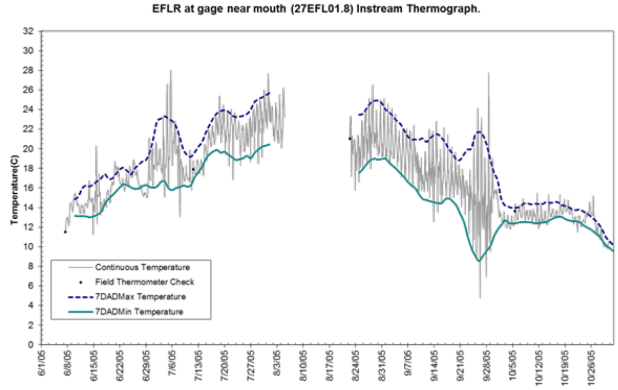

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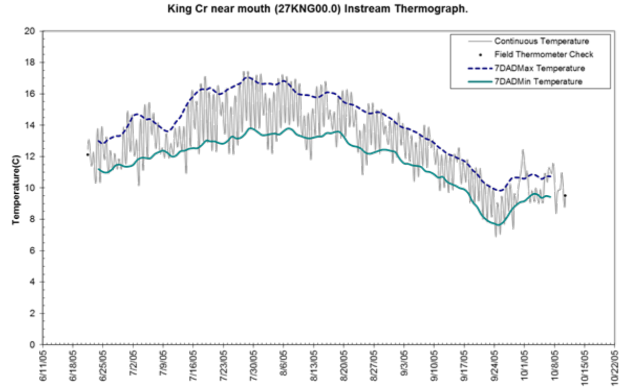

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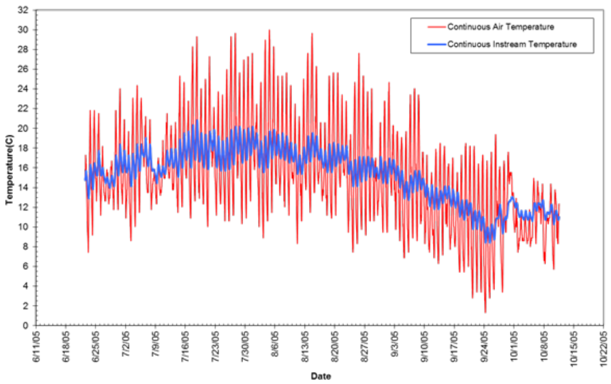
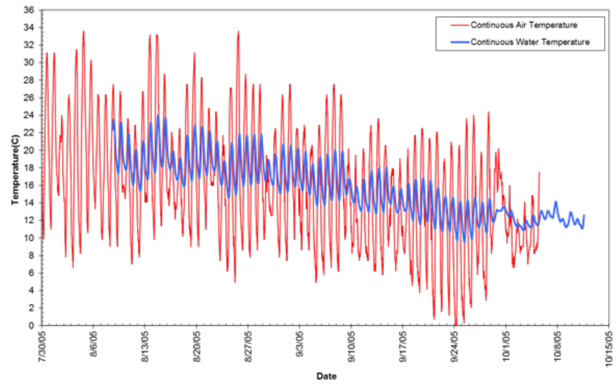


Comparison of Lockwood Cr (27LOC00.0) Water Temperatures and Air Temperatures at 27EFL07.3Met Thermograph.



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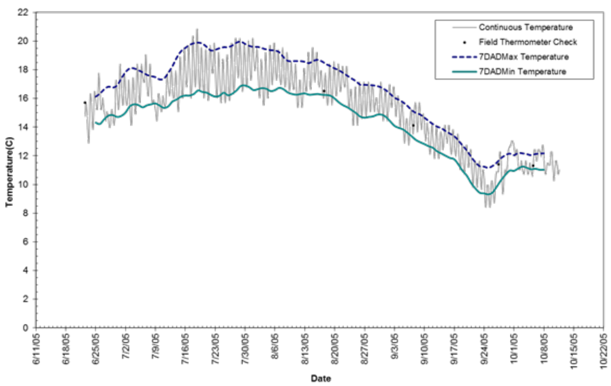
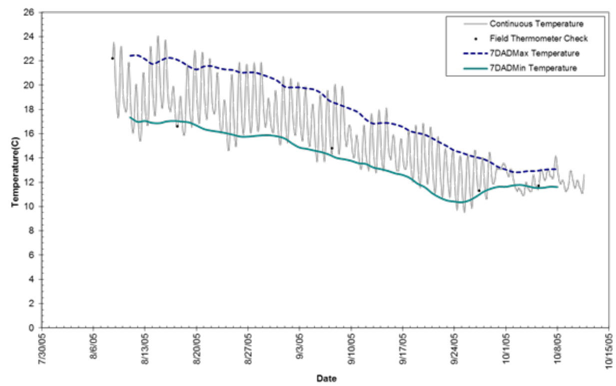
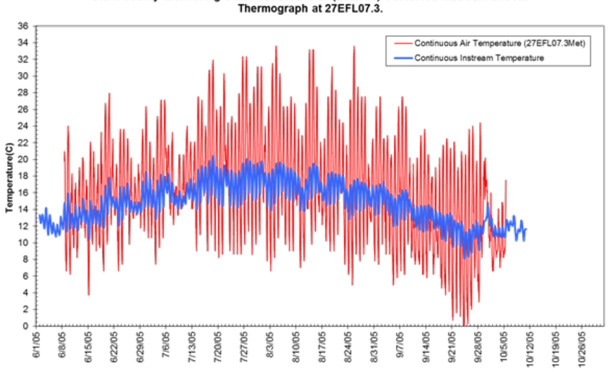


Lockwood Creek at Mouth (27LOC00.0) Instream Thermograph.



Clark County Monitoring Station at Brezee Cr (BRZ010) Combined Instream and Air Thermograph at 27EFL07.3.



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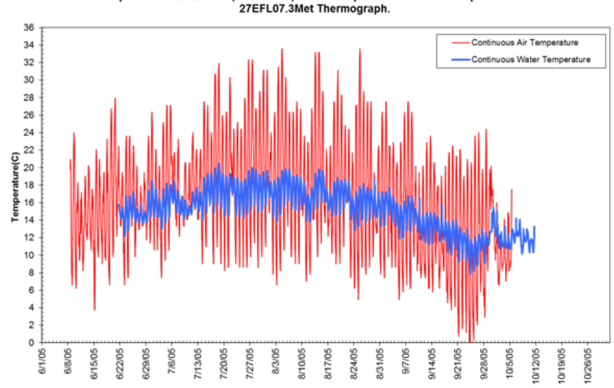

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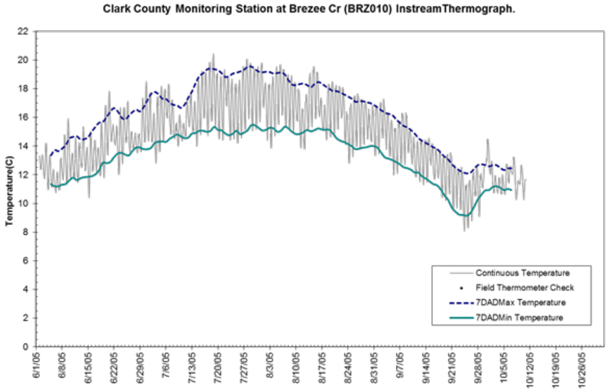
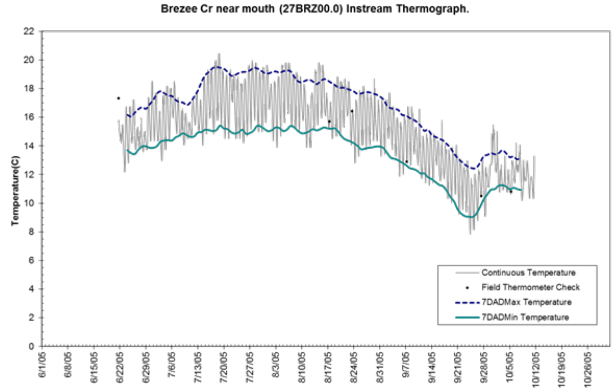
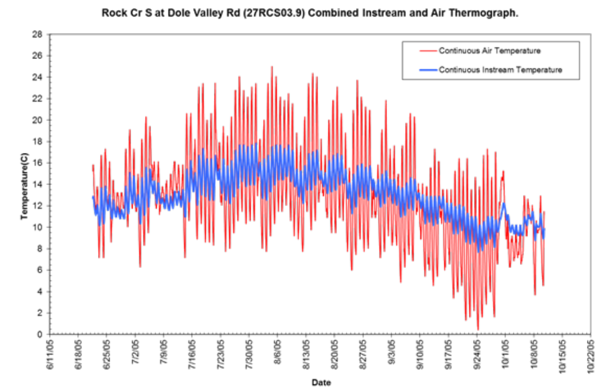
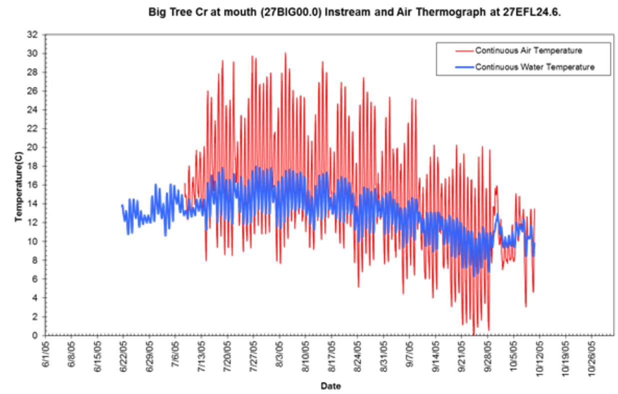
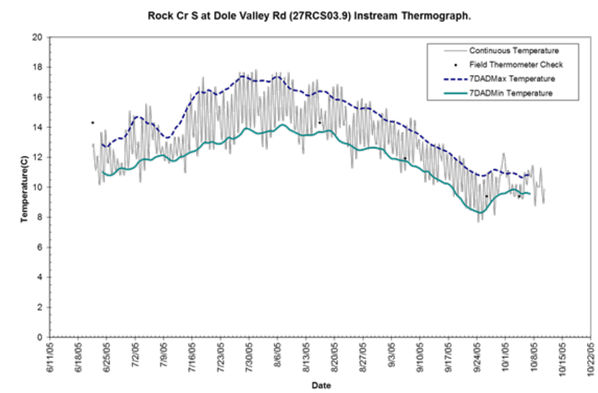


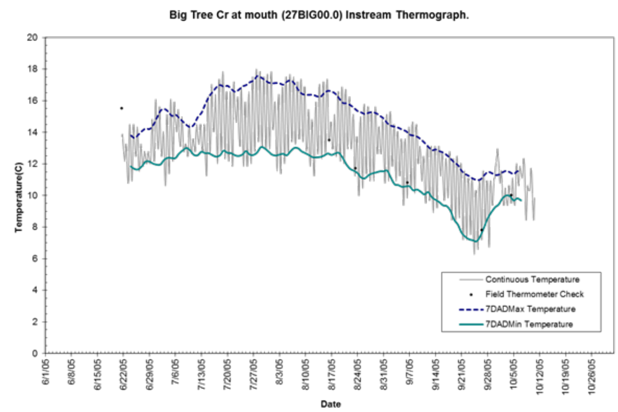
Brezee Cr near mouth (27BRZ00.0) Instream Thermograph.




Rock Cr S at Dole Valley Rd (27RCS03.9) Combined Instream and Air Thermograph.
Continuous Air Temperature
Continuous Instream Temperature
Temperature(C)
Date


Big Tree Cr at mouth (27BIG00.0) Instream and Air Thermograph at 27EFL24.6.
Continuous Air Temperature
Continuous Water Temperature
Temperature(C)
Date


Rock Cr S at Dole Valley Rd (27RCS03.9) Instream Thermograph.
Continuous Temperature
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date


Big Tree Cr at mouth (27BIG00.0) Instream Thermograph.
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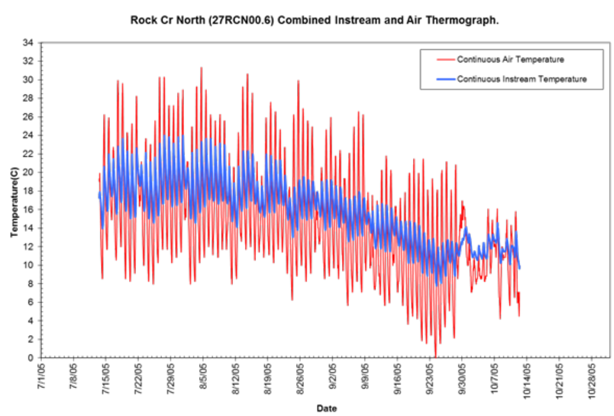
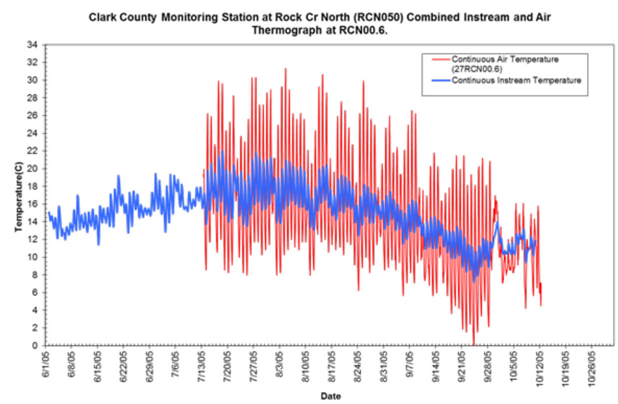
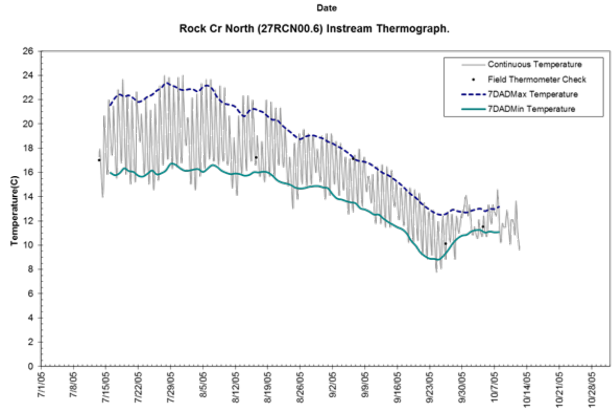
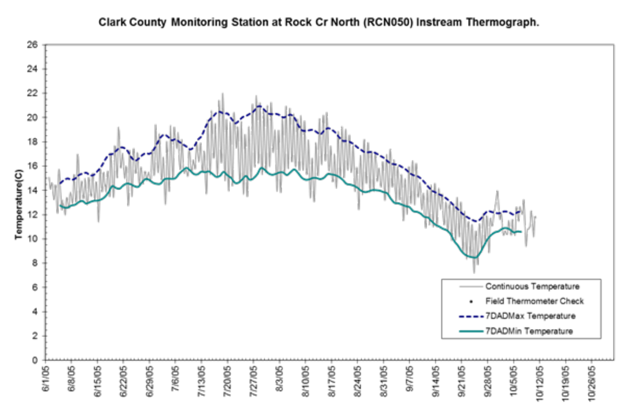
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date


Rock Cr North (27RCN00.6) Combined Instream and Air Thermograph.
Continuous Air Temperature
Continuous Instream Temperature
Temperature(C)
Date


Clark County Monitoring Station at Rock Cr North (RCN050) Combined Instream and Air Thermograph at RCN00.6.
Continuous Air Temperature (27RCN00.6)
Continuous Instream Temperature
Temperature(C)
Date


Rock Cr North (27RCN00.6) Instream Thermograph.
Continuous Temperature
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date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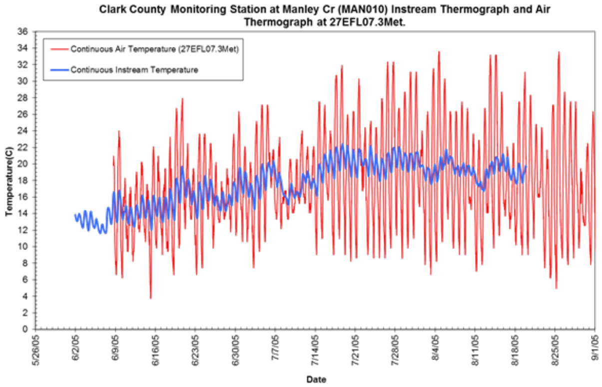
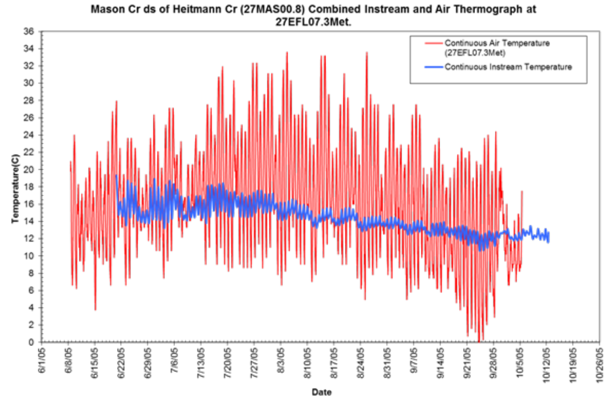
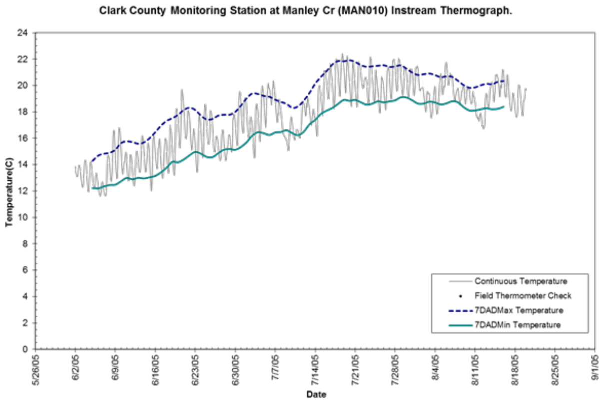
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date


Clark County Monitoring Station at Manley Cr (MAN010) Instream Thermograph and Air Thermograph at 27EFL07.3Met.
Continuous Air Temperature (27EFL07.3Met)
Continuous Instream Temperature
Temperature(C)
Date


Mason Cr ds of Heitmann Cr (27MAS00.8) Combined Instream and Air Thermograph at 27EFL07.3Met.
Continuous Air Temperature (27EFL07.3Met)
Continuous Instream Temperature
Temperature(C)
Date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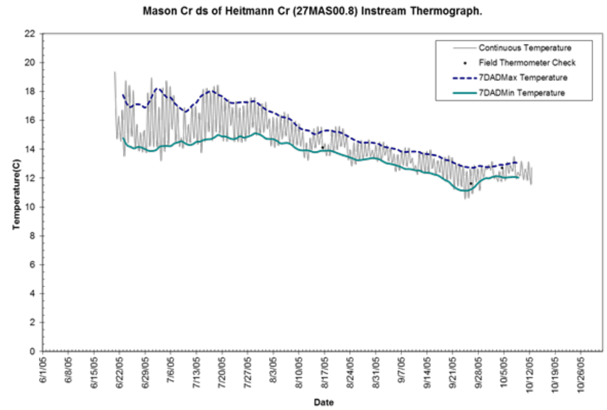
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date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Field Thermometer Check
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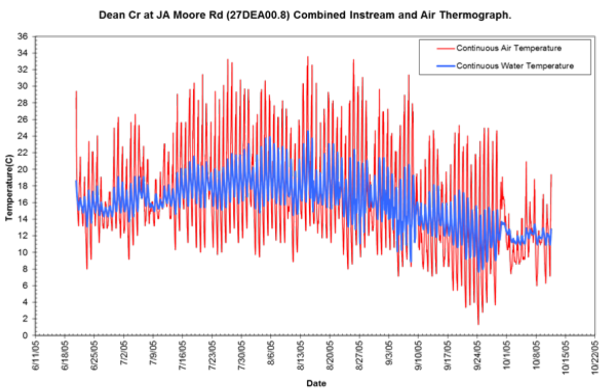
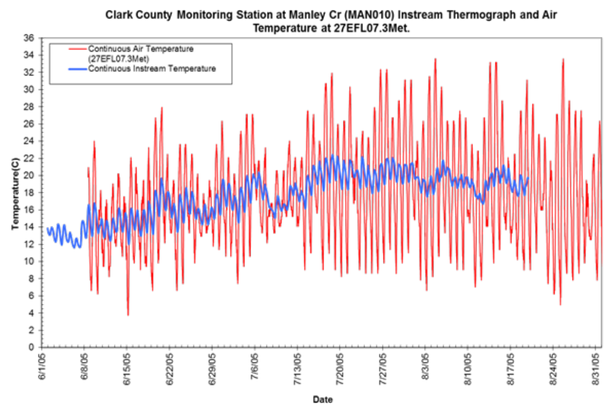
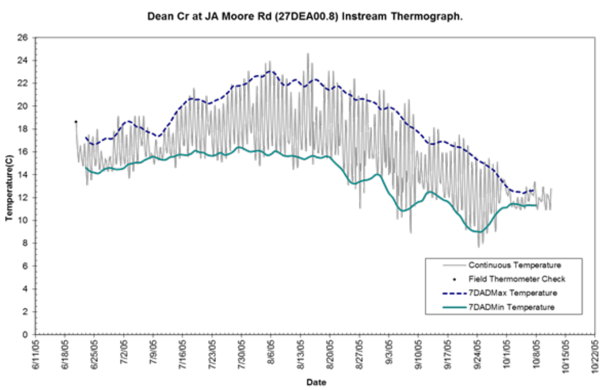
Temperature(C)
Date


Dean Cr at JA Moore Rd (27DEA00.8) Combined Instream and Air Thermograph.
Continuous Air Temperature
Continuous Water Temperature
Temperature(C)
Date


Clark County Monitoring Station at Manley Cr (MAN010) Instream Thermograph and Air Temperature at 27EFL07.3Met.
Continuous Air Temperature (27EFL07.3Met)
Continuous Instream Temperature
Temperature(C)
Date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Field Thermometer Check
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Temperature(C)
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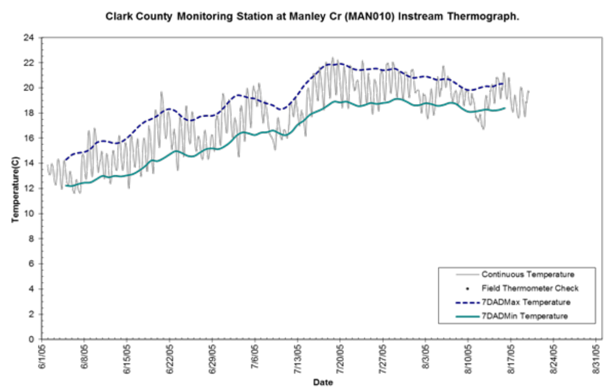
Clark County Monitoring Station at Manley Cr (MAN010) Instream Thermograph.
Continuous Temperature
Field Thermometer Check
7DADMax Temperature
7DADMin Temperature
Temperature(C)
Date

Appendix H. Overview of Effective Shade and Riparian Cover

The following sections provide an overview of the role of riparian vegetation and effective shade in the temperature of streams and rivers.

Thermal role of vegetation

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

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2M Hill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. Important benefits that riparian vegetation has upon the stream temperature include the following:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.
- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.
- Channel morphology can be strongly affected by near-stream vegetation. Specifically, stream vegetation is often part of human impacts on land-cover type and condition, which can affect flood plain and instream roughness, the contribution of coarse woody debris, sedimentation, stream substrate composition, and stream bank stability.

Although the warming of water temperatures as a stream flows downstream can be a natural process, the rates of heating can be dramatically lower when high levels of shade exist and heat flux from solar radiation is minimized. There is a natural maximum potential level of vegetation and associated shade that a given stream is capable of attaining in an undisturbed situation. In general, the importance of shade decreases as the width of a stream increases.

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

Effective shade

Stream shade may be measured or calculated using a variety of methods (Chen, 1996; Chen et al., 1998; Ice, 2001; OWEB, 1999; Teti, 2001; Teti and Pike, 2005). Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

$$\text{effective shade} = (J_1 - J_2)/J_1$$

where J_1 is the potential solar heat flux above the influence of riparian vegetation and topography, and J_2 is the solar heat flux at the stream surface.

Canopy cover is the percent of sky covered by vegetation and topography at a given point. Shade is influenced by cover but changes throughout each day, as the position of sun changes spatially and temporally with respect to the canopy cover (Kelley and Krueger, 2005).

In the Northern Hemisphere, the earth tilts on its axis toward the sun during the summer, allowing longer day length and higher solar altitude. Both are functions of solar declination, a measure of the earth's tilt toward the sun. Latitude and longitude positions fix the stream to a position on the globe, while aspect provides the direction of streamflow. Near-stream vegetation height, width, and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation, producing shade (Table J-1). The solar position has a vertical component (solar altitude) and a horizontal component (solar azimuth); both are functions of time, date, and the earth's rotation.

While the interaction of these shade variables may seem complex, the mathematics that describe them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including (Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005):

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

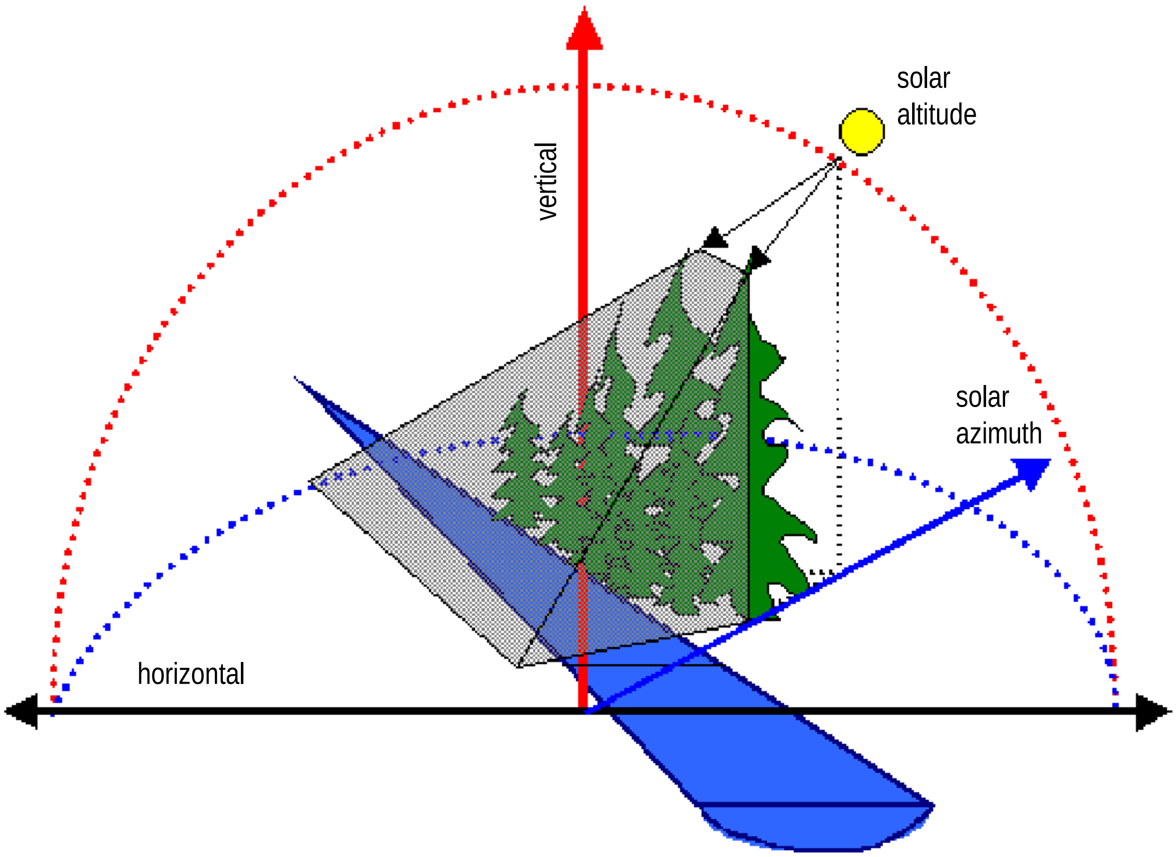

Figure H-1. Parameters that affect shade and geometric relationships. *Solar altitude* is a measure of the vertical angle of the sun's position relative to the horizon. *Solar azimuth* is a measure of the horizontal angle of the sun's position relative to the north. (Boyd and Kasper, 2003).

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers (ACD) and solar pathfinders provide a good balance of cost and accuracy for measuring the ability of riparian vegetation to prevent increases in stream temperature (Beschta et al., 1987; Teti, 2001, 2005). Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the ACD is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 AM and 2 PM in mid to late summer) when the potential solar heat flux is most significant. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80% to 90%. (Brazier and Brown, 1973; Steinblums et al., 1984).

Computer programs for the mathematical simulation of shade may also be used to estimate shade from measurements or estimates of the key parameters listed in Table H-1 (Ecology 2003; Chen, 1996; Chen et al., 1998; Boyd, 1996; Boyd and Park, 1998).

Table H-1. Factors that influence stream shade.

Description	Parameter
Season/time	Date/time
Stream characteristics	Aspect, **channel width**
Geographic position	Latitude, longitude
Vegetative characteristics	**Riparian vegetation height, width, and density**
Solar position	Solar altitude, solar azimuth

Bold indicates influenced by human activities.

Riparian buffers and effective shade

Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure H-7). The shade as represented by angular canopy density (ACD) for a given riparian buffer width varies over space and time because of differences among site potential vegetation, forest development stages (e.g., height and density), and stream width. For example, a 50-foot-wide riparian area with fully developed trees could provide from 45% to 72% of the potential shade in the two studies shown in Figure H-7.

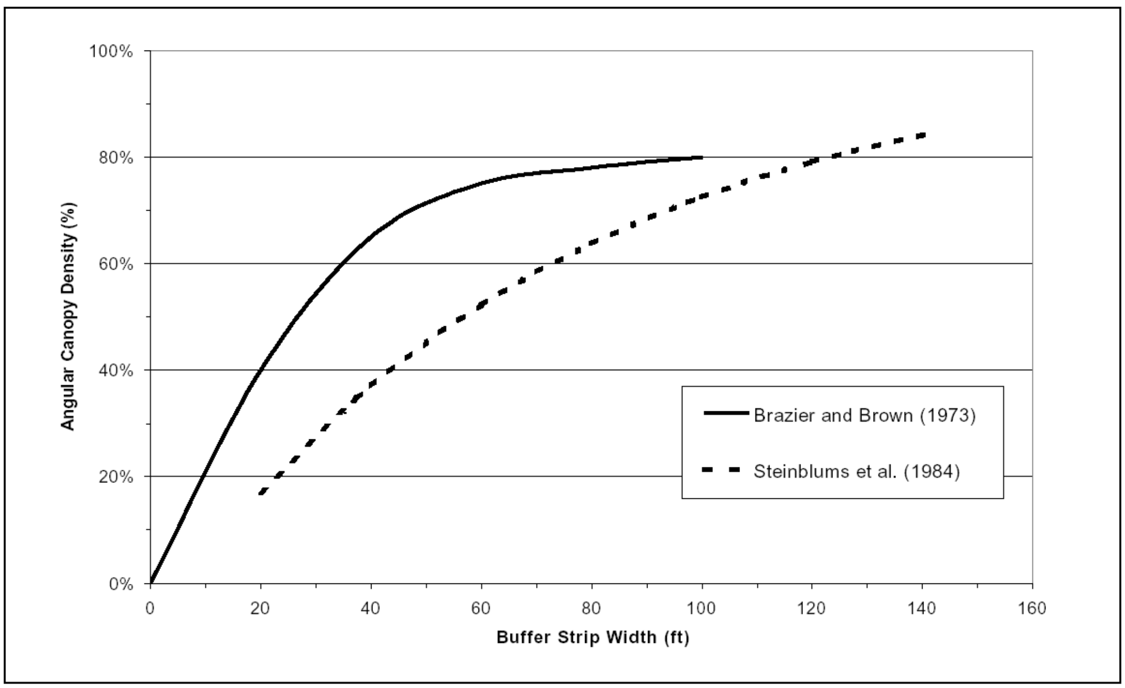

Figure J-2. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands (after Beschta et al., 1987; and CH2M Hill, 2000).

The Brazier and Brown (1973) shade data show a stronger relationship between ACD and buffer strip width than the Steinblums et al. (1984) data; the r^2 correlation for ACD and buffer width was 0.87 and 0.61 in Brazier and Brown (1973) and Steinblums et al., (1984), respectively. This difference supports the use of the Brazier and Brown curve as a base for measuring shade effectiveness under various riparian buffer proposals. These results reflect the natural variation among old-growth sites studied, and show a possible range of potential shade.

Several studies of stream shading report that most of the potential shade comes from the riparian area within about 75 feet (23 m) of the channel (CH2M Hill, 2000; Castelle and Johnson, 2000):

- Beschta et al. (1987) report that a 98-foot (30-m) wide buffer provides the same level of shading as that of an old-growth stand.
- Brazier and Brown (1973) found that a 79-foot (24-m) buffer provides maximum shade to streams.
- Steinblums et al. (1984) concluded that a 56-foot (17-m) buffer provides 90% of the maximum ACD.
- Corbett and Lynch (1985) concluded that a 39-foot (12-m) buffer should adequately protect small streams from large temperature changes following logging.
- Broderson (1973) reported that a 49-foot (15-m) wide buffer provides 85% of the maximum shade for small streams.
- Lynch et al. (1984) found that a 98-foot (30-m) wide buffer maintains water temperatures within 2°F (1°C) of their former average temperature in small streams (channel width less than 3 m).

GEI (2002) reviewed the scientific literature related to the effectiveness of buffers for shade protection in agricultural areas in Washington and concluded that buffer widths of 10 m (33 feet) provide nearly 80% of the maximum potential shade in agricultural areas. Wenger (1999) concluded that a minimum continuous buffer width of 10-30 m should be preserved or restored along each side of all streams on a municipal or county-wide scale to provide stream temperature control and maintain aquatic habitat. GEI (2002) considered the recommendations of Wenger (1999) to be relevant for agricultural areas in Washington.

Steinblums et al. (1984) concluded that shade could be delivered to forest streams from beyond 75 feet (22 m) and potentially out to 140 feet (43 m). In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively minimal because the potential solar radiation decreases significantly as solar elevation decreases.

References for Appendix H

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Appendix I. Hemispherical Photograph Analysis

Digital hemispherical photographs were taken along the EF Lewis River during the summer 2005 as part of the field collection. These photographs were taken at the location of the instream temperature logger, located near the center of the stream, and then used to estimate riparian shade. The pictures were taken with a digital camera looking upward to accommodate vegetation canopy using a fish-eye lens.

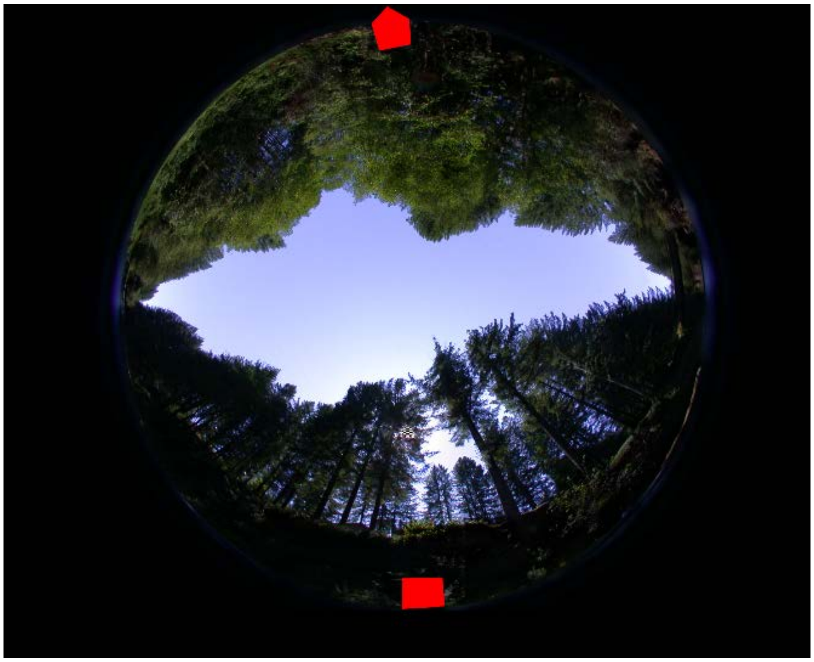

Figure I-1. Example of hemispherical photograph taken along EF Lewis River.

Following the field collection of these photographs, these photos were analyzed by Ecology staff using HemiView software. The photos were processed to calculate the daily and annual effective shade and annual canopy cover. Ecology staff then exported the photos and HemiView processing for future reference and analysis.

The original field collection took pictures at the same location as the instream temperature logger sites, along with other locations throughout the river's mainstem. The location accuracy for the hemispherical photographs taken is +/- 1.1 km. However for this analysis, only the photos taken at the instream temperature logger site or with specific location details were used due to lack of sufficient location information for the photographs taken outside of these sites.

Canopy cover is the percentage of sky that is blocked by vegetation or topography. Annual canopy cover was calculated using the HemiView processing results as the difference of canopy cover from the VisSky value (visible sky) and multiplied by 100 to be represented as a percentage.

Effective shade is the fraction of the total possible solar radiation heat energy that is prevented from reaching the surface of the water. Effective shade is influenced by canopy cover, but changes during the day depending on the position of the sun both spatially and temporally in relation to the canopy cover (Kelley and Krueger, 2005). Annual and daily effective shade were calculated using the values for direct and diffuse radiation from the HemiView processing analysis.

Table I-1 presents the results for the HemiView canopy cover and effective shade analysis. It presents the results for the annual average effective shade (%), annual average canopy cover (%), and daily effective shade for July 1 (%). The daily effective shade percentages were used as a source for comparison with Ecology's Shade model results.

Table I-1. Results (%) from hemispherical photograph analysis.

Station	Annual Average Canopy Cover	Annual Average Effective Shade	Daily Effective Shade - July 1
EFL01.5	29	4	2
EFL04.6	25	8	9
EFL07.3	34	8	10
EFL08.1	42	11	11
EFL10.1	55	31	19
EFL13.2	63	23	6
EFL14.7	52	29	4
EFL20.3	66	35	27
EFL24.6	87	66	69
EFL26.9	75	63	54
EFL29.0	75	40	25

Appendix J. Response to External Comments

Hey Andrew,

Impressive report.
One correction: Figure 42 is an image of Mason Creek at JR Anderson Road, not Rock Creek North (you can verify this with Google Maps street view address: 8019 NE J R Anderson Rd., La Center, Washington).

Brice

Brice Crayne

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Ecology Response:
Comment noted, caption was revised.

Andrew,

The various conservation & fisheries restoration groups I represent greatly appreciate the assessment work on the EF Lewis River that you & the Dept. of Ecology are doing on this very important watershed & stream.
Here are some of my brief but key comments on the draft assessment report.

1. More needs to be addressed on the high bed load sedimentation problems & associated effects below Lewisville Park & on down past La Center, WA. Historical photos & a study by nationally recognized fluvial-geomorphologist Dr. Frank Reckondorf point out the details of this major problem.
2. There is not the level of laws & regulations enforcement required, being done by Clark County. The apparent culture of rapid growth & development at any cost to other resources is a major problem. The federal stormwater runoff suit that the County lost is a classic example. And, our settlement thru 2 “Consent Decrees using both the Federal Clean Water Act & the Endangered Species Act are also further indicators of the need for change in the Counties enforcement staff and direction from the Clark County Councilors & Manager.
3. The high width to depth ratios in the lower 1/3 of the river cause critical summer flows to expose more cross-sectional area to heating. There are 5 major sources of high bedload sedimentation, some from newer sources, & some from historical but all are man-made anthropogenic sources.
4. Planting more trees will have a limited effect on these wide & shallow reaches of the river. Other types of stream bank & channel treatment are needed.

5. The high sediment bedload rate has filled in many of the pools that used to exist (stereoscopic review of 1930's aerial photos & to the present time show this quite clearly as well as a USGS study done on the West Cascades) reduce river cooling ability.
6. Mill Creek North which is the north branch of Mill Creek that splits at Dollars Corner to north & south segments, one going to the East Fork & the other to Salmon Creek, and is a significant source of Coho & Steelhead fisheries.
7. Fish First, Friends of the East Fork, & the Healing Waters Veterans Group have done over 40 in-stream & stream bank/channel restoration projects on the East Fork & tributaries ---they should be recognized as another group of organizations doing monitored effective restoration work.
8. We (our various groups that now collaborate with several others) have a history of working directly with the Dept. of Ecology, including my own past assistance as a professional hydrologist in doing stream flow metering at various points on the East Fork with Dept. of Ecology Field Crews.
9. We also use HoBo summer stream temperature units in key reaches below Lewisville Park, GoPro underwater cameras, licensed Drones, & would be glad to share that data with the Dept. of Ecology. I have had EPA training when I worked in various regions of the west as a federal hydrologist & am qualified to do monitoring work.

We look forward to more cooperation with the Dept. of Ecology on a wide range of water related issues & concerns & greatly appreciate what you have been doing to support the long-term effort to improve watershed, riparian, & instream proper balance functioning of the East Fork Lewis River.

Kind regards,

Richard Dyrland, retired Federal Regional Hydrologist
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Member: Board of Directors Fish First, Friends of the East Fork, & Project Staff Healing Waters Veterans Group Vancouver, WA

Comment #1

The purpose of this study did not include evaluating the effects on sedimentation and hydromodifications or enhancement projects. This was noted in the 2005 QAPP, with the recognition that " bank/channel enhancements and implementation measures that reduce width/depth ratios will reduce heating impacts in a reach that is too wide and shallow and/or will protect riparian vegetation projects from being washed away by an aggrading stream channel" (Bilhimer et al., 2005). For this report, the Fishery Resources and Habitat Assessment section under Watershed Description (p. 29) includes the avulsion of the East Fork Lewis River into the Ridgefield gravel pits and its influence on sediment load and supply. We recognize that channel morphology affects temperature in the lower reaches of the East Fork Lewis River. The results of this study showed that temperature exceedances were not limited to the lower watershed, and the middle watershed (RM 7-15) also had high temperature exceedances and a large shade deficit.

Comment #2
We will pass this comment on to Clark County. The Department of Ecology is working to improve water quality in many waterbodies in the state. There are thousands of waterbodies in the state that do not meet our water quality standards. Cleaning up the water to meet those standards will take the combined effort of everyone involved. Climate change and population growth will make this work even harder. Our efforts, your efforts, and the efforts of others on the East Fork Lewis River will help improve this river.

Comment #3
Comment noted. See response to Comment 1.

Comment #4
Yes, we agree that trees have more impact on narrow reaches and less impact on wide and shallow reaches. Other types of restoration is needed as well: restoring and protecting wetlands, flood plains, riparian habitat, cold water refuges, and other restoration projects (especially salmon-related efforts). We added text to the Recommendations section of the report.

Comment #5
Comment noted. See response to Comment 1.

Comment #6
Due to resource constraints, we did not sample this creek for fecal coliform or temperature. We understand the importance of Mill Creek to coho and steelhead fisheries, and the lack of sampling is not intended to suggest that it is not an important resource.

Comment #7
Fish First and the Healing Waters Veterans Group were added to the Current Restoration Efforts section in the report. Friends of the East Fork Lewis River are included in this section as well. The work of these and other organizations is very important to the long-term improvements in the EF Lewis River.

Comment #8
Ecology appreciates your work with East Fork Lewis River, and we worked to incorporate many of the studies that have focused on findings that influence the temperature and fecal coliform bacteria water quality impairments in the watershed for this project.

Comment #9
This work analyzed the data from a large field collection effort conducted in 2005-06, in addition to some 2017 bacteria sampling. This work focused on fecal coliform bacteria sampling and temperature monitoring following Ecology’s Standard Operating Procedures and Quality Assurance Project Plans. We appreciate and support your ongoing monitoring and efforts to improve the river.

Andrew,

Thank you for the opportunity to review and provide feedback on the February 2018 draft EF Lewis River Watershed Bacteria and Temperature Source Assessment Report. The LCFRB provides the following comments and questions:

- Figure 4: were the spawning/incubation criteria areas in this map based upon recent monitoring data provided by WDFW or other sources?
- Stream gage and surface water – groundwater exchange study sites are all in the mainstem EF Lewis River, yet tributaries can provide important habitat to listed salmon and steelhead. How were flows (or lack of flows) in tributaries accounted for through this assessment?
- We appreciate the SalmonPORT reference in the section "Current Restoration Efforts", but recommend that projects and actions identified through the watershed management plan and Lower EF Lewis habitat strategy process are also referenced or provided. Additionally, we encourage Ecology to closely review and incorporate pertinent technical information and analyses from the WRIA 27/28 Watershed Management Plan.
- In the "Additional information and data" section, the Lower EF Lewis Habitat Assessment reference should note that a diverse set of stakeholders participated in this process as the assessment development involved more than Cramer Fish Sciences and the LCFRB.
- Although general guidance related to Best Management Practices and outreach are provided later in the document, more details on how to best obtain the recommended targets would improve certainty and efficiency in planning for and reaching these goals in the "Reduced Fecal Coliform and Improve Water Quality recommendations" section.
- This draft does not incorporate predicted climate change impacts to water quality and quantity, yet studies suggest that temperature and hydraulic regimes will change this century.
- The report states that the quantity of cold water refuges should be increased. We recommend that habitat quality is incorporated into this statement, as cold water is only one aspect of quality salmon and steelhead rearing and spawning needs. Additionally, we recommend that the reference to "salmon and other fish species" is either changed to "salmonids and other fish species" or "salmon, steelhead and other fish species".
- The report states that restoration projects and activities should be continued. We suggest that conservation is added to this statement as protecting already functioning habitat can also support salmon recovery and watershed health efforts.

Thank you,

--Amelia Johnson
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Bullet #1
The map in Figure 4 is from the state's water quality standards (WAC 173-201A). These maps were last updated before 2011. Ecology has to conduct a rule revision to update these water quality criteria.

Bullet #2
Yes, the surface water and groundwater exchange study focused on reaches of the mainstem of the East Fork Lewis River. Flow measurements were taken at the mouth of major tributaries to create a mass balance of water for the East Fork Lewis River that was used to estimate groundwater inflows and outflows (Carey and Bilhimer, 2009). This study did not focus on seasonal tributary flows, although we recognize the importance of tributaries for habitat of salmonids and other fish species.

Bullet #3
As we move forward with implementation in the EF Lewis River, we will consult the WRIA 27/28 Watershed Management Plan and talk with agencies working in the watershed such as the LCFRB. Working with our partners to support projects that achieve our collective goals will be critical for success in the watershed.

Bullet #4
Comment noted, section was revised.

Bullet #5
This next level of detail will be determined as we progress with the program to improve water quality in the East Fork Lewis River. We will work with our partners in the watershed to identify and correct specific sources of bacteria. Likewise, we will use the general guidance in the report to work with partners to conduct restoration activities to lower water temperature in the river.

Bullet #6
We agree that temperature and hydraulic regimes will change due to climate change in future years, however this study did not model the influence of climate change on the East Fork Lewis River. The focus of this study was to understand areas with high temperatures and elevated levels of fecal bacteria sampling based on 2005-06 and 2017 data. The impacts of climate change make the work of all stakeholders in the watershed even more important. Site-specific improvements in river function can help counteract the impacts of climate change.

Bullet #7
Language that incorporates habitat quality into recommendations regarding improving the number of cold water refuges was added. Language was also changed to "salmonids and other fish species" throughout the report.

Bullet #8
These statements were updated to include conservation projects as well.

Appendix K. Glossary, Acronyms, and Abbreviations

Glossary

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Critical conditions: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either (1) taking the n^{th} root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from the distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum and minimum thermometers or continuous monitoring probes having sampling intervals of 30 minutes or less.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days prior and the three days after that date.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every 10 years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

Acronyms and Abbreviations

BMP	Best management practice
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EF	East Fork
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform bacteria
GIS	Geographic Information System software
LCFRB	Lower Columbia Fisheries Recovery Board
MEL	Manchester Environmental Laboratory
NSDZ	Near stream disturbance zone
NPDES	(See Glossary above)
QA	Quality Assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedure

SRM	Standard reference materials
STP	Sewage treatment plant
TMDL	(See Glossary above)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
ft	feet
km	kilometer, a unit of length equal to 1,000 meters
m	meter
mL	milliliters