Appendix A. Background

Clean Water Act and TMDLs

What is a Total Maximum Daily Load (TMDL)

A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to develop and maintain water quality standards that protect, restore, and preserve water quality. Water quality standards consist of (1) a set of designated uses for all water bodies, such as salmon spawning, swimming, and fish & shellfish harvesting; (2) numeric and narrative criteria to achieve those uses; and (3) an antidegradation policy to protect high quality waters that surpass these conditions.

The Water Quality Assessment and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet water quality standards. This list is called the CWA 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. Ecology reviews all data in this WQA to ensure that they were collected using appropriate scientific methods before using them to develop the assessment. The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list.

Category 1 – Meets standards for parameter(s) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

Category 4 – Polluted waters that do not require a TMDL because:

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website[1].

The CWA requires that a total maximum daily load (TMDL) be developed for each of the water bodies on the 303(d) list.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. A TMDL study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water standards. Ecology, with the assistance of local governments, tribes, agencies, and the community, then develops a plan to control and reduce pollution sources, as well as a monitoring plan to assess effectiveness of the water quality improvement activities. This comprises the water quality improvement report (WQIR) and implementation plan (IP). The IP section identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

After the public comment period, Ecology addresses the comments as appropriate. Then, Ecology submits the WQIR/IP to the U.S. Environmental Protection Agency (EPA) for approval.

Watershed Description

Geographic setting

The Little Spokane River watershed is located in the northeastern part of Washington, with a small amount of the drainage area originating in Idaho. The Little Spokane River begins near Newport, and flows approximately 52 miles to its confluence with the Spokane River, at the head of Lake Spokane. The total watershed area is approximately 710 mi^2, which includes 417 mi^2 in Spokane County, 180 mi^2 in Pend Oreille County, 91 mi^2 in Stevens County, and 21 mi^2 in Bonner County, Idaho. However, the watershed boundary in Idaho is ambiguous due to some flat "saddle" areas in the Spring Valley/Blanchard/Hoodoo area. For this study, we are considering only the watershed within Washington State, which is designated as Water Resource Inventory Area (WRIA) 55.

The Little Spokane watershed includes a wide variety of landforms, including mountainous areas, foothills, valley bottoms, and wetlands. The section of the river from the upstream boundary of the state park near Rutter parkway to the mouth is designated as a Washington State Scenic River System.

The Little Spokane River is unusual in that its headwaters originate in a low elevation valley near Newport. Thus, the mainstem Little Spokane River is a low-elevation stream for its entire length. However, the watershed does contain high-elevation areas, and many tributaries drain these areas. These include Deer Creek, Little Deep Creek, and Deadman Creek, which drain the west and south slopes of Mount Spokane (5867 ft), as well as Buck Creek and Heel Creek, which drain the southern slopes of Boyer Mountain (5277 ft).

[1] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

The geology of the Little Spokane watershed is highly complex. High elevation areas along the west, north, and east edges of the watershed are formed by mostly granitic bedrock. In the southern portion of the watershed, a number of bluffs including Orchard Bluff, Green Bluff, and Five Mile Prairie are formed by remnants of Columbia Basin basalt flows, topped by Palouse loess soil. Low elevation areas, encompassing the majority of the watershed, are formed by material deposited and shaped by glacial floodwaters. During the last ice age, much of the basin was inundated by Glacial Lake Spokane. Additionally, toward the end of the ice age, the present-day Little Spokane basin was a route for floodwaters rushing from Glacial Lake Missoula toward the Columbia Basin. Detailed information about the hydrogeology of the Little Spokane River basin can be found in the report by the USGS (Kahle, et. al, 2013).

Figure A-1 shows the landforms in the Little Spokane River watershed.

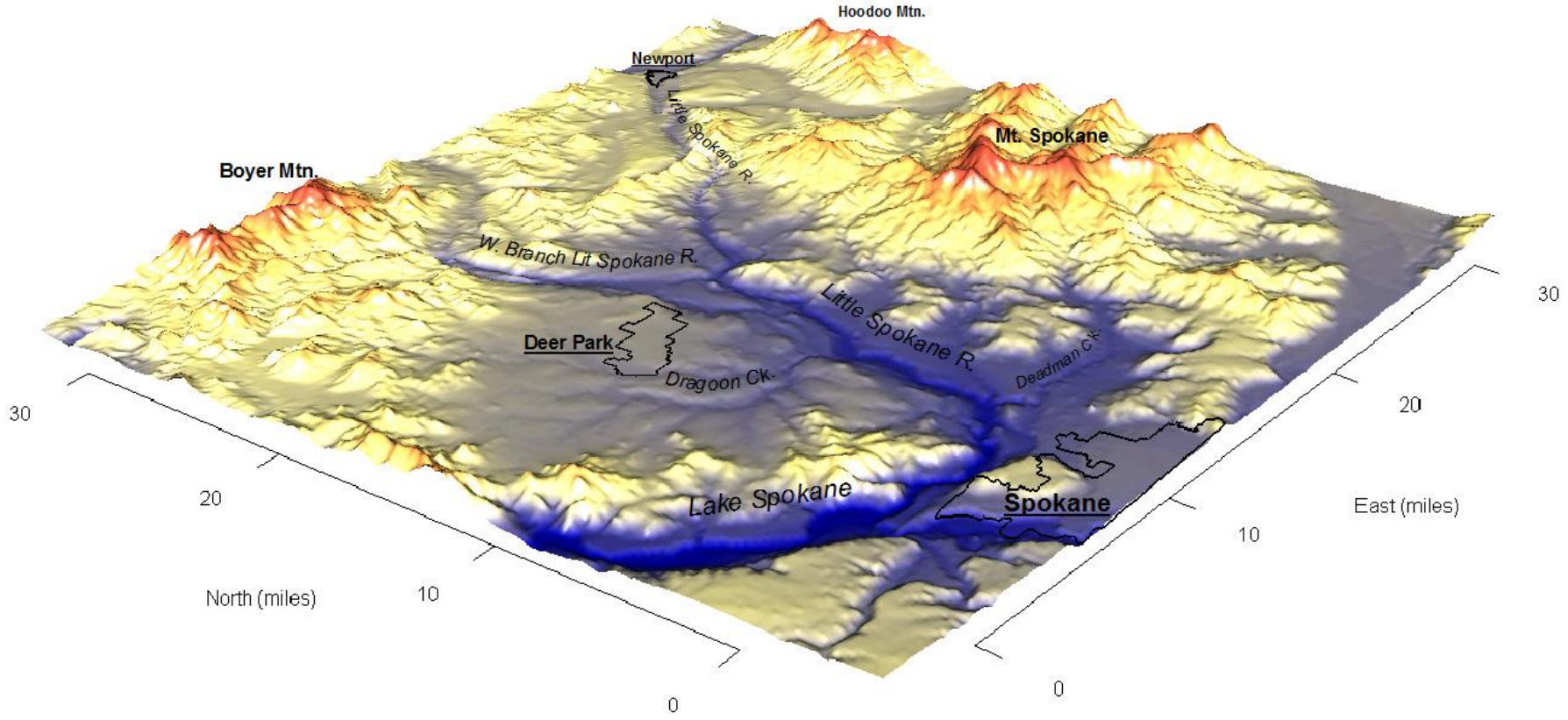


Figure A-1. Schematic showing landforms in and around the Little Spokane River watershed

Climate

The Little Spokane Watershed is located within, but near the edge of the Northern Rockies ecoregion. The climate is transitional between the arid climate of the Columbia Basin and the cold, wet climate of the mountain chains of far northeast Washington and northern Idaho. Average annual precipitation ranges from around 15 inches per year in the southern part of the watershed to around 40 inches per year at the top of Boyer Mountain. Normal summertime high temperatures at Deer Park range from 71°F (22°C) to 86°F (30°C), with temperatures occasionally exceeding 100°F (38°C). Winters are cold and snowy, with normal temperatures at Deer Park during December and January ranging from 18°F (-8°C) to 36°F (2°C).

Hydrology

The hydrology of the Little Spokane River is complex, with groundwater-surface water interactions playing a defining role. The Little Spokane River begins as a set of springs at Penrith, located approximately 4 miles southwest of Newport. Additional springs contribute streamflow upstream of Scotia Gap, where the Little Spokane River passes in a narrow canyon through an east-west range of hills. Relatively steady streamflow in the upper portion of the Little Spokane River reflect the spring-fed character of this part of the stream.

The geology of the basin has produced some unusual features. The northeast boundary of the watershed in the Spring Valley/Blanchard area south of Newport is difficult to delineate. Watershed boundaries cross very flat valleys, so it's unclear exactly where flow splits northwest towards the Little Spokane River or southeast towards Spirit Lake. In addition, tributaries draining from the eastern mountains often "disappear" below the surface when the streams hit the alluvial valley bottom and then reappear as springs closer to their confluence with the Little Spokane River.

A number of lakes are located in the northern half of the watershed. These include Chain Lake, located along the upper part of the main stem of the Little Spokane River, as well as Diamond, Sacheen, Trout, Horseshoe, and Eloika Lakes, located along the West Branch Little Spokane River. The West Branch LSR also includes large areas of wetlands.

Between Elk and Dartford, the increase in streamflow comes primarily from tributaries, particularly the West Branch Little Spokane River (14% of total watershed area), Dragoon Creek (25% of total watershed area), and Deadman Creek (17% of total watershed area). However, groundwater also discharges directly to the stream in much of this reach, providing a significant contribution to baseflows in the summer months.

Downstream of Dartford, the Little Spokane Valley cuts across a north-flowing lobe of the Spokane Valley – Rathdrum Prairie (SVRP) aquifer. In just a few miles, the SVRP aquifer contributes approximately 250 cfs to the flow of the Little Spokane River, approximately tripling streamflow during the late summer months. These inflows can readily be observed as the differences between two USGS gages, illustrated in Figure A-2. Several surface springs flow into the Little Spokane from the hillside south of the river in this area, the largest being Waikiki and Griffith Springs.

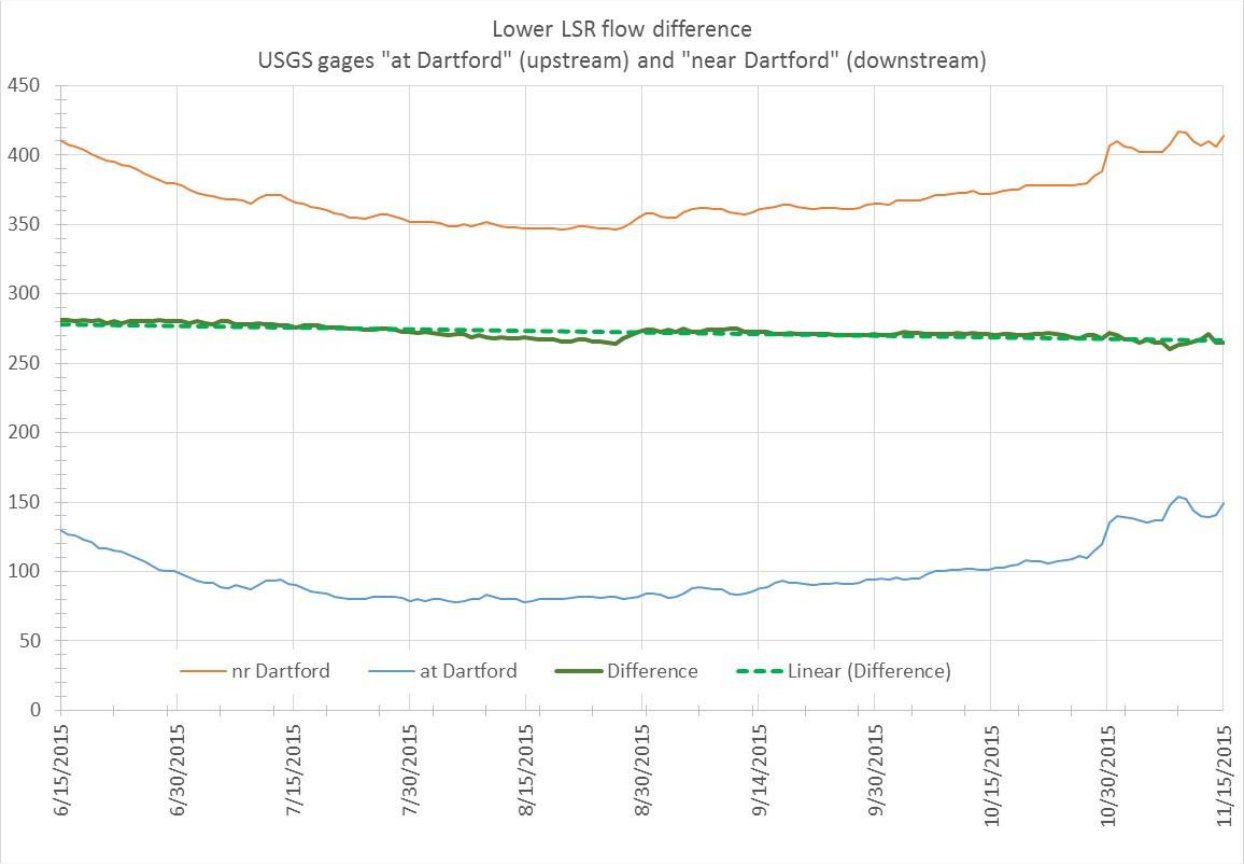


Figure A-2. Little Spokane River flow at two USGS stations, illustrating inflows from the Spokane Valley – Rathdrum Prairie Aquifer.

The United States Geological Survey (USGS) currently operates three streamflow gages on the Little Spokane River:

- Gage #12427000, "Little Spokane River at Elk, WA", is located at Elk Park, in the upper part of the watershed above the confluence with the West Branch Little Spokane River.
- Gage #12431000, "Little Spokane River at Dartford, WA", is located where Hwy 395 crosses the river, next to the Wandermere Golf Course. This gage captures most of the watershed and all of the major tributaries, but is located upstream of the large groundwater inputs from the SVRP aquifer.
- Gage #12431500, "Little Spokane River near Dartford, WA" is located at the Rutter Parkway bridge (Painted Rocks). This gage captures streamflow conditions below the SVRP aquifer groundwater inputs.

Spokane Conservation District (SCD) and Spokane Community College (SCC) have operated additional streamflow gages in the watershed. See Figure 13 for a map of all streamflow gage locations.

Figures A-3 through A-8 show box-plots of monthly flows at the three USGS gaging stations in the Little Spokane River, and at three stations in the West Branch Little Spokane River, Dragoon Creek, and Deadman Creek where Ecology and the Spokane Conservation District have monitored flows. Throughout the watershed, annual streamflow variability is low compared to

many other streams in eastern Washington. This is likely a result of strong groundwater-fed baseflows, variable timing of snowpack release from different elevations and landforms, and water storage by wetlands.

We evaluated trends in the annual minimum 7-day average summer low flow in the Little Spokane River at Dartford using the same methodology as Ecology's summer low flow trend indicator[2]. We determined the annual minimum summer 7-day average low flow for each year beginning in 1975. We then evaluated the trend with a linear regression between year and annual minimum flow, and with a Mann-Kendall (M-K) nonparametric trend test. The p value shows the probability that the trend is random, so the lower the p, the stronger the trend's significance.

Figure A-9 shows the results of this trend regression and statistical analysis. The slope of the regression trend shows the long-term change in low flows, and when divided by the average low flow over 44 years provides a percent change per year. Since 1975, 7-day summer low flows have declined by an average of 10.8 cfs, or about 0.2% per year. This trend can be considered to be "weakly significant" ($0.1<p<0.5$) – in other words, "more likely than not" the trend is real and not random.

[2] https://data.wa.gov/Natural-Resources-Environment/Summer-Low-Flow-Trend-Indicator-1975-2013/hdw4-yhs4

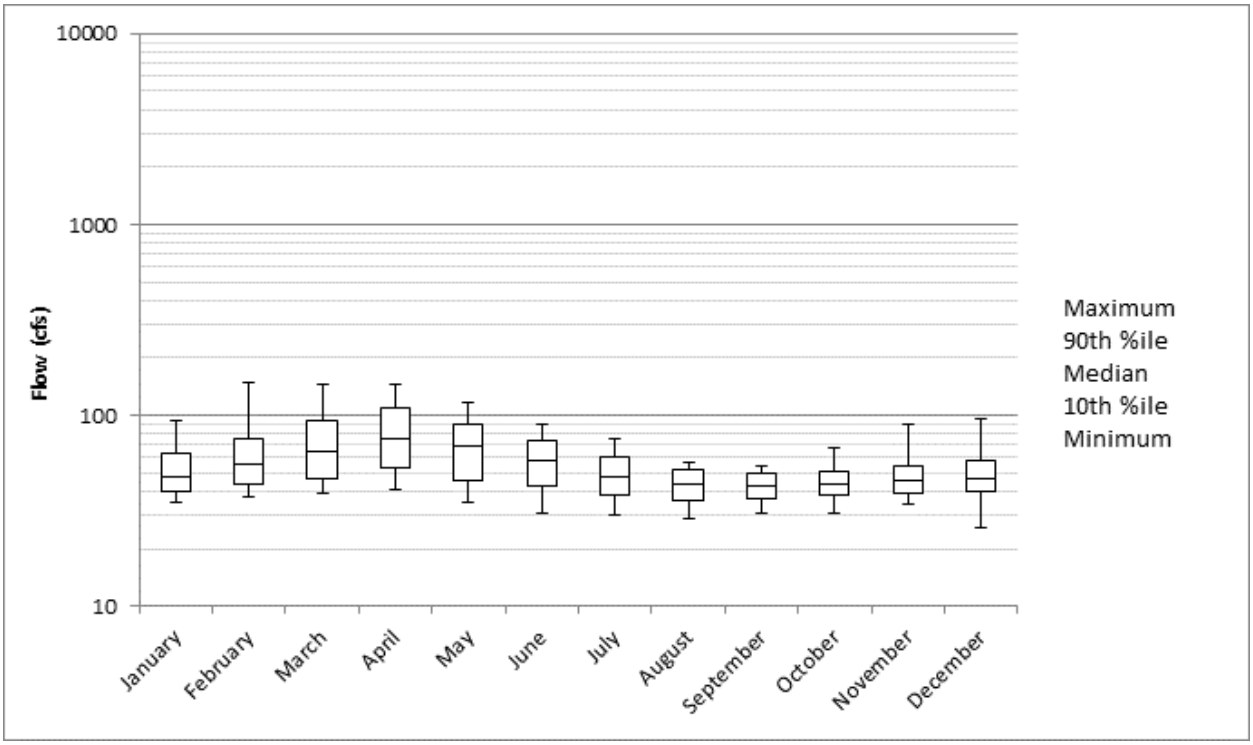


Figure A-3. USGS stream-gage monthly flow statistics for the Little Spokane River at Elk.
Flows are plotted on a log-scale

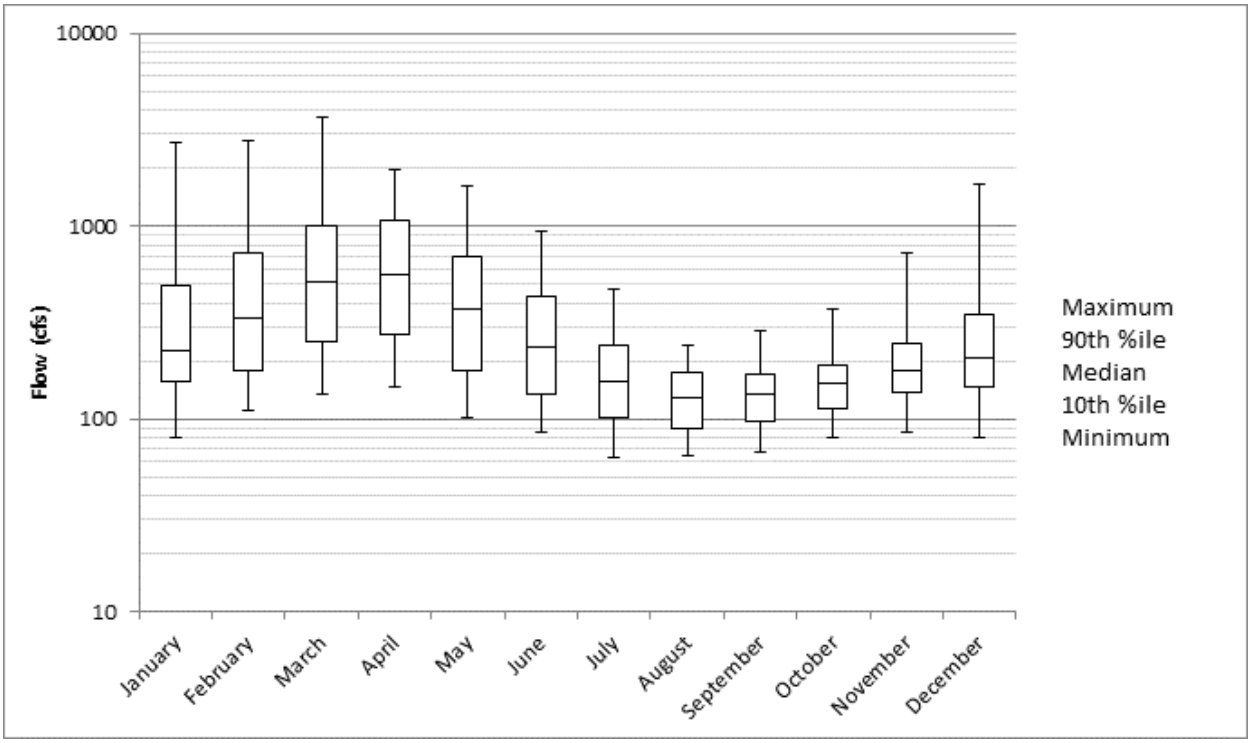


Figure A-4. USGS stream-gage monthly flow statistics for the Little Spokane River at Dartford.
Flows are plotted on a log-scale

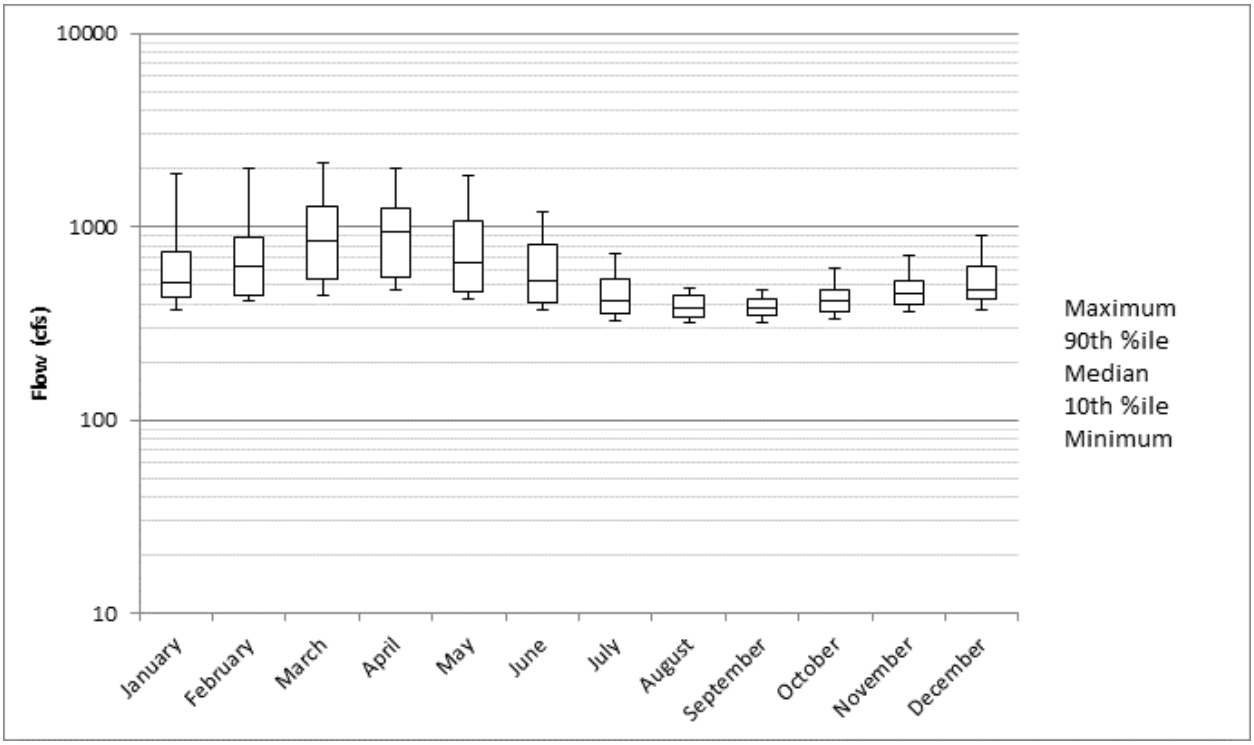


Figure A-5. USGS stream-gage monthly flow statistics for the Little Spokane River near Dartford (Painted Rocks).
Flows are plotted on a log-scale.

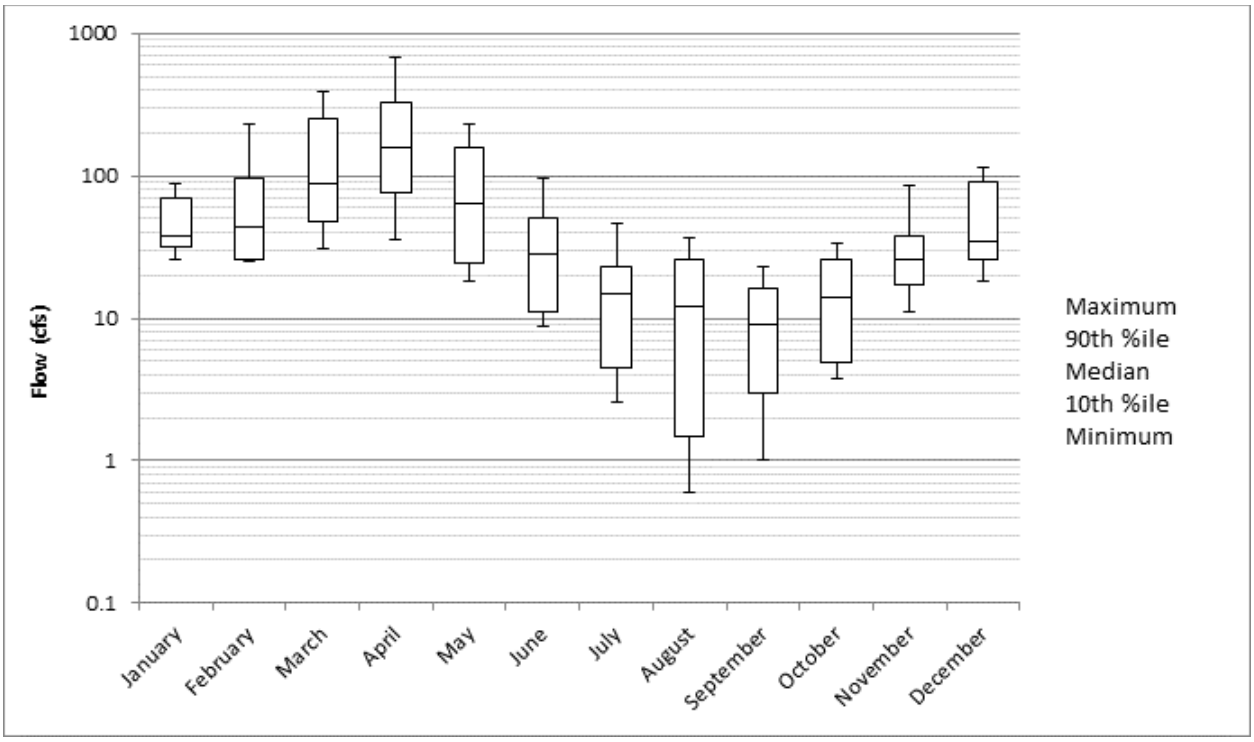


Figure A-6. Spokane CD/Ecology stream-gage monthly flow statistics for the West Branch Little Spokane River at the outlet of Eloika Lake.
Flows are plotted on a log-scale.

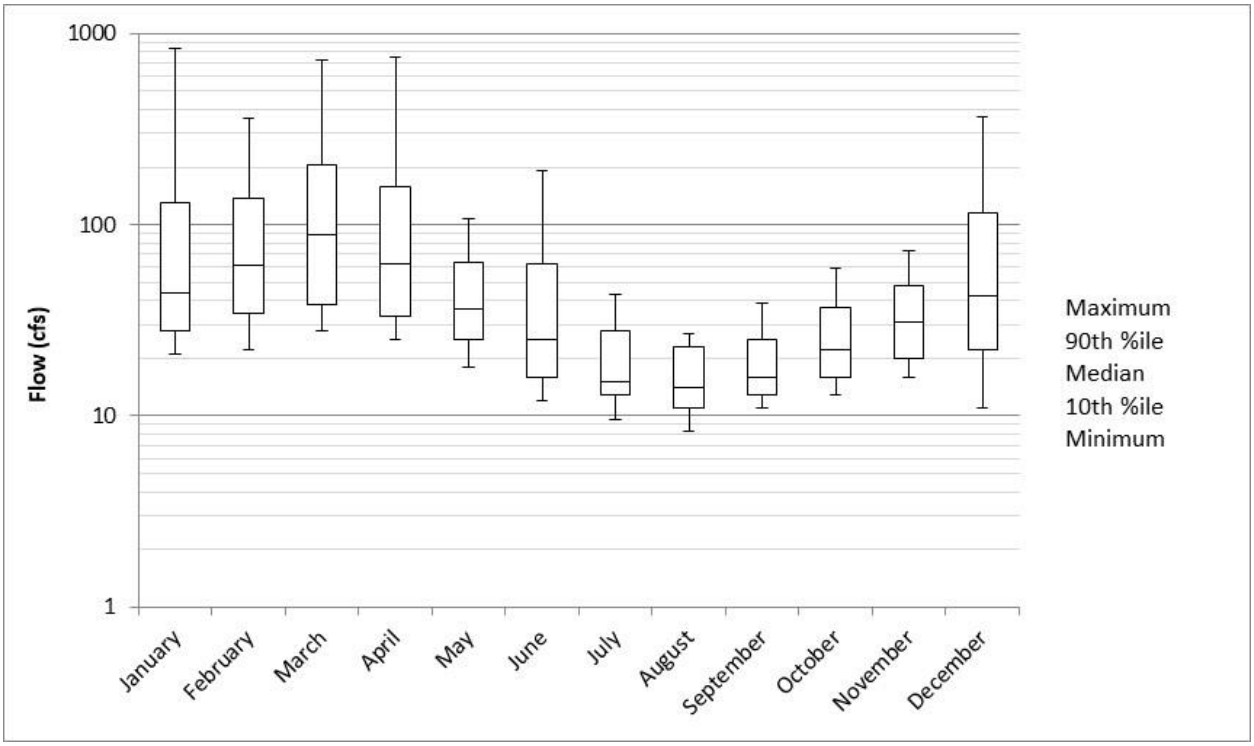


Figure A-7. Spokane CD/Ecology stream-gage monthly flow statistics for Dragoon Creek at the mouth.

Flows are plotted on a log-scale.

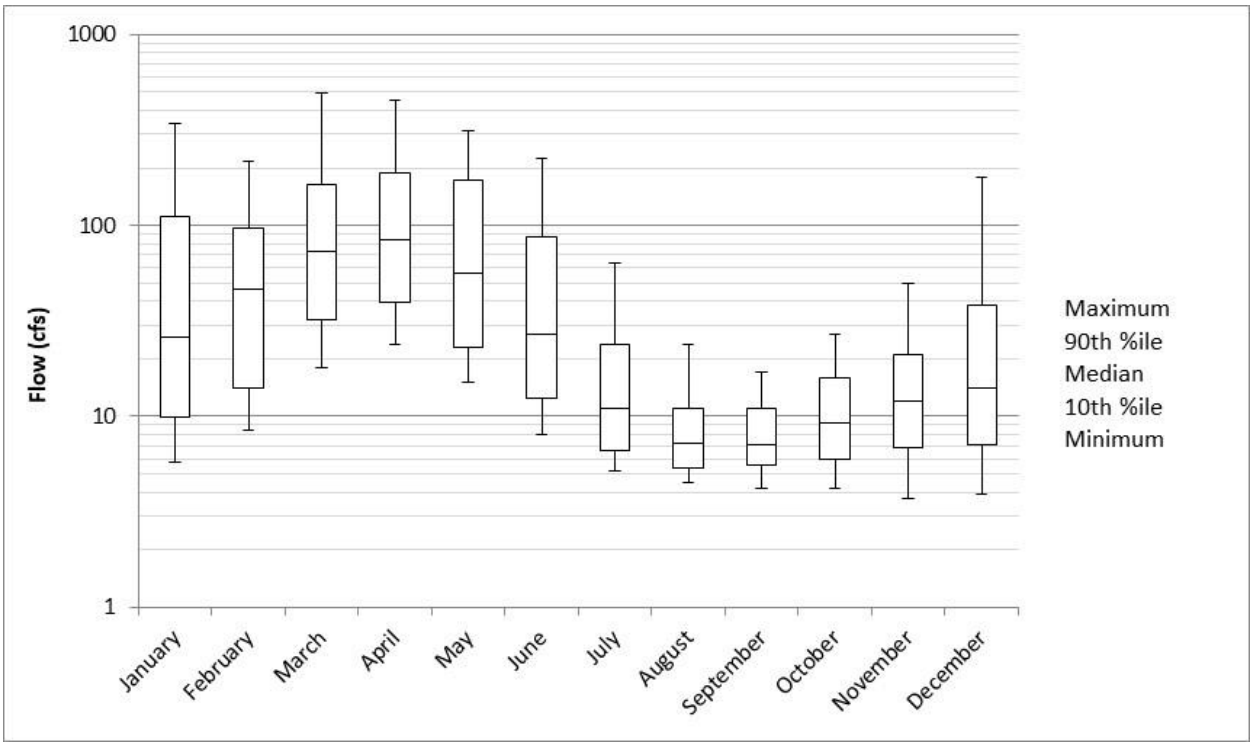


Figure A-8. Spokane CD/Ecology stream-gage monthly flow statistics for Deadman Creek near the mouth.

Flows are plotted on a log-scale.

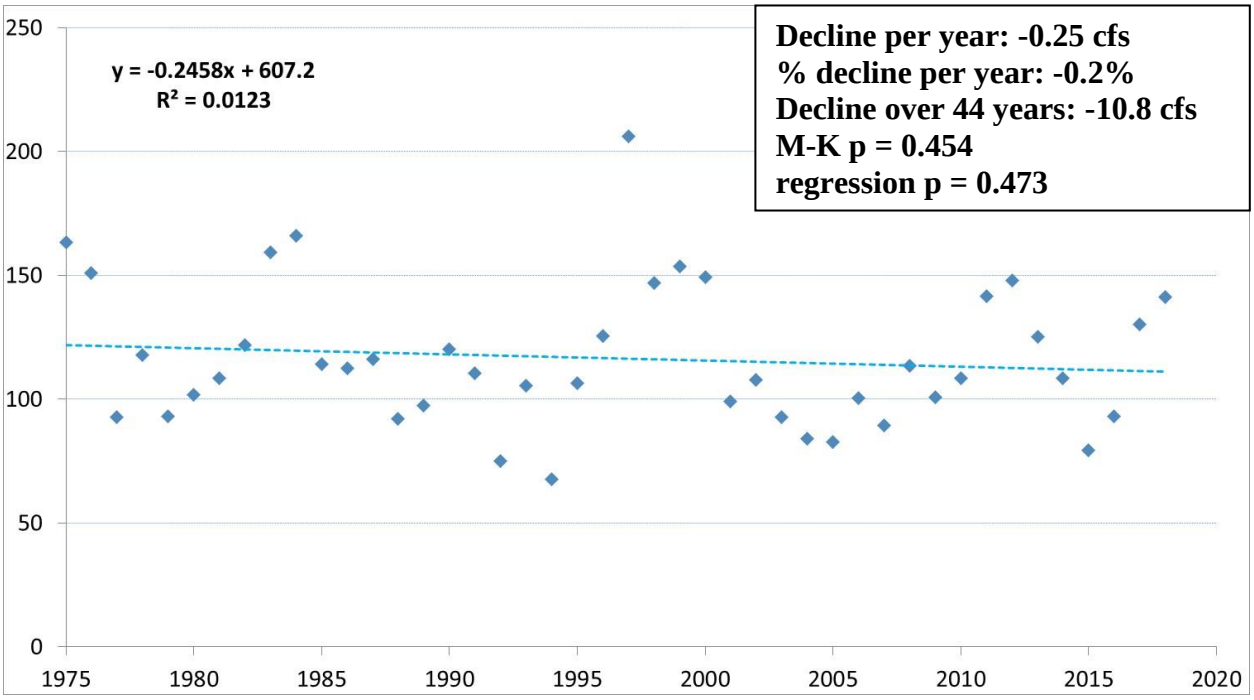


Figure A-9. Summer annual minimum 7-day average low flow trends in the Little Spokane River at Dartford.

Land use and potential pollutant sources

Most of the Little Spokane River watershed is primarily a rural landscape consisting of forested ridges, small agricultural valleys, small urban centers, and abundant wildlife. Agricultural activities are most concentrated in the Dragoon Creek and Deadman Creek sub-watersheds. Dairies and larger livestock operations are located in the Dragoon Creek, upper mainstem LSR, and Deadman Creek sub-watersheds. Urban influence from the city of Spokane's residential, commercial, and industrial developments are mostly evident in the Lower LSR sub-watershed and along the lower Deadman and Little Deep Creek drainages. Figure A-10 shows general land use patterns in the Little Spokane River watershed.

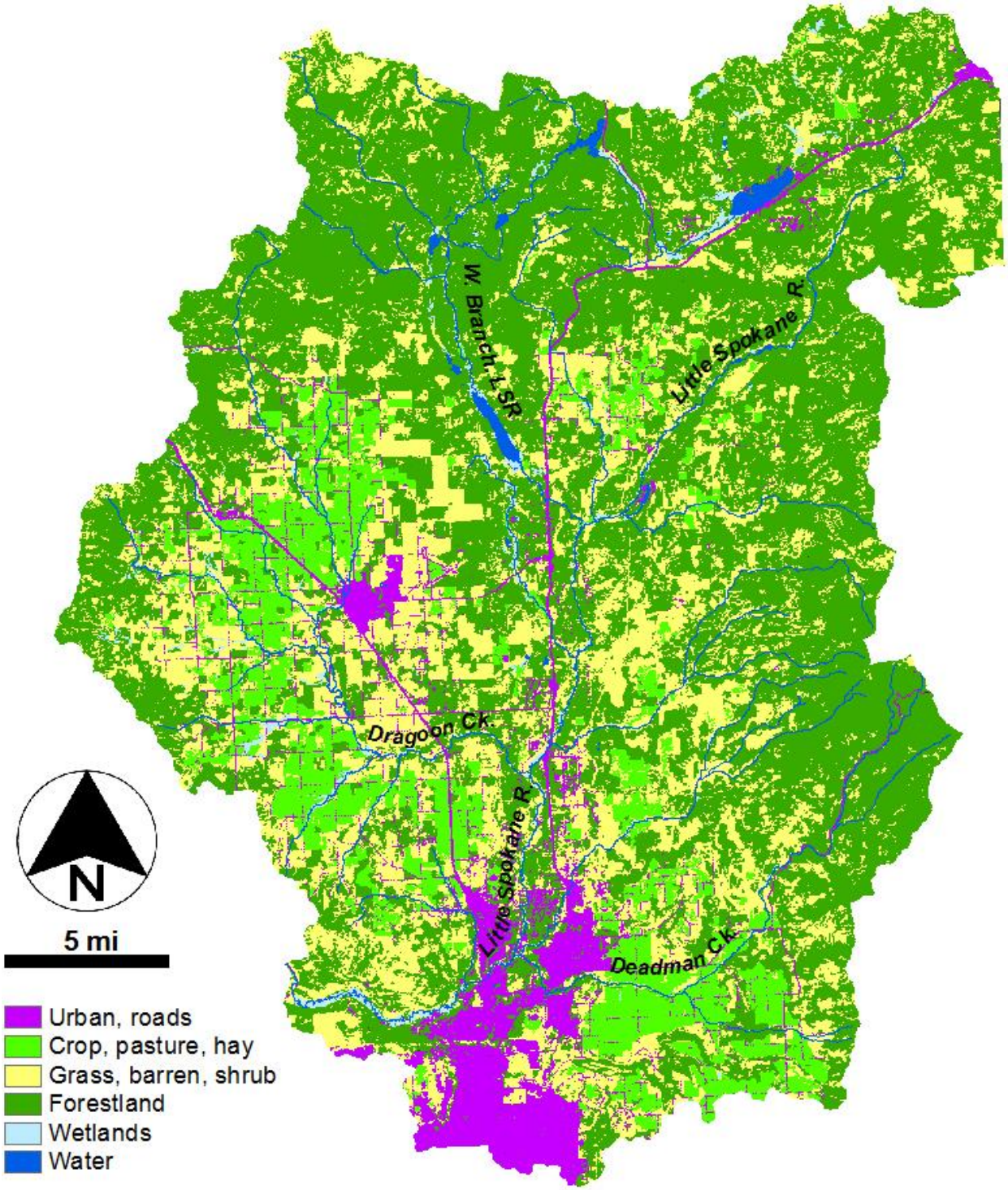


Figure A-10. Map showing land use in the Little Spokane River watershed.
Source: National Land Cover Database, 2006 (USGS, 2006).

Agricultural areas

Agricultural land use comprises about 27% of the watershed area. This varies considerably throughout the watershed – 48% the Dragoon Creek subbasin and 35% of the Deadman Creek subbasin are agricultural, as compared to 5% of the West Branch LSR subbasin. Agricultural activities include orchards, hay, grain, rotational crops, and livestock. Historically, farming has impacted the LSR by removing riparian habitat and draining wetlands to raise crops. Farming practices potentially increase the nutrient loads when fertilizer or manure are allowed to reach the stream through runoff or groundwater. Pesticide contamination is another possible result of poor agricultural practices. Some livestock owners in the watershed have not prevented their animals from trampling the banks of the river or contaminating the stream and banks directly with their urine and feces, which contain high concentrations of nutrients.

Residential areas

Population growth and increased residential development have especially impacted the Lower LSR sub-watershed. Approximately 24% of the land in the watershed area below the confluence with Deadman Creek (the last 13 miles of the Little Spokane River) is designated urban. Under the Spokane County Comprehensive Plan, all land immediately adjacent to the LSR is designated Rural Conservation. Other than the urban areas surrounding Riverside, Mead, Colbert, Chattaroy, and Eloika, the remainder of the land in the LSR watershed in Spokane County is designated Rural Conservation, Rural Traditional, Forest Land, or Small Tract Agriculture. These designations have a minimum lot size of 10 to 20 acres. But if the land was divided into smaller lots prior to the adoption of the Comprehensive Plan, the lots are still available for development. North of the Spokane metropolitan area, there are a number of smaller residential areas, including Deer Park (population 3704), and Newport (population 2115), as well as small communities including Clayton, Chattaroy, Riverside, and Elk. In addition, residential development surrounds certain lakes, particularly Diamond and Sacheen.

Residential and commercial development within the watershed decreases the amount of land surface that is able to absorb moisture from rain and snowfall. Paved roadways and rooftops are impervious (impenetrable) surfaces that cause stormwater to run quickly off the landscape. Moisture is no longer stored within the topsoil and groundwater but instead enters the creeks and rivers quickly, causing flooding for short periods followed by reduced water flow over extended periods. Peak flows occur more frequently, increasing the erosive force and downstream sedimentation, as well as affecting groundwater infiltration and storage volumes. Ecology has issued stormwater permits for these urbanized areas to the city of Spokane, Spokane County, and Washington State Department of Transportation (WSDOT).

Lawn and garden care in residential neighborhoods can impact the quality of the river by the misuse or overuse of chemical fertilizers and pesticides. These fertilizers and insecticides can run off to the river during rain events or with over watering. Some property owners adjacent to the waterways dump lawn clippings and other vegetative debris next to, or in, the river where it is washed down during high-flow events.

Residential areas on the edge of urban development are frequently beyond the areas served by sewage waste treatment facilities. Septic systems are designed to remove the solids and allow the water to enter the soil, where nutrients should be retained by plants or soil particles. Improperly

designed, poorly maintained, or failing septic systems increase pollutant delivery to surface water via contamination of shallow groundwater supplies or even surface run-off.

As population and development increase in the watershed, construction sites can pose problems by destabilizing soils and increasing sedimentation, causing changes in streamflows. These sites also compact the soil, creating less pervious surfaces that increase runoff that could result in flooding. Runoff can carry eroded soil with attached nutrients to nearby waterways. Planning and installing stormwater infrastructure systems help protect surface waters from stormwater runoff (Figure A-11).

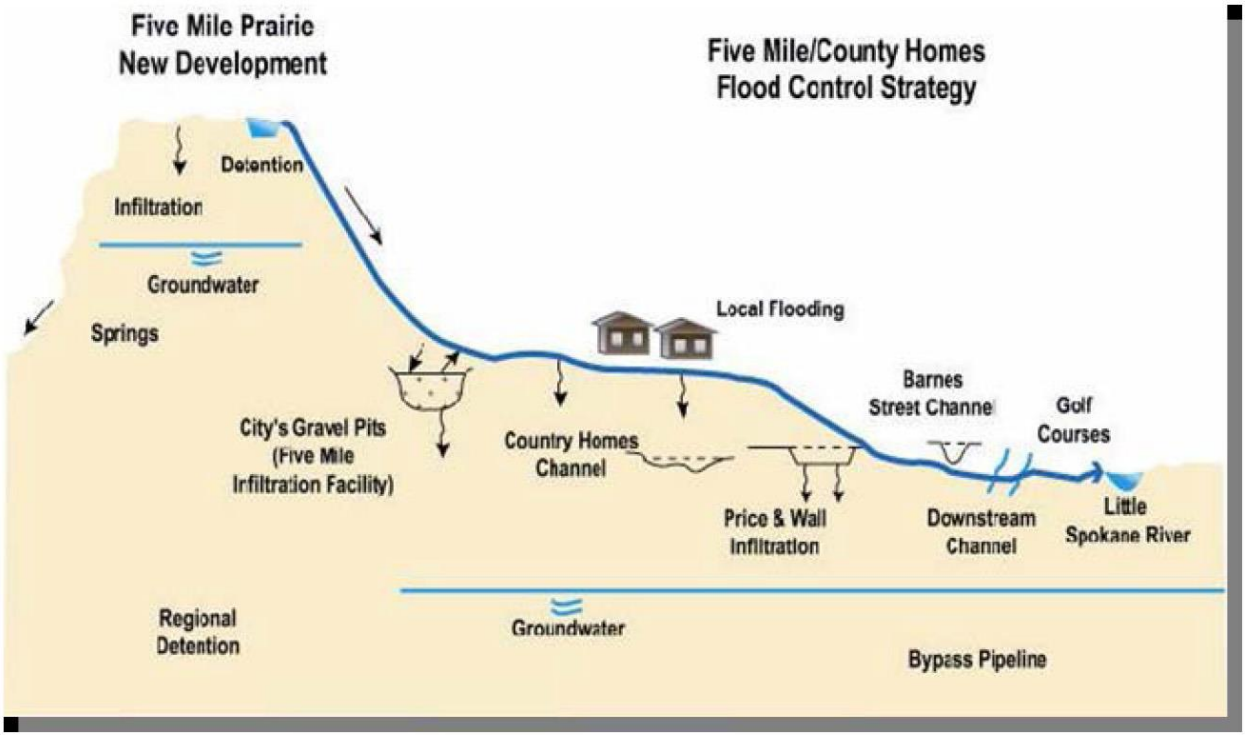


Figure A-11. An example of stormwater treatment methods used in the urbanizing areas of the Little Spokane River watershed (Spokane County, 2009c)

Forested areas

About 2/3 of the land in the LSR watershed is forest. Forested land stabilizes hillsides, provides habitat for a variety of wildlife, and keeps streams cool. Logging, if not done properly, has the potential to destabilize soils and eliminate habitat. Logging activities close to wetlands can impact water quality. Along with possible wetland destruction, the construction of roads can be very damaging to streambeds, resulting in increased sedimentation in the stream. Nutrients are typically attached to sediment which erodes into streams.

Reforestation along streams in the LSR watershed is essential to not only decrease temperature so the water can hold more dissolved oxygen, but also to stabilize streambanks to reduce nutrient-laden sediment wasting to the streams. Streambank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land-cover type and condition by (1) affecting flood plain and instream roughness, (2) contributing coarse

woody debris, and (3) influencing sedimentation, stream substrate compositions, and streambank stability. Decreased erosion is the benefit of stable streambanks.

Permitted facilities

Relative to its size and proximity to the city of Spokane, there are few facilities in the LSR watershed with NPDES permits. Several small communities in the watershed use individual on-site septic tanks. Table A-1 lists facilities with NPDES Permits, or state General Permits. All dairies in the Little Spokane are unpermitted; there are no CAFOs.

Table A-1. Wastewater and stormwater permits in the Little Spokane River watershed.

Permittee	Permit Number	Permit Type	Location	Receiving water
WDFW Spokane Hatchery	WAG137007	Upland Fish Hatchery GP	Spokane	Little Spokane River
Colbert Landfill	TCP Cleanup	Cleanup Groundwater	Colbert	Little Spokane River
Spokane County Muni SW	WAR046506	Municipal SW Phase II Eastern WA GP	County Urban Growth Area	Little Spokane River, Deadman Creek, Little Deep Creek, Dartford Creek
Washington State Dept. of Transportation	WAR043000A	Municipal SW GP	Any WSDOT highways or facilities within the County Urban Growth Area	Little Spokane River, Deadman Creek, Little Deep Creek
Spokane Recyling (Former Kaiser Site)	WAR304975	Industrial SW GP	Spokane	Deadman Creek
First Student 22018	CNE126283	Industrial SW GP	Chattaroy	To ground
Durham School Services Newport	WAR127295	Industrial SW GP	Newport	To ground
Darigold	WAR301800	Industrial SW GP	Spokane	Spokane River via City of Spokane MS4 system; does not stay in LSR watershed.
Deer Park STP	ST0008016	Municipal to ground SWDP IP	Deer Park	To ground
Diamond Lake STP	ST0008029	Municipal to ground SWDP IP	Newport	To ground
Sacheen Lake Water & Sewer District	ST0501294	Municipal to ground SWDP IP	Newport	To ground
Various Construction Stormwater	Various	Construction Stormwater GP	Various	Various surface and ground
Various Sand and Gravel Permits	Various	Sand and Gravel GP	Various	To ground
Those shown in yellow do not discharge or discharge to ground and therefore do not require a WLA. This is equivalent of a zero WLA to surface water.				

Water Quality Issues

Monitoring conducted by a variety of entities, including Pend Oreille Conservation District, Spokane Conservation District, Washington State University, and Ecology, has resulted in listings for several parameters within the Little Spokane watershed. These include temperature, turbidity, bacteria, total phosphorus, ammonia-N, chlorine, dissolved oxygen, pH, polychlorinated biphenyls (PCBs), and 4, 4'-DDE. The *Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity TMDL* (Joy and Jones, 2012) addresses the temperature, turbidity, and bacteria listings. The *Dragoon Creek BOD TMDL* (Jones, 1993) addresses the total phosphorus, ammonia-N, and chlorine listings. This TMDL addresses the DO and pH listings.

The Little Spokane River is also listed as impaired for polychlorinated biphenyls (PCBs) and Fan Lake is listed as impaired for 4, 4'-DDE (a breakdown product of DDT). This report does not address these listings because the potential sources of these pollutants are unrelated to pollutant sources contributing to low dissolved oxygen and high pH. The Spokane River Regional Toxics Task Force is working to characterize sources of toxics in the Spokane River watershed to facilitate the implementation of appropriate actions needed to meet applicable water quality standards for PCBs and other toxics.

The **Introduction** section in the main report body lists all DO and pH listings addressed by this TMDL.

Protection of Designated Uses and Downstream Waterbodies

Washington water quality standards require upstream actions to be conducted in a manner that meets downstream water body criteria. The standards also require that the most stringent water quality criteria apply where multiple criteria for the same water quality parameter are assigned to a water body to protect different uses and at the boundary between water bodies protected for different uses.

The water quality standards language in WAC 173-201A-260(3)(b)-(d) states:

> (b) Upstream actions must be conducted in manners that meet downstream water body criteria. Except where and to the extent described otherwise in this chapter, the criteria associated with the most upstream uses designated for a water body are to be applied to headwaters to protect nonfish aquatic species and the designated downstream uses.
>
> (c) Where multiple criteria for the same water quality parameter are assigned to a water body to protect different uses, the most stringent criterion for each parameter is to be applied.
>
> (d) At the boundary between water bodies protected for different uses, the more stringent criteria apply.

In developing TMDLs, Ecology routinely identifies and considers all designated uses (also described as beneficial uses) of the impaired waterbody and waterbodies directly downstream of the impairment. This is done to ensure the chosen TMDL target and associated allocations will protect all designated uses and downstream designated uses.

The **Introduction** section in the main report body lists the designated uses that apply to the Little Spokane River watershed. Only aquatic life uses have specific criteria for dissolved oxygen and pH. The Core Summer Salmonid Habitat designated use applies to the entire watershed. The allocations in this TMDL are based on meeting the more stringent of the DO and pH standards for this beneficial use, in any given location.

In addition to protecting the designated uses of water bodies in the Little Spokane watershed, this TMDL is based on protecting downstream waters, i.e. Lake Spokane. The load allocation for total phosphorus for the mouth of the Little Spokane River, set in the *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010), drives the load and wasteload allocations for total phosphorus in this TMDL; meeting this load allocation is one of the primary purposes of this TMDL.

Besides this, the designated use in Lake Spokane is Core Summer Salmonid Habitat, the same as for the Little Spokane Watershed. The numeric criteria are the same. Therefore in addition to meeting the TP allocations for the mouth of the Little Spokane River, the other allocations in this TMDL, by protecting the Little Spokane River, are also protective of Lake Spokane.

Appendix B. Public Participation

Outreach to Stakeholders

Prior to the completion of the draft TMDL, Ecology invited key stakeholders to participate in one-on-one meetings. These meetings were an opportunity for Ecology to discuss the technical study and analysis as well as proposed implementation strategies. The meetings, held throughout 2020, created a forum for open dialogue and valuable feedback. Two separate meetings were held with Washington Department of Fish and Wildlife to discuss the implications of the TMDL for operation of the Little Spokane Fish Hatchery. The other stakeholders involved in these early meetings included:

- Spokane Conservation District
- Friends of the Little Spokane River
- Spokane Riverkeeper
- Avista
- The Lands Council
- Spokane River Forum
- Spokane Regional Toxics Task Force
- Spokane Tribe

Public Comment Period

A Little Spokane River DO and pH TMDL 30 day public comment period was held from October 12, 2020 to November 12, 2020.

Ecology sent e-mail notification of the public comment period and workshop to five different list-servs we believed would include parties interested in the draft Little Spokane River DO and pH TMDL. The list-servs included a large, statewide TMDL interested parties list as well as a Spokane River interested parties list.

Ecology posted information about the public comment period and a link to the draft document on our Little Spokane River website. In addition, a blog post appeared on our website on October 12th, 2020 to inform interested parties of the draft TMDL and announce the public comment period. The blog also included information on participating in the virtual workshop and providing comments on the draft water quality improvement report and implementation plan.

Public Workshop

On October 20th, 2020, Ecology hosted a public workshop. Due to the covid-19 pandemic, the meeting was conducted virtually via WebEx. Approximately 8-12 people attended the workshop. Ecology staff presented a slide show on the draft TMDL and hosted a question and answer period. The slides are attached below.

Top Portion of the Blog Post

Blog > What We Do >

Little Spokane River cleanup plan ready for public review

The draft plan will address multiple pollution issues in the watershed



The Little Spokane River watershed consists of forested ridges, small agricultural valleys, small urban centers, and abundant wildlife.

Plans to improve the health of the Little Spokane River and its tributaries are now available for public feedback. Our draft water quality improvement plan aims to address two issues in the river — low dissolved oxygen and high pH levels.

Oct. 12, 2020
Colleen Keltz

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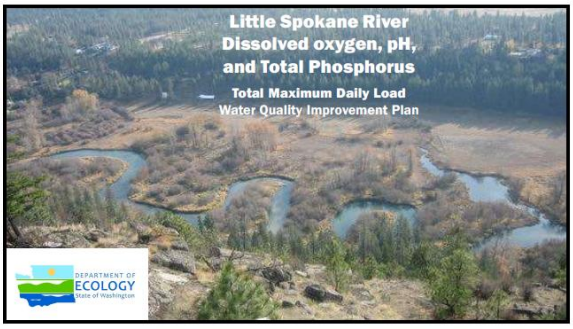
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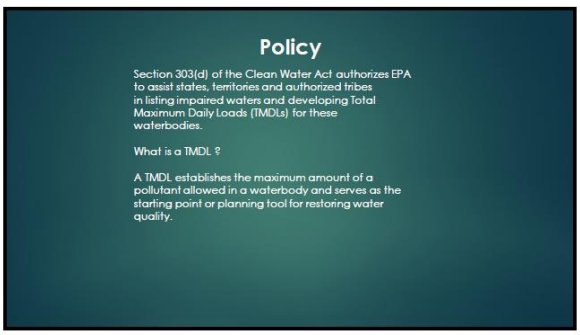
Little Spokane River water quality improvement page

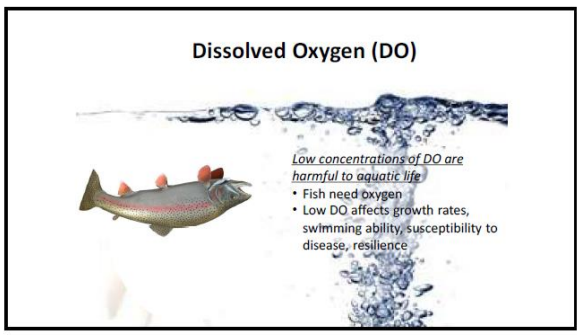
Draft water quality improvement plan

Webinar Slides

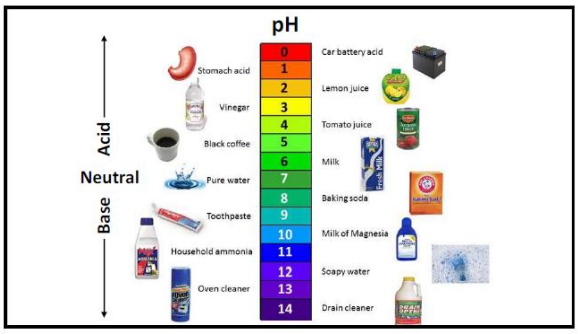


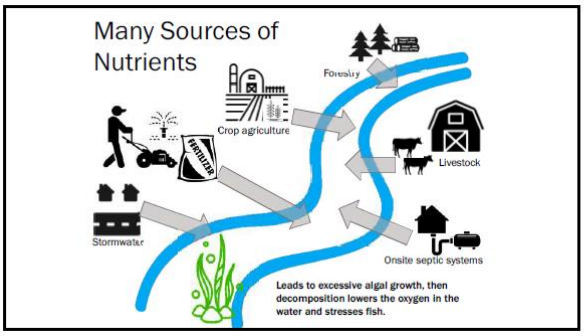


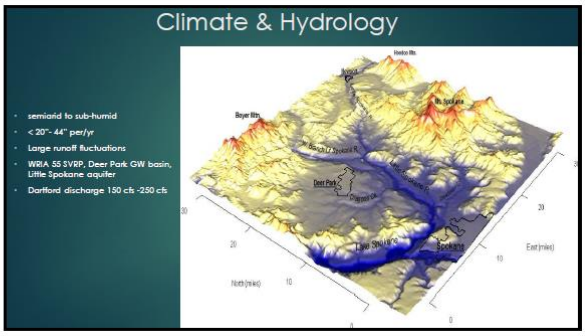


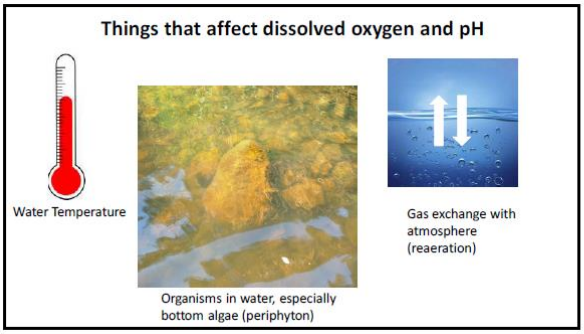



Why this matters ?
Sections of the Little Spokane R and tributaries on 303d list
• 2004-2006 – WA Water Research Center, WSU, SCCD
• 2010 – Spokane R/Lake Spokane TMDL
• 2012 – Little Spokane R Fecal Coliform, Temp, and Turbidity TMDL
• 2020 – Dissolved oxygen, pH, and TP
Little Spokane River
Dissolved oxygen, pH, and Total Phosphorus
Total Maximum Daily Load
Water Quality Improvement
Implementation Plan
DEPARTMENT OF ECOLOGY

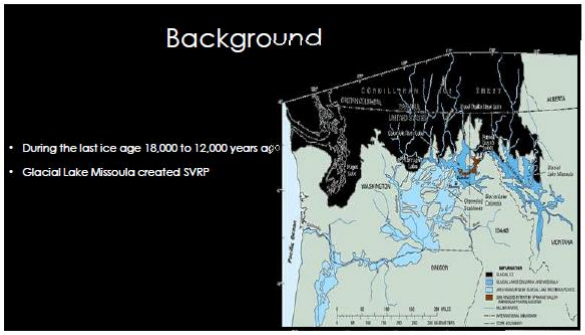

pH
Acid
Neutral
Base
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Stomach acid
Vinegar
Black coffee
Pure water
Toothpaste
Household ammonia
Oven cleaner
Car battery acid
Lemon juice
Tomato juice
Milk
Baking soda
Milk of Magnesia
Soapy water
Drain cleaner

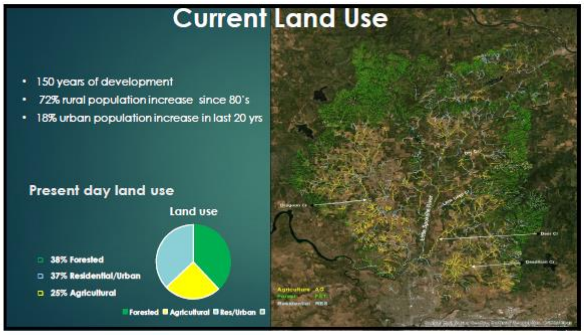

Many Sources of Nutrients
Forestry
Crop agriculture
Livestock
Stormwater
Onsite septic systems
Leads to excessive algal growth, then decomposition lowers the oxygen in the water and stresses fish.


Climate & Hydrology
• semiarid to sub-humid
• < 20"- 44" per/yr
• Large runoff fluctuations
• WRIA 55 SVRP, Deer Park GW basin, Little Spokane aquifer
• Dartford discharge 150 cfs -250 cfs


Things that affect dissolved oxygen and pH
Water Temperature
Organisms in water, especially bottom algae (periphyton)
Gas exchange with atmosphere (reaeration)


Spokane Indians--"children of the sun"


Background
• During the last ice age 18,000 to 12,000 years ago
• Glacial Lake Missoula created SVRP

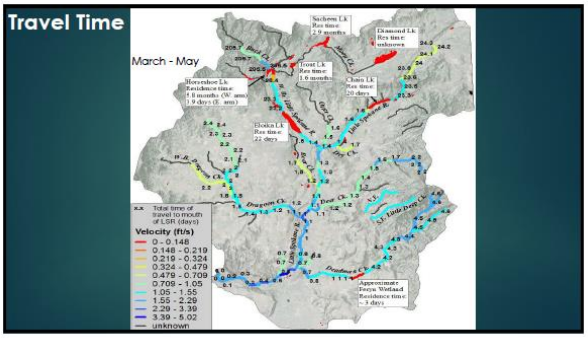

Current Land Use
• 150 years of development
• 72% rural population increase since 80's
• 18% urban population increase in last 20 yrs
Present day land use
Land use
38% Forested
37% Residential/Urban
25% Agricultural
Forested
Agricultural
Res/Urban


Little Spokane River Watershed
Otter Cr
E Branch
W Branch
Dry Cr
LSR
Beard Cr
Little Deep Cr
Dragoon Cr
Dartford Cr
Deadman Cr
Sampling locations

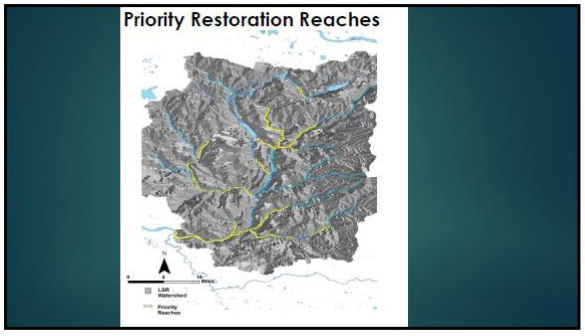

Dragoon Cr Spring Runoff


Flow Analysis

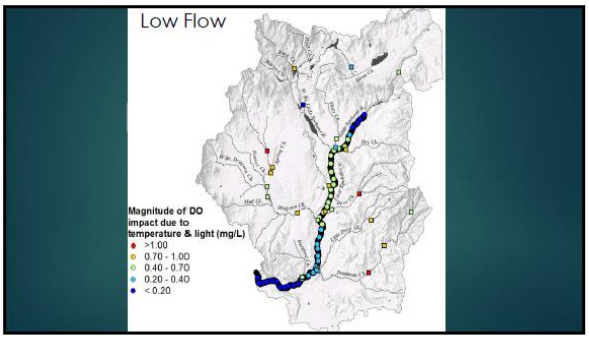


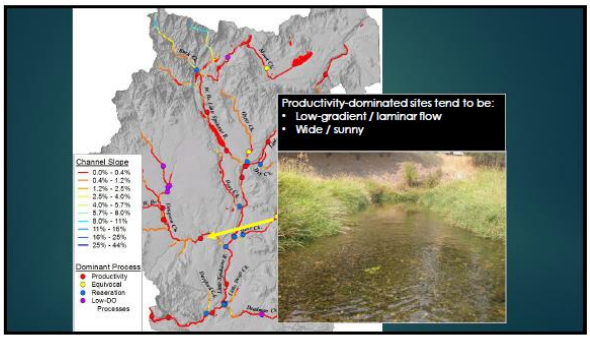

Travel Time
March - May
Velocity (ft/s)
0 - 0.148
0.148 - 0.219
0.219 - 0.324
0.324 - 0.479
0.479 - 0.709
0.709 - 1.05
1.05 - 1.55
1.55 - 2.29
2.29 - 3.39
3.39 - 5.02
unknown

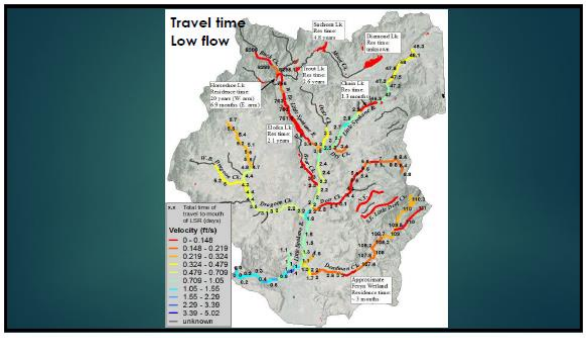

Dry Cr


Priority Restoration Reaches


Summer Conditions
Low DO
High Temp
Algal Production


Low Flow
Magnitude of DO impact due to temperature & light (mg/L)
>1.00
0.70 - 1.00
0.40 - 0.70
0.20 - 0.40
< 0.20


Productivity-dominated sites tend to be:
Low-gradient / laminar flow
Wide / sunny
Channel Slope
Dominant Process
Productivity
Equivocal
Reaeration
Low-DO Processes


Travel time
Low flow
Velocity (ft/s)



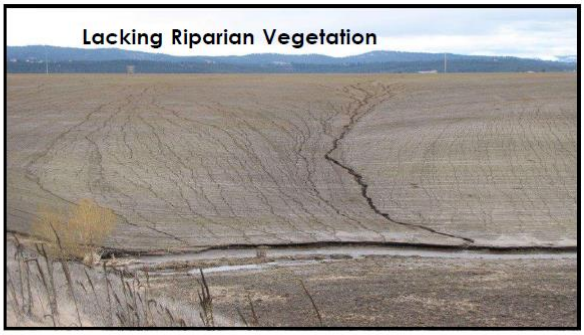



Riparian Buffers
Shade
Filtration
Bank Stability
Commodity Buffer Program

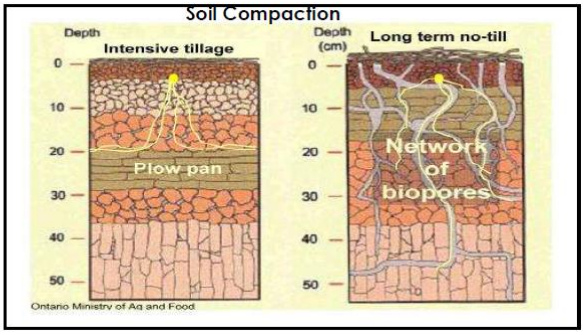

Best Management Practices (BMPs)
Recommended BMPs
Riparian Buffers
Conservation Tillage
Fertilizer Application
Livestock Exclusion
Tile Drain Management
Irrigation Efficiency
Recommended Supporting BMPs
Streambank Protection
On-site Septic Tank
Stormwater Management


Riparian Buffer Restoration


A Few of our Partners
Spokane Tribe
Spokane & Pend Oreille Co CD
The Lands Council
The Spokane RiverKeeper
Friends of the Little Spokane River
Funding & Programs
Centennial Clean Water Program
Clean Water Section 319 Program
Stormwater Financial Assistance Program
Washington State Water Pollution Control Revolving Fund Program


Lacking Riparian Vegetation


Loss of Native Vegetation


Soil Compaction
Depth
Intensive tillage
Plow pan
Depth (cm)
Long term no-till
Network of biopores
0
10
20
30
40
50
Ontario Ministry of Ag and Food

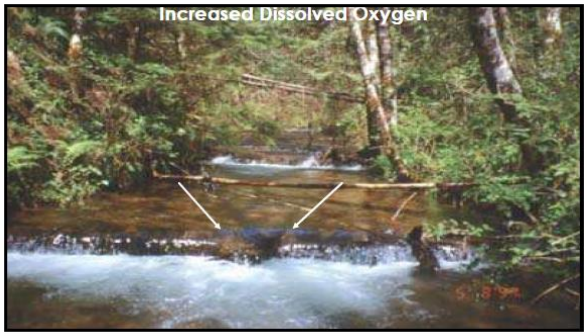

Conservation Tillage
No-till
Direct Seeding
Cover Crops
Soil Organic Matter
Infiltration

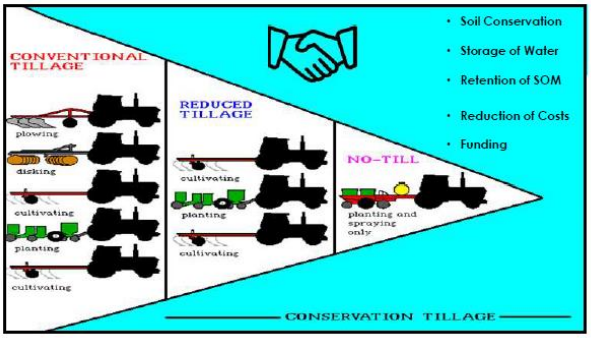

Soil Mobility


Conventional Tillage


NORTHWEST
direct seed
ASSOCIATION
Soil Health Benefits
Every drop of water is captured and kept in the soil
Low disturbance soils have 40-50% higher water infiltration and holding capacity –which means more water available for the crop to grow

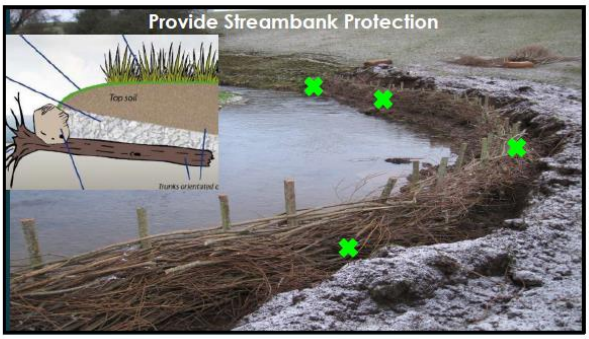

Cover Cropping
Conventional Tillage
12-13-2015

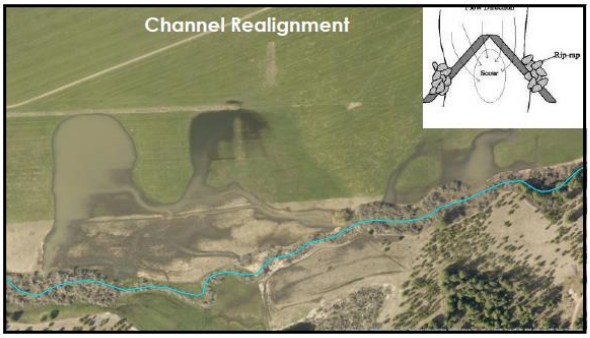

Increased Dissolved Oxygen


CONVENTIONAL TILLAGE
plowing
disking
cultivating
planting
cultivating
REDUCED TILLAGE
cultivating
planting
cultivating
NO-TILL
planting and spraying only
Soil Conservation
Storage of Water
Retention of SOM
Reduction of Costs
Funding
CONSERVATION TILLAGE


Increase Channel Diversity
SCOUR


Channel Function and Protection

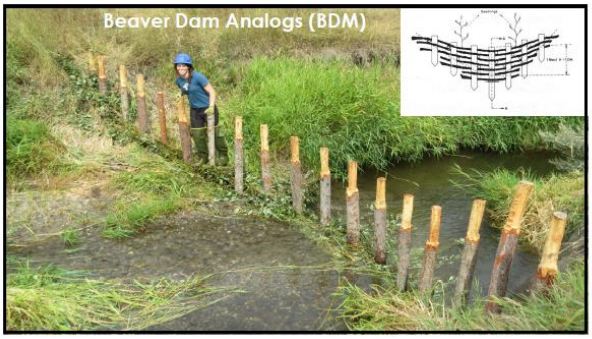

Provide Streambank Protection
Top soil

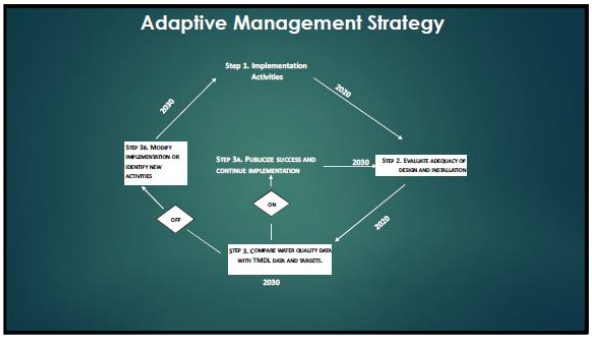

Channel Realignment
Rip-rap
Scour

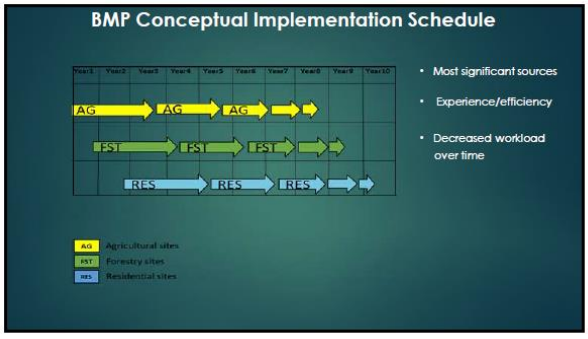

Roadside Erosion

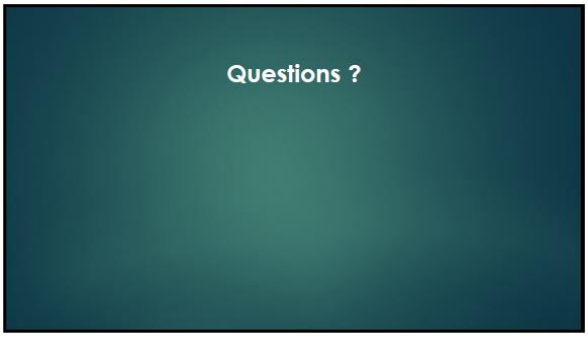

Intermittent and Ephemeral Restoration

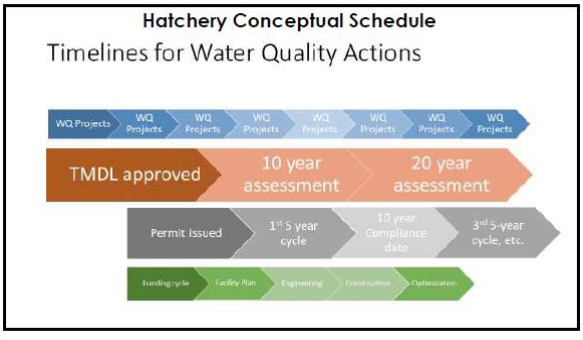

Spokane Fish Hatchery
Constructed in 1934
One of the largest rainbow trout brood-stock facilities
Supplies more than 7 million eggs
LEGEND
Upper Intake
Intake Sample Location
Outfall Sample Location
Other Sample Location
Project Location
Washington

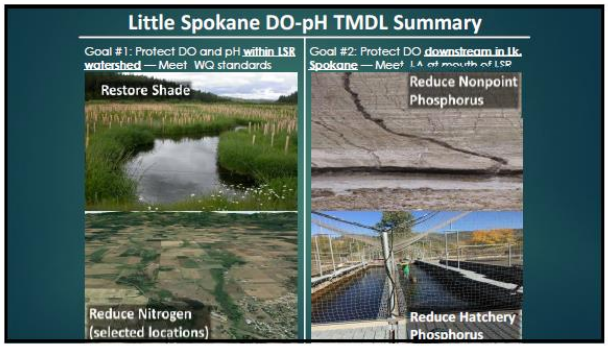

Beaver Dam Analogs (BDM)


Adaptive Management Strategy
Step 1. Implementation Activities
2030
2030
Step 3a. Modify implementation or identify new activities
Step 3A. Publicize success and continue implementation
2030
Step 2. Evaluate adequacy of design and installation
ON
OFF
2030
Step 3. Compare water quality data with TMDL data and targets.
2030


BMP Conceptual Implementation Schedule
AG
AG
AG
FST
FST
FST
RES
RES
RES
Most significant sources
Experience/efficiency
Decreased workload over time
AG Agricultural sites
FST Forestry sites
RES Residential sites


Questions ?


Hatchery Conceptual Schedule
Timelines for Water Quality Actions
WQ Projects
WQ Projects
WQ Projects
WQ Projects
WQ Projects
WQ Projects
WQ Projects
WQ Projects
TMDL approved
10 year assessment
20 year assessment
Permit issued
1st 5 year cycle
10 year Compliance date
3rd 5-year cycle, etc.
Funding cycle
Facility Plan
Engineering
Construction
Optimization


Little Spokane DO-pH TMDL Summary
Goal #1: Protect DO and pH within LSR watershed — Meet WQ standards
Goal #2: Protect DO downstream in Lk. Spokane — Meet
Restore Shade
Reduce Nonpoint Phosphorus
Reduce Nitrogen (selected locations)
Reduce Hatchery Phosphorus

Public Comments and Ecology Responses

Comments from Jana Crawford, Washington Dept. of Transportation

Comment:
Dear Mr. Curtis Johnson,

The Washington State Department of Transportation (WSDOT) Environmental Services Office has reviewed the draft TMDL and appreciates the opportunity to provide public comments. First and foremost, WSDOT is committed to working collaboratively with the Department of Ecology (Ecology) and others to help improve water quality across the state. WSDOT understands the draft TMDL is based on older data and development of this TMDL was put on hold due to other priorities.

WSDOT believes that proactive stakeholder engagement from Ecology could have minimized our comments, or at least provided the clarity needed to understand Ecology's approach in the draft TMDL. We respectfully ask that Ecology work collaboratively with TMDL stakeholders prior to releasing public comment draft TMDLs in the future, rather than using the short timelines of the public comment mechanism to address potentially substantive issues.

WSDOT's current Municipal Stormwater Permit (MS4 Permit) has 31 TMDLs statewide, which makes consistency very important for tracking and compliance assurance purposes. WSDOT is interested in having higher-level discussions with Ecology regarding inconsistencies across the state on TMDL approaches, wasteload (WLA) vs. load allocation (LA) calculations and assignments, and NPDES implications. WSDOT seeks additional clarification on existing policies for TMDL development related to these topics, especially related to WLAs vs. LAs as demonstrated by the following comments.

Ecology's response:
Thank you. Comment noted. Ecology continues to look for ways to improve engagement and communication with stakeholders.

Specific comments and recommendations:

Comments:
1. (p. 18, third paragraph) "A zero WLA is the equivalent of no WLA. A few permitted sources are listed in this table as having zero WLA; these are instances where it might not be obvious that this source does not have a discharge to surface waters."

Comment: This is inconsistent with WSDOT's understanding of what a zero WLA means and is potentially precedent setting. WSDOT does not agree that a WLA needs to be assigned in "instances where it might not be obvious that this source does not have a discharge to surface waters." If a permitted point source does not have a discharge to surface waters, they should not be assigned a WLA.

Recommendation: Remove WLAs of zero from the TMDL. If Ecology does not agree, WSDOT requests a discussion about the intent and future implications of a zero WLA prior to TMDL approval.

2. (p. 18, fourth paragraph)

Comment: WSDOT appreciates the efforts made to clarify the areas where the MS4 Permit requirements apply. However, the extent to which the TMDL boundary falls outside MS4 Permit coverage area could be more clear using a visual.

Recommendation: WSDOT recommends using a map to show the TMDL boundary and the Phase I/II MS4 Permit coverage area.

3. p. 19, (Table 6)

Comment: Same as comment #1. As identified in the footnote to Table 6, WSDOT is not a source within our MS4 Permit coverage area. Therefore, WSDOT questions the rationale and future implications behind the assignment of a WLA.

Recommendation: Remove the WLA for WSDOT in this TMDL as we have not been identified as loading source within our MS4 Permit coverage area. If Ecology does not agree, WSDOT requests a discussion about the intent and future implications of a zero WLA prior to TMDL approval.

Ecology's response to the previous three comments:
We agree that WSDOT should not have been assigned a zero WLA. The draft TMDL assigned a zero WLA based on an incorrect understanding of the permit area boundary due to using out-of-date information. In fact the permit area includes highway infrastructure in the suburban areas north of Spokane, including highway crossings of the Little Spokane River, Deadman Creek, and Little Deep Creek. We have reassessed the WLA for WSDOT, and this is now a non-zero WLA.

We had included the "zero" WLAs simply to clarify that certain sources do not discharge to surface water. However, there should be a small numeric values assigned stormwater and other applicable general permit sources in case a discharge did occur. We have updated the TMDL to include WLAs for those permits.

We agree that a map is a better way to communicate complex permit boundaries. We have added a map that includes this permit boundary, along with the discharge locations of all point sources receiving WLAs in this TMDL. ***Located in Headings*** *** (TMDL Allocations > Loading Capacity > Wasteload allocations > Figure 3)**

Comment:
4. (p. 57)

Comment: Concerns regarding sediment run-on from adjacent lands to our MS4 system outside of our MS4 Permit coverage area (covered by non-point source load allocations in draft TMDL) are already addressed by existing WSDOT operations and other regulatory mechanisms, such as:

- WSDOT Maintenance and Operations to maintain the public safety of our roadways
- WSDOT Illicit Discharge Detection and Elimination program implemented statewide
- Local jurisdictional authority, such as Ecology enforcement of RCW 90.48
- Clean Water Act Section 319 funding mechanisms and actions identified in Ecology's Non-Point Source Management Plan, Publication no. 15-10-015

However, as we've collaborated in the past, we continue to see value in working with Ecology and others to resolve identified challenges presented by sediment run-on from adjacent lands into our MS4.

Recommendation: WSDOT remains committed to collaborating with Ecology on the implementation actions identified at the bottom of page 57, even though the area is outside of our MS4 Permit coverage area.

Thank you for considering our comments. If you have questions or wish to discuss thesecomments, please contact WSDOT's Statewide TMDL Lead, Elsa Pond.

Ecology's response:
Thank you for your comment. Within the dryland agricultural production areas in our eastern region, Ecology continues to observe widespread tillage, erosion, and sediment transport. Sediment often makes its way to surface waters via state stormwater infrastructure. We appreciate the opportunity to work with WSDOT to address these issues.

Comments from U.S. Environmental Protection Agency (EPA), Region 10

Comment:
We recommend that a discussion on pollutant sources be included or summarized in Section 1 Introduction of the TMDL document.

Ecology's response:
We added a brief summary of pollutant sources to the **Introduction** section, along with references to the more comprehensive discussions in the **Implementation Plan** and **Land use and potential pollutant sources** (Appendix A) sections.

Comment:
We recommend that the TMDL provide more detail regarding the connection between this TMDL and the 2012 Little Spokane River Temperature TMDL.

Ecology's response:
We agree that the TMDL would benefit from more detail on the connection to temperature. We updated the TMDL to provide explicit shade and heat targets, rather than simply referencing the 2012 TMDL. We have included additional language explaning and clarifying the relationship between the shade/heat targets in this TMDL, and those in the 2012 TMDL. ***Located in Headings*** ***** **(TMDL Allocations > Load allocations > Shade and heat)**

Comment:
We recommend that the TMDL provide more detail for the public regarding the connection between the dissolved inorganic nitrogen (DIN) and total phosphorus (TP) loading capacity and load/wasteload allocations and the State of Washington's dissolved oxygen (DO) and pH water quality standards.

Ecology's response:
We added a paragraph to the beginning of the **Targets within the Little Spokane River and tributaries** section summarizing our use of water quality models to determine shade/heat and nutrient load capacities based on the water quality standards for DO and pH. ***Located in Headings* * (Introduction > Targets > Targets within the Little Spokane River and tributaries)**

Comment:
Under the reasonable assurance section, we recommend that the TMDL clarify the estimated timeframe for completing the implementation actions and meeting the water quality standards for the dissolved oxygen and pH impairments, as well as for temperature impairments, as this TMDL is linked to the 2012 Little Spokane River Temperature TMDL, as previously noted. We also recommend including a citation to Washington's legal authority for addressing nonpoint source pollution in this section.

Ecology's response:
We have added language to help clarify the difference between when TMDL implementation is to be completed and when water quality standards will be met. "Meaning, when implementation is completed in 20 years (2040), it will take an additional 10 years (2050), for dissolved oxygen and pH goals to be met watershed wide." ***Located in Headings* * (Implementation Plan > Tracking Progress > Reasonable Assurance)**

Comment:
We recommend that the TMDL also clearly explain the connection between the TP allocations in this TMDL and the downstream Spokane River/Lake Spokane Dissolved Oxygen TMDL including how the total phosphorus allocations in this TMDL will result in compliance with the downstream total phosphorus target from the Lake Spokane DO TMDL.

Ecology's response:
We added a heading to the **Watershed Loading TMDL Analysis > Loading capacity for phosphorus from LSR watershed** section of the report, titled **Compliance with Load Allocations from Spokane TMDL**. In this section, we provide an analysis of the effects of the TP reductions outlined in this TMDL during various years with various hydrologic conditions. We conclude that this TMDL will result in compliance with the LA set for the mouth of the Little Spokane River by the *Spokane River and Lake Spokane DO TMDL* over 90% of the time**.** ***Located in Headings* * (Technical study and analysis > Watershed Loading TMDL Analysis > Loading Capacity for phosphorus from LSR watershed > Compliance with Load Allocations from Spokane TMDL)**

Comment:
We recommend that the TMDL provide an explanation regarding the selection of the explicit margin of safety (MOS). For the implicit MOS, we recommend that the TMDL explain why each assumption is conservative with respect to the analysis or alternatively remove the assumption from the MOS section. For example, it would be helpful for Ecology to explain how the use of higher flow analysis would be considered a conservative assumption for an implicit MOS.

Ecology's response:
In the **Margin of Safety** section, we added an explanation of how we calculated the explicit MOS for TP, as well as adding a few lines to the table showing the numbers involved. For the implicit MOS, we removed two items from the list which were really critical conditions factors rather than true conservative assumptions. ***Located in Headings*** *** (TMDL Allocations > Margin of safety > Explicit margin of safety)**

Comment:
We recommend that Ecology clearly explain why two different water quality models were used for this TMDL project and how they model outputs work together.

Ecology's response:
We added a paragraph to the first page of the **Instream DO and pH TMDL Analysis** section explaining the need for two models. ***Located in Headings*** ***** (**Technical study and analysis > Instream DO and pH TMDL analysis > Overview)**

Comment:
We recommend that the TMDL clearly explain how the critical periods for the total phosphorus load allocations were determined and why the load allocations only apply during these critical periods.

Ecology's response:
We added language to the **Loading Capacity** section clarifying that the March-May, June, and July-October seasons were determined by the *Spokane River and Lake Spokane DO TMDL*, and explaining why it makes sense to carry those seasons over into this Little Spokane River DO/pH/TP TMDL. We also added language to the **Watershed Loading TMDL Analysis** section explaining that although these seasons were originally developed for the Spokane River, they make good hydrological sense for the Little Spokane River watershed as well. ***Located in Headings*** *** (TMDL Allocations > Loading Capacity >Loading Capacity for Total Phosphurus)**

Comment:
Please include the following tables of waters and pollutants addressed in the TMDL. In each of these tables, please include the assessment unit, 2012 listing ID, impairment(s), pollutant(s) (for which the TMDL loads are expressed), MOS (if explicit), load allocation, wasteload allocation, andif there is a future reserve:

1) Waters on the 2012 list
2) Unlisted but impaired waters

3) Waters not meeting the criteria for listing, but likely impaired based on available information.

In order to make both Ecology's and EPA's intentions and actions transparent, we request that you identify all waters for which you have prepared TMDLs and that you request EPA approval for those TMDLs. Such submittal and approval will clarify the Clean Water Act status of those waters and the associated allocations.

Ecology's response:
We have added an appendix (Appendix O) that contains this information.

Comment:
We recommend that each of the separate Appendices to this TMDL document be included as part of the Table of Contents of the TMDL document (the appendices are currently not referenced)

Ecology's response:
The Table of Contents now lists the Appendices and provides a link to the separate document that contains them.

Comments from Spokane Tribe

Comment:
We are concerned by the lack progress made since the 2012 TMDL and how few restoration projects were implemented in the watershed. It is not clear why or how the 2012 implementation strategy fell short. However, we hope that it was a learning opportunity for Ecology and that lessons learned will be applied to implementing the 2020 plan presently under review. We encourage Ecology to hire a consultant to develop a comprehensive outreach strategy the agency can use to foster positive relationships with private landowners, agricultural interests, and the forestry community.

Ecology's response:
Thank you for the suggestion for a comprehensive outreach strategy. We agree that positive relationships in the watershed help aid in successful implementation.

Comment:
Incorporate recommendations within the TMDL that will improve the Little Spokane watershed for future reintroductions of anadromous species that were historically abundant, rather than set objectives that are less stringent and only focus on resident species. Using these recommendations set within the 2020 and the 2012 TMDLs, the Spokane Tribe can coordinate with Ecology and others to protect and restore the Little Spokane watershed for current and future use.

Ecology's response:
We have added a recognition in the TMDL that the Little Spokane River historically provided important habitat for salmon and steelhead. The Little Spokane River DO and pH TMDL is designed to meet water quality standards and protect beneficial uses in the Little Spokane River, including core summer salmonid habitat. Although not a recovery strategy, the TMDL should

provide the water quality protection needed for all indigenous aquatic species. Ecology believes the recommended BMP's, including the recommended instream structures, will benefit resident fish species, as well as any future reintroductions of anadromous species. Ecology looks forward to working with the Spokane Tribe to protect and restore the Little Spokane watershed for current and future use. ***Located in Headings*** *** (Introduction > Overview > TMDL goals)**

Comment:
Incorporate recommendations within the TMDL for Polychlorinated Biphenyls (PCB) contaminants. The recent reports of PCB in Deadman Creek and the EPA cleanup of the former Kaiser smelter site in Mead points to the need for the inclusion of PCB's in the TMDL recommendations for the Little Spokane River.

Response:
Thank you for your comment. The Little Spokane River is currently listed as a category 5 (polluted) waterbody for Polychlorinated Biphenyls (PCBs). This DO and pH TMDL was not intended to address that PCB listing. Ecology is currently working with the Spokane River Regional Toxics Task Force (SRRTTF) on Spokane River PCB issues. The SRRTTF has identified specific actions to reduce PCBs in the Spokane River watershed. Currently, a Spokane Recycling (Formerly Kaiser Mead) clean-up effort is underway in coordination with the Environmental Protection Agency (EPA). EPA's Time Critical Removal Action at this location will remove significant quantities of source material from the site and limit the potential for future contributions of PCBs to Deadman Creek. It should also be noted that this TMDL recommends upgrades to the existing Spokane hatchery to reduce phosphorus pollution. Recommended upgrades are likely to also address potential PCB contaminants coming from the aging facility.

Comments from Spokane Riverkeeper

Comment:
The SRK believes that this draft TMDL could refer to the WRIA 55 Watershed addendum insofar as they both refer to and/or contain habitat improvement actions affecting the riparian quality of the Little Spokane Drainage. The TMDL could begin to leverage this WRIA plan to produce immediate success in the watershed.

Ecology's response:
Thank you for your comments. We agree with the importance and relevancy of the WRIA 55 watershed plan addendum prepared in November 2020. The most recent WRIA55 planning effort looks to offset impacts to flow from exempt well drilling and is primarily driven by water quantity needs rather than water quality. Yet, the plan also identifies non-water offset opportunities including floodplain and habitat restoration that would benefit water quality in the Little Spokane watershed. We have added language in the TMDL that refers to the plan.
Located in Headings *** (Implementation Plan > Best Management Practices)**

Comment:
SRK believes that Climate Change will affect the flows in the Little Spokane River as will continued human development and growth and that these factors will affect the assessments of

pollution loading and attainment of loading goals. Climate change and human development will also affect the effectiveness of solutions and riparian recovery through time. This plan should discuss the implications and impacts of both on water quality attainment.

Ecology's response:
We recognize the importance of climate change and its potential impact on water quality in Washington. Due to the difficulty in predicting the effect of climate change in the Little Spokane watershed, we have not attempted to incorporate those changes into our load and waste load calculations. At the same time, our suite of recommended non-point BMPs are designed to protect aquatic life in a changing climate. For instance; conversion to a direct seed-no till system with cover crops will not only protect soils from rain on snow events but will also store water and decrease evapotranspiration. The riparian buffer and in-stream structure recommendations are designed to reconnect floodplains, slow and infiltrate run-off, redirect flows during flashy conditions, and enhance flows during critical low flow periods. We believe the BMPs needed to meet water quality standards in this TMDL are the same practices needed to build resiliency in the watershed to buffer against the future impacts of climate change. Furthermore, Appendix N discusses climate change and its relation to water quality in the Pacific Northwest and the LSR watershed.

Comment:
This draft TMDL should have a complete analysis of flow regimes and a workup of how those flow regimes affect nitrogen and Total Phosphorus (TP) pollution and how changes in those flows will affect pollution loading and concentrations now and in the future.

Ecology's response:
A new section has been added to the final TMDL. ***Located in Headings** **** (**Technical Study and Analysis > Watershed loading TMDL analysis > Loading capacity for phosphorus from LSR watershed > Compliance with Load Allocations from Spokane TMDL)**. This new section analyzes compliance with Total Phosphorus load allocations during a variety of years with different hydrologic conditions. In addition, we also analyzed the effect of various changes, including flow (in this case, restoring about 14cfs of natural flow to the system), on instream DO and pH ***Located in Headings** **** **(Technical Study and Analysis > Instream DO and pH TMDL analysis > Model scenario results > Little Spokane River (QUAL2Kw) model scenarios)**. Again, Appendix N discusses the effect of climate change on water quality in the Pacific Northwest and the LSR watershed.

Comment:
While we appreciate the designated uses of native Redband trout, whitefish, and rainbow trout habitat (and one or more salmonids; or foraging by adult and subadult native char) as a stated goal. SRK recommends including a full paragraph on the Tribal efforts to recover salmon and the Upper Columbia United Tribes Phased studies that identify the basin as future salmon and steelhead habitat.

Ecology's response:
Thank you for your comments. We recognize and are grateful for our local tribal efforts to restore salmon and steelhead to the Spokane River watershed. We include a recognition in the TMDL that the Little Spokane River historically provided important habitat for salmon and

steelhead. The Little Spokane River DO and pH TMDL is designed to meet water quality standards and protect beneficial uses in the Little Spokane River, including core summer salmonid habitat. Although not a recovery strategy, the TMDL should provide the water quality protection needed for indigenous aquatic species. The recommended suite of BMPs will play a vital role in improving water quality that should ultimately benefit recovery of anadromous fish. ***Located in Headings* (Implementation Plan > Overview > TMDL goals)**

Comment:
We agree and appreciate that WDOE recognizes and clearly states that to achieve the pollution loading goals, the primary (implementation) work in the basin will be addressing non-point source (NPS) pollution. Tillage practices in this region with its friable soil, steep slopes, and high precipitation levels make this basin very vulnerable to NPS pollution. We recommend explicitly stating that older tillage styles are particularly hard on water quality and aquatic life. Finally, freeze-thaw and rain on snow events are common in this basin and they readily mobilize soil movement and exacerbate soil and nutrient runoff to surface waters.

Ecology's response:
We have added a section to the document that describes this condition. The added language notes that many farmers still use conventional tillage practices that expose soils to high erosion rates. Rain on snow events are common in the basin and readily mobilize soils and exacerbate nutrient runoff to surface waters. The suite of non-point BMPs also recommends replacing conventional tillage with conservation tillage practices. ***Located in Headings* (Implementation Plan>Watershed Land Use>Agricultural Areas)**

Comment:
Page 35 under subheading "Drainage": SRK agrees and supports this section. Further, it should be noted in implementation stages that Spokane County continues to spray pre-emergent herbicides on its roadside ditches making water and pollution highly prone to run off roads and ditches and into surface water. Conversely, Stevens County lets the grass grow on the shoulders of their roads and this provides a high degree of interception and pollution prevention.

Ecology's response:
We have not explored how herbicides are used by local transportation departments. But, we have added a new paragraph (Implementation Plan>Best Management Practices> Recommended Non Agricultural BMPs > Stormwater Management) to reinforce the importance of proper road side ditch maintenance in order to capture and treat sediment and nutrient laden run-off. ***Located in Headings* (Implementation Plan>Best Management Practices> Recommended Non Agricultural BMPs > Stormwater Management)**

Comment:
"Persons engaged in agricultural operations who implement and maintain the recommended BMPs below will be presumed to be in compliance with the Little Spokane River DO and pH TMDL and the State Water Pollution Control Act (90.48 RCW)." We agree that in most cases implementation of effective BMPs can protect water quality. However, we find the statement of presumption problematic. It should be readily stated that BMPs are outcome-oriented and not process-oriented. That is to say that the correct suite of BMPs will have to be worked out until

water quality standards – as outcomes - and/or site conditions - as outcomes - are attained that are fully protective of Washington Water Quality Standards (WQS) and surface water.

Ecology's response:
We have updated this section. While the BMPs are currently presumed to be sufficient to fully protect water quality, we now reference the need for adaptive management if water quality standards are not being met and/or we determine that more protective BMPs are needed for compliance with the Water Pollution Control Act. ***Located in Headings* * (Implementation Plan >Best Management Practices > Recommended Primary BMPs for Agricultural Operations)**

Comment:
Page 36 - SRK recommends that WDOE heavily qualify that Natural Resource Conservation Service (NRCS) codes in the Field Office Technical Guide (FOTG) were not designed to meet Washington State Water Quality Standards. Further, please include a section referring to the impending Agricultural BMP Clean Water Guidance that is under development and is designed to meet Washington WQS under the Washington State Non-Point Pollution Plan approved by the EPA. This pending guidance will have a place as implementation tools suitable for TMDL implementation plans like this one. Page 38: Table 13 - SRK recommends again to make it clear - perhaps with a subheading or footnote - that NRCS guidance (FOTG)s is not designed to achieve Water Quality Standards in Washington State and the newer pending, agricultural BMP Guidance is designed to meet WQS in TMDL implementation.

Ecology's response:
NRCS practice standards provide important construction standards we rely on in our suites of recommended BMPs. The reference to NRCS standards is not intended to suggest the NRCS codes are Water Pollution Control Act compliance standards. We have added language in the document to clarify the purpose for NRCS practice standard codes. "NRCS codes provide important construction standards but are not considered state compliance standards for agricultural operations." We further clarify by stating "Implementation partners can quickly access reference information regarding the engineering/design of the BMP. Referencing NRCS codes should in no way be interpreted to imply that the NRCS requirements supersede Ecology's water quality recommendations. Where discrepancies exist between Ecology and NRCS guidance, to comply with state water quality standards operators must follow Ecology's recommendations as expressed in this TMDL or implement practices that provide an equivalent level of protection. If NRCS requirements are more stringent, we encourage operators to follow those requirements."

We also recognize the importance of the Agricultural BMP Clean Water Guidance documentation that is being developed, and have added the reference to the document as a source for BMP recommendations for agricultural operations. ***Located in Headings* * (Implementation Plan > Best Management Practices)**.

Comment:
Tillage recommendations - the draft TMDL is silent on residue height recommendations. The LSR Basin receives a great deal of snow in the winter and this exacerbates soil runoff when

snowmelt and rain-on-snow events are occurring. Crop stubble heights of 15" or higher should be recommended to prevent sheet erosion into surface waters.

Ecology's response:
Tillage recommendations in this TMDL are consistent with recommendations in the draft Clean Water Guidance for Agriculture BMPs. The recommendation includes both a Soil Tillage Intensity Rating (STIR) of 30 and a minimum residue cover threshold of 60 percent. The Clean Water Guidance for Agriculture and the TMDL implementation plan do not include an overwinter residue height recommendation because residue height plays a less certain role in determining soil mobility, erosion, and pollution. ***Located in Headings*** *** (Implementation Plan > Best Management Practices)**

Comment:
The SRK recommends that the TMDL team consider Site Potential Tree Height as a prescription for certain sections of the Little Spokane River riparian habitat recovery and pollution prevention plan.

Ecology's response:
We agree Site Potential Tree Height is valuable tool for full restoration of ecological stream function and encourage restoration partners to implement to that standard. In an effort to ensure we meet water quality standards, we have identified minimum buffer widths in this TMDL. We recognize that larger setback distances may provide additional fish and wildlife habitat benefit beyond the water quality criteria addressed here. It should be noted, we also have addressed System-Potential Vegetation in our 2012 *Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity TMDL*. The same 2012 TMDL recommendations to decrease temperatures (mature system-potential vegetation) are also included to address dissolved oxygen for this TMDL.

Comment:
On this page, WDOE states: "Despite the best efforts of Ecology and partners in the watershed, some landowners may be unwilling to perform the steps needed to protect water quality at their property. It then becomes Ecology's responsibility to evaluate whether their activities are causing or have the potential to cause pollution in violation of the state's Water Pollution Control Act (RCW 90.48). In these situations, Ecology can pursue enforcement steps needed to gain compliance." For the record, this has been, to date, a persistent and fundamental failure of WDOE in other basins across the state. The low rate of enforcement and the use of regulations under RCW 98.48 has left the surface waters across Washington vulnerable to the notion that the WDOE is not serious about protecting the public nor its treasured clean water. SRK suggests that this language be changed to "WDOE WILL pursue enforcement, when and where necessary to uphold RCW 90.48 and protect the public values of clean water". Without this statement, and without commitment to utilizing these regulatory tools, the endeavor to protect the public's waters and the attainment of TMDL goals in this watershed plan will fail. While SRK understands that WDOE has discretionary power in this area, communicating with the WDOE leadership team (and the public) that the transparent, clear, prudent use of regulatory tools is necessary, and will play an essential role in the success or failure of this TMDL plan.

Ecology's response:
It is important that Ecology maintains its regulatory discretion and cannot commit to taking regulatory action in all cases where landowners fail to act proactively. That being said, we do intend to use our regulatory tools as a backstop to ensure the TMDL is implemented and water quality standards are met in the watershed. Ecology has made edits to the TMDL that better define our regulatory role and provide more transparency. ***Located in Headings** **(Implementation Plan > Reasonable Assurance)**

Comment:
Please include a summary of the Forest Practices Act (FPA) buffer widths referred to in the table.

Ecology's response:
While WA Forest Practices Act (FPA) tends to align with Ecology BMPs, the FPA buffer widths contain many site specific variables based on stream type, tree size, and forest density, etc. The variability cannot be captured in a simple table. Ecology staff review and comment on forest practices applications. Staff also perform site inspections to ensure buffer implementation is consistent with the requirements of the FPA.

Comment:
SRK believes that the "Costs" section can be misleading. WDOE makes the statement: "It is important to understand the financial burden associated with the implementation of the TMDL" . Traditionally the protection of the State's surface waters is presented as a "cost", but SRK submits this as a simple matter of framing. SRK asks that you please qualify (or follow up) this statement by stating that these are costs borne by landowners who are not protecting water quality and public values. In the larger Columbia Basin frame, the implementation of BMPs may save society economic burdens.

Ecology's response:
We agree that water quality protection often provides economic benefit. Ecology did not perform a cost-benefit analysis as part of this TMDL, and therefore, have not quantified economic benefit in the TMDL. We have added general language to the document noting a both cost and benefits with TMDL implementation. The language indicates "There are almost certainly economic benefits of TMDL implementation in terms of aquatic and human health, property value, and flood protection". We also changed "financial burden" to "financial costs." ***Located in Headings** **(Implementation Plan > Costs)**

Comment:
Following the section on Water Quality Monitoring, SRK recommends a section on Water Quantity. Perhaps working with the Water Resources section at WDOE and discussing the monitoring of flow data from several points in the watershed would be positive given the association between river flow and water qualityPage 76: Tracking Nonpoint BMP Implementation. SRK appreciates the rigorous list of metrics that will be tracked in association with implementing BMPs. This data could also be folded into a simple spreadsheet and/or doc that is presented to and/or shared with the Spokane River DO TMDL Implementation workgroup as well as the public (posted to the WDOE Website).

Ecology's response:
Ecology will be tracking progress through our Adaptive Management strategy. That information will be available to the public.

Comment:
Following the section on Water Quality Monitoring, SRK recommends a section on Water Quantity. Perhaps working with the Water Resources section at WDOE and discussing the monitoring of flow data from several points in the watershed would be positive given the association between river flow and water quality.

Ecology's response:
While we understand there may be a relationship between water quantity and water quality, the primary focus of TMDLs is to achieve water quality standards in the watershed. We have added a section that analyzes the effect of changes in flow (restoring about 14cfs of natural flow to the system), on instream DO and pH model scenarios). Ecology water quality staff will continue to collaborate with Ecology water resource staff on TMDL and WRIA 55 plan actions that benefit both water quantity and quality. ***Located in Headings*** *** (The Technical Study and Analysis > Instream DO and pH TMDL analysis > Model scenario results > Little Spokane River (QUAL2Kw)**

Comment:
The SRK agrees with the statement: "Project success and accomplishments should be publicized and reported to continue project implementation and increase public support." However, we also feel there is also a place for judicious publication of the challenges and setbacks as well. That is to say, if the goal is to increase awareness and begin to shape public opinion in favor of water protection, the publication of lawbreaking and intransigence - for example - should also be identified and put out in public view so that all people understand the barriers to progress.

Ecology's response:
Our formal compliance documents, including administrative orders and penalties, are available to the public for review.

Comments from Avista Utilities

Comment:
We were curious if a more appropriate term for entities that were consulted during TMDL development, in the "Outreach" section would be *stakeholders* rather than *key implementation partners,* especially as we are not listed in the "Organizations that implement the TMDL" section (pg. 61)?

Ecology's response:
We have changed the language in the document to clarify the distintion between stakeholders and implementation partners. ***Located in Headings*** *** (Implementation Plan > Outreach > Public Involvement in TMDL Development)**

Comment:
"Loading Capacity for Dissolved Inorganic Nitrogen" (pg. 15). The second sentence of the third paragraph states "These loading capacities for DIN apply during May-November, which is the season when dissolved oxygen saturation levels below 90 percent and above 110 percent were observed at these six locations, indicating the potential for DO impairments linked to algae growth1." My question is if 90% and 110% saturation are used by Ecology as indicators of acceptable dissolved oxygen content? Is 90%-110% a target range and if so, where do these numbers come from?

Ecology's response:
The 90%-110% DO saturation range is not a water quality standard, nor a target range. Our load allocation values for DIN in this TMDL are based on the 0.2 mg/L DO and/or 0.1 S.U. pH allowance for human impacts. This is the same basis that we used for the Spokane TMDL. The section you are referencing describes how we decided when the LA's apply. Because this project followed a legacy data collection and modeling approach, all of the data and modeling for these LAs was for July/August critical period. We knew that these allocations should apply during the critical season of warm, low-flow conditions. We also knew that there was a winter-springtime season when some combination of cold water and high flows would make these LAs inappropriate, as DO and pH are generally not sensitive to nutrients during cold-water/high-flow conditions. Therefore we needed some basis for determining what season to apply these LAs, based on the very limited amount of data we had available outside the July/August window.

It's also worth noting that the LA's for DIN pertain to nonpoint sources. The BMPs that will be used to implement these LAs don't have a season. Activities like riparian restoration, livestock exclusion, septic tank repair, etc. will benefit a variety of water quality parameters (including phosphorus) year-round.

Appendix C. Glossary, acronyms, and abbreviations

Glossary

Analyte: Water quality constituent being measured (parameter).

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold, 1978).

Best management practices (BMPs): Physical, structural, or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

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.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Critical condition: 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 (see definition) flow event unless determined otherwise by the department.

Diel: Of, or pertaining to, a 24-hour period.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (for example, diurnal temperature rises during the day and falls during the night.).

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.

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Exceeded criteria: Did not meet criteria.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to

Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Geometric mean: A mathematical expression of the central tendency (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 nth 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.

Load: The mass of a constituent transported by a stream in a given amount of time, usually expressed in units such as kg/day or lbs/day. It is calculated by multiplying constituent concentration times streamflow.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit 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.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

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 National Pollutant Discharge Elimination System 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.

Orthophoto: An aerial photograph from which distortions owing to camera tilt and ground relief have been removed, so that it has the same scale throughout and can be used as a map.

Pan Evaporation: A direct measurement of surface evaporation of water, typically using a circular pan of standard dimensions at ground level.

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.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

Plume: Describes the three-dimensional concentration of particles in the water column (example, a cloud of sediment).

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 that clear more than five acres of land.

Pollution: Such 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, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

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

Reach: A specific portion or segment of a stream.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

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 watercourses within the jurisdiction of Washington State.

Surrogate measures: To provide more meaningful andmeasurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

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

System potential: The design condition used for TMDL analysis.

System potential channel morphology: The more stable configuration that would occur with less human disturbance.

S**ystem potential mature riparian vegetation:** Vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

System potential riparian microclimate: The best estimate of air temperature reductions that are expected under mature riparian vegetation. System potential riparian microclimate can also include expected changes to wind speed and relative humidity.

System potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system potential condition uses best estimates of *mature riparian vegetation, system potential channel morphology, and system potential riparian microclimate* that would occur absent any human alteration.

Total maximum daily load (TMDL): A distribution of a substance in a water body designed to protect it from 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.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

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.

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.

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to 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 water bodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards, and are not expected to improve within the next two years.

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.

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

Acronyms and abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMPs	best management practices
CAFO	confined animal feeding operation
CBOD	carbonaceous biochemical oxygen deman
CC	Country Club
CD	conservation district
CWA	Clean Water Act
DEM	digital elevation model
DIN	dissolved inorganic nitrogen
DO	dissolved oxygen
DOH	Washington State Deparment of Health
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
ECY	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
ER	ecosystem respiration
GIS	Geographic Information System software
GPP	gross primary productivity
GW	groundwater
HTS	hyporheic transient storage
IDEQ	Idaho Department of Environmental Quality
IP	Implementation Plan
LA	Load Allocation
LSR	Little Spokane River
MQO	measurement quality objective
MS4	municipal separate storm sewer system
MW	monitoring well
NAIP	National Agricultural Imagery Program
NIST	National Institute of Standards and Technology
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PAR	photosynthetically active radiation
PRA	percent relative abundance
QAPP	Quality Assurance Project Plan
QC	quality control
RM	river mile
RMA	River Metabolism Anlyzer modeling tool
RMSE	root mean squared error
RPD	relative percent difference
RSD	relative standard deviation
SCC	Spokane Community College

SCD	Spokane Conservation District
SNOTEL	SNOw TELemetry system
SOD	sediment oxygen demand
SRP	soluble reactive phosphorus
SVRPA	Spokane Valley-Rathdrum Prairie Aquifer
TMDL	total maximum daily load (water cleanup plan)
TN	total nitrogen
TP	total phosphorus
TPN	total persulfate nitrogen
TSS	total suspended solids
USGS	United States Geological Survey
WAC	Washington Administrative Code
WBLSR	West Branch Little Spokane River
WD	Water District
WDFW	Washington Department of Fish and Wildlife
WLA	Wasteload Allocation
WQA	Water Quality Assessment
WRIA	Water Resources Inventory Area
WSDOT	Washington State Deparment of Transportation
WSU	Washington State University
WWRC	Washington Water Research Center

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cms	cubic meters per second, a unit of flow.
cm^2/s	square centimeters per second
cm/yr	centimeters per year
°F	degrees Fahrenheit
ft	feet
ft/s	feet per second
g	gram, a unit of mass
g/d	grams per day
g/m^2	grams per square meter (a unit of areal biomass)
$gO_2/m^2/d$	grams of oxygen per square meter per day (a unit of productivity or respiration)
in	inches
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters.
km^2	square kilometer
lbs/d	pounds per day
m	meter
m/d	meters per day (a unit of upward groundwater inflow)
m/s	meters per second
mi	mile
mi^2	square mile

mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
mg/m^2	milligrams per square meter (a unit of areal biomass)
ppm	parts per million
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity
W/m/°C	Watts per meter per degree centigrade

Appendix D. Ecology data summary 2013 and 2015-2016

This appendix summarizes data collected by Ecology during 2013 and 2015-2016. TMDL data collected during 2010 and Spokane Hatchery data collected during 2009 are available in a separately published data summary report (Stuart, 2012).

Sample Locations

Table D-1. Sampling locations used during the 2013 and 2015-2016 data collection efforts.

EIM Location ID	Study Specific Location ID	Sampling Location	Latitude	Longitude	2015-2016 Nutrients	2015 Lakes	2013 Diel Hlab	2015 Diel Hlab	2015 Periphyton	2013 Seepage/Flow	2015 Temperature
55B300	55LSR-46.7	LSR @ Scotia	48.1059	-117.1528	X			X			X
55LSR-42.3	55LSR-42.3	LSR @ Chain Lk inlet	48.0599	-117.1948	*						
55LSR-39.5	55LSR-39.5	LSR @ Frideger Rd	48.0407	-117.2437	X			X		X	
55LSR-37.5	55LSR-37.5	LSR @ Elk Park	48.0226	-117.2730					X		X
55LSR-37.1	55LSR-37.1	LSR @ Elk	48.0166	-117.2770	X		X	X			
55LSR-33.2	55LSR-33.2	LSR @ E Eloika Rd	47.9849	-117.3248			X			X	
LSRTMDL-2	55LSR-31.8	LSR @ Deer Park-Milan Rd	47.9695	-117.3339			X	X		X	
55LSR-25.4	55LSR-25.4	LSR @ Riverway Rd	47.9040	-117.3435						X	
55B200	55LSR-23.4	LSR @ Chattaroy	47.8894	-117.3553	X		X	X	X	X	
55LSR-19.8	55LSR-19.8	LSR @ Colbert Landfill outfall	47.8618	-117.3610			X				
55LSR-18.0	55LSR-18.0	LSR @ LSR Dr in Buckeye	47.8426	-117.3746						X	
55LSR-16.0	55LSR-16.0	LSR @ E Colbert Rd	47.8239	-117.3741			X			X	
55B100	55LSR-13.5	LSR @ N LSR Dr	47.7983	-117.3817	X		X	X		X	X
55LSR-11.7	55LSR-11.7	LSR @ Pine River Park (upper)	47.7913	-117.3984					X		
55B080	55LSR-07.5	LSR @ W Waikiki Rd	47.7700	-117.4525						X	
55B075	55LSR-03.9	LSR @ Rutter Pkwy (Painted Rocks)	47.7809	-117.4952			X				
55B070	55LSR-01.1	LSR @ Mouth	47.7832	-117.5297	X		X	X			
55CHA-00.2	55CHA-00.2	Unnamed trib to Chain Lake @ Mouth	48.0592	-117.2091	*						
55JON-00.5	55JON-00.5	Jones Ck (Camden Ck?) @ Mouth	48.0515	-117.2394	*						
55REFL-NOUT	55REFL-NOUT	Reflection Lk @ North outlet	48.0029	-117.2836	Q						
55SHE-00.6	55SHE-00.6	Sheets Ck @ Reflection Lake outlet	47.9930	-117.2889	X						
55DRY-01.2	55DRY-01.2	Dry Ck @ Dunn Rd	47.9823	-117.2846	Q						
LSRTMDL-15	55DRY-00.4	Dry Ck @ Mouth	47.9865	-117.2951	X			X		X	
55OTT-02.0	55OTT-02.0	Otter Ck @ 3rd Valley Rd xing	48.0090	-117.3112	Q						
55OTT-01.4	55OTT-01.4	Otter Ck @ 2nd Valley Rd xing	48.0041	-117.3173				X			
55OTT-00.3	55OTT-00.3	Otter Ck @ Mouth	47.9903	-117.3212	X			X		X	
LSRTMDL-17	55MOO-02.9	Moon Ck @ Hwy 211	48.1180	-117.2737	X			X			
LSRTMDL-20	55WBLS-17.7	WBLSR @ Harworth Rd	48.1354	-117.3526	X			X			
55WBLS-12.4	55WBLS-12.4	WBLSR @ Horseshoe Lk inlet	48.1142	-117.4115	*						
LSRTMDL-6	55BUC-00.3	Buck Ck @ Mouth	48.1192	-117.4181	X			X			
55WBLS-11.1	55WBLS-11.1	WBLSR blw Horseshoe Lk	48.0979	-117.4114	X						
LSRTMDL-5	55BEAV-00.5	Beaver Ck (WBLSR trib) @ Mouth	48.0969	-117.4230	X						

EIM Location ID	Study Specific Location ID	Sampling Location	Latitude	Longitude	2015-2016 Nutrients	2015 Lakes	2013 Diel Hlab	2015 Diel Hlab	2015 Periphyton	2013 Seepage/Flow	2015 Temperature
LSRTMDL-22	55WBLS-07.7	WBLSR @ Fan Lk Rd	48.0607	-117.3994	X			X	X		
55FAN-00.3	55FAN-00.3	Fan Lk outlet	48.0561	-117.4038	Q						
LSRTMDL-23	55WBLS-03.1	WBLSR @ Eloika Lk Rd	48.0071	-117.3627	X			X		X	X
55BEA-03.7	55BEAR-03.7	Bear Ck @ Deer Park-Milan Rd	47.9644	-117.3716	Q						
55BEA-00.4	55BEAR-00.4	Bear Ck @ Mouth	47.9297	-117.3416	X			X		X	
55DEE-05.9	55DEE-05.9	Deer Ck abv Little Deer Ck	47.9139	-117.2653	X			X			
55LDR-00.1	55LDR-00.1	Little Deer Ck @ Mouth	47.9138	-117.2645	X						
55DEE-03.2	55DEE-03.2	Deer Ck @ Bruce Rd	47.8946	-117.3043	Q						
55DEE-01.4	55DEE-01.4	Deer Ck @ Elk-Chattaroy Rd	47.8908	-117.3366				X			
55D070	55DEE-00.1	Deer Ck @ Mouth	47.8883	-117.3536	X			X		X	
55DRA-19.6	55DRA-19.6	Dragoon Ck @ Montgomery Rd	47.9894	-117.4947				X			
LSRTMDL-11	55DRA-17.0	Dragoon Ck @ Dahl Rd	47.9603	-117.4872	X			X			
55SPR-00.4	55SPR-00.4	Spring Ck @ Spring Ck Rd	47.9622	-117.4831	X			X			
55E-CRAWFORD	55DRA-16.4	Dragoon Ck @ Hwy 395 nr Deer Park	47.9537	-117.4878	X			X			
55BEAV2-00.1	55BEAV2-00.1	Beaver Ck (Dragoon trib) @ Mouth	47.9471	-117.5075	*						
55DRA-13.2	55DRA-13.2	Dragoon Ck abv WB Dragoon Ck	47.9320	-117.4985	X			X			
LSRTMDL-14	55WBDR-00.1	WB Dragoon Ck @ Mouth	47.9157	-117.4983	X			X			
55MUD-00.7	55MUD-00.7	Mud Ck @ Mouth (@ Monroe Rd)	47.9039	-117.4981	*						
55DRA-05.4	55DRA-05.4	Dragoon Ck @ DNR campground	47.8862	-117.4406					X		
55DRA-04.3	55DRA-04.3	Dragoon Ck @ North Rd	47.8879	-117.4232	X			X			
LSRTMDL-13	55DRA-00.3	Dragoon Ck @ Mouth	47.8751	-117.3728	X			X		X	X
55SFLD-03.0	55SFLD-03.0	SF Little Deep Ck abv Day-Mt Spokane Rd	47.8870	-117.2070	Q						
LD-1	55SFLD-01.1	SF Little Deep Ck @ Big Meadows Rd	47.8708	-117.2378	X			X			
55LDP-00.1	55LDP-00.1	Little Deep Ck @ Shady Slope Rd	47.7972	-117.3783	X			X			
55DEA-20.2	55DEA-20.2	Deadman Ck @ Park Bdy	47.8819	-117.1350	X			X			
55C200	55DEA-13.8	Deadman Ck @ Holcomb Rd	47.8298	-117.2077	X			X	X		
LSRTMDL-9	55DEA-09.2	Deadman Ck @ Heglar Rd	47.7875	-117.2489	**			X			
LSRTMDL-9.5	55DEA-05.9	Deadman Ck @ Bruce Rd	47.7802	-117.3044	X			X			
55DEA-02.6	55DEA-02.6	Deadman Ck blw Market St	47.7793	-117.3540	**						
55DEA-00.6	55DEA-00.6	Deadman Ck @ Shady Slope Rd	47.7937	-117.3771	X			X			
55SBD-00.5	55SBD-00.5	SB Deadman Ck @ Shady Slope Rd	47.7929	-117.3772	Q						
LSRTMDL-8	55DEA-00.2	Deadman Ck blw Little Deep Ck	47.7956	-117.3808						X	X
LSRTMDL-7	55DAR-00.2	Dartford Ck @ Mouth	47.7847	-117.4173	X			X		X	
55CHAI-W	55CHAI-W	Chain Lake deep location near west end	48.0546	-117.2196		X					
55CHAI-E	55CHAI-E	Chain Lake deep location near east end	48.0598	-117.1997		h					
55DIAM	55DIAM	Diamond Lake deep location near east end	48.1312	-117.1889		X					
55SACH-E	55SACH-E	Sacheen Lake deep location in NE portion	48.1582	-117.3077		X					
55SACH-W	55SACH-W	Sacheen Lake deep location nr outlet at W end	48.1478	-117.3346		X					
55HORS-E	55HORS-E	Horseshoe Lake deep location in east arm	48.1079	-117.4094		X					
55HORS-W	55HORS-W	Horseshoe Lake deep location in west arm	48.1128	-117.4198		X					
55ELOI-N	55ELOI-N	Eloika Lake location near north end	48.0372	-117.3876		X					
55ELOI-S	55ELOI-S	Eloika Lake location near south end	48.0227	-117.3757		X					

*We sampled these locations once each during summer low-flow period.

**We sampled these locations four times each during 2015-2016 during runoff conditions.

Q We only measured flow at these locations, but did not collect samples.

h We took a measurement profile at this lake location but did not collect nutrient samples.

Laboratory Data

Table D-2. Abbreviations and units of measurement used in this section.

Abbreviation	Parameter	Unit of Measurement
Alk	Alkalinity, Total as $CaCO_3$	mg/L
NH4-N	Ammonia Nitrogen	mg/L
Cl	Chloride	mg/L
Chl a	Chlorophyll a	ug/L
DOC	Dissolved Organic Carbon	mg/L
NO2-3N	Nitrite-Nitrate Nitrogen	mg/L
SRP	Soluble Reactive Phosphorus (Orthophosphate)	mg/L
TOC	Total Organic Carbon	mg/L
TP	Total Phosphorus	mg/L
TPN	Total Persulfate Nitrogen	mg/L
TSS	Total Suspended Solids	mg/L

Table D-3. Data qualifiers used in this section.

Qualifier	Meaning
U	The analyte was not detected at or above the reported result.
J	The analyte was positively identified. The associated numerical result is an estimate.
UJ	The analyte was not detected at or above the reported estimated result.

Table D-4. Laboratory water quality results from the 2015-2016 Little Spokane River data collection effort.

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55LSR-46.7	2/17/2015	13:58	0.013	0.3	0.355	0.0138	0.0207	1.1	1 U	5	4.44		
55LSR-46.7	3/17/2015	13:55	0.01 U	0.275	0.326	0.0137 J	0.0237			6	4.7		
55LSR-46.7	4/21/2015	14:25	0.011	0.181	0.232	0.0097	0.0204 J			6	3.87		
55LSR-46.7	5/19/2015	15:45	0.01	0.133	0.198	0.0084	0.0151	1.1	1	3	3.82		
55LSR-46.7	6/16/2015	14:18	0.01 U	0.141	0.205	0.0089	0.0136			2	3.67		
55LSR-46.7	7/21/2015	14:43	0.01 U	0.086	0.149	0.0079	0.0105			1 U	3.71	117	
55LSR-46.7	8/18/2015	14:46	0.015	0.074	0.168	0.006	0.0081	1.1	1.1	1 U	3.7 J	118 J	
55LSR-46.7	9/22/2015	14:42	0.01 U	0.167	0.223	0.0061	0.0092			1 U	3.43		
55LSR-46.7	10/20/2015	13:11	0.01 UJ	0.24 J	0.241 J	0.0061	0.008			1 U	3.29		
55LSR-46.7	11/17/2015	13:53	0.017	0.291	0.361	0.0096	0.0527	1	1.2	3	3.22		
55LSR-46.7	1/19/2016	14:30	0.021	0.336	0.417	0.0145	0.0332			13	4.12 J		
55LSR-46.7	2/22/2016	15:50	0.013	0.297	0.367	0.0141	0.0245			4 J	4.85		
55LSR-46.7	3/16/2016	15:10	0.01 UJ	0.277 J	0.353 J	0.0126 J	0.0224			5	4.03 J		
55LSR-42.3	9/1/2015	13:49	0.013	0.054	0.196	0.0055	0.0115						
55LSR-39.5	2/17/2015	13:05	0.01 U	0.224	0.31	0.0059	0.0142	1.9	1.6	2 U	3.42		
55LSR-39.5	3/4/2015	9:11	0.012	0.216	0.299	0.005	0.0112			2	3.45		
55LSR-39.5	3/17/2015	12:57	0.011 J	0.191 J	0.275 J	0.0063 J	0.012			2 U	3.27		
55LSR-39.5	4/8/2015	10:55	0.022	0.108	0.219	0.0059	0.0125			2	3.26		
55LSR-39.5	4/21/2015	13:15	0.027 J	0.085 J	0.2 J	0.008 J	0.0145			2	3.26		
55LSR-39.5	5/6/2015	10:45	0.013	0.039	0.134	0.006	0.015			2	3.15		
55LSR-39.5	5/19/2015	14:50	0.011	0.021	0.126	0.0058	0.0124	1.3	1.6	2	3.15		1.9
55LSR-39.5	6/3/2015	10:05	0.01 U	0.012	0.14	0.0064	0.0131			2	2.99		
55LSR-39.5	6/16/2015	13:25	0.01 U	0.01	0.139	0.006	0.0103			1 U	3.08		1.5
55LSR-39.5	7/8/2015	10:50	0.01 U	0.01 U	0.117	0.0054	0.0079			1 U	3.1 J		
55LSR-39.5	7/21/2015	13:49	0.01 U	0.01 U	0.107	0.0051	0.0081			1 U	3.12		2.2
55LSR-39.5	8/4/2015	11:25	0.01 U	0.01 U	0.114	0.004	0.0184			1 U	3.36		
55LSR-39.5	8/18/2015	13:27	0.019	0.01 U	0.157	0.0046	0.0068	2	2.5	1 U	3.34 J		2.1
55LSR-39.5 (QC)	8/18/2015	13:27	0.01 U	0.01 U	0.131	0.0041	0.0075	1.7	1.8	1 U	3.29		1.9
55LSR-39.5	9/9/2015	9:45	0.01 U	0.01 U	0.105	0.003 U	0.0082 J			1 U	3.4 J		
55LSR-39.5	9/22/2015	12:45	0.01 U	0.01 U	0.114	0.0037	0.007			1	3.1		2.7
55LSR-39.5	10/7/2015	10:40	0.01 U	0.011	0.11	0.0047	0.0073			1 U	3.1 J		
55LSR-39.5	10/20/2015	12:21	0.01 U	0.022	0.1	0.0048 J	0.0085			1 U	2.99		2.1
55LSR-39.5	11/5/2015	10:30	0.016	0.081	0.174	0.0042	0.0092			1 U	3.02		
55LSR-39.5	11/17/2015	13:03	0.06	0.154	0.304	0.0047	0.0112	1.1	1.3	2	3		3.9 J
55LSR-39.5	12/11/2015	11:11	0.093	0.252	0.418	0.0069 J	0.0149			1 J	3.02 J		
55LSR-39.5	1/5/2016	11:10	0.026	0.367	0.432	0.0086	0.0127			2	3.54		
55LSR-39.5	1/19/2016	13:29	0.03	0.331	0.422	0.0095 J	0.012			1	3.29		
55LSR-39.5	2/3/2016	11:34	0.016	0.309	0.381	0.0078	0.0148			1 U	3.36		
55LSR-39.5	2/22/2016	14:42	0.01 U	0.252 J	0.349 J	0.0044	0.0144			3	3.77 J		
55LSR-39.5	3/16/2016	14:29	0.011	0.248	0.349	0.005	0.0136			3 J	2.97		
55LSR-37.1	2/17/2015	12:24	0.01 U	0.374	0.484	0.0103	0.0137	1.8	1.6	3	3.36		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55LSR-37.1	3/17/2015	12:23	0.01 UJ	0.35 J	0.422 J	0.0083 J	0.0163			2	3.16		
55LSR-37.1	4/21/2015	13:00	0.017	0.261	0.357	0.0092 J	0.0176			4	3.13		
55LSR-37.1	5/19/2015	14:15	0.013	0.167	0.253	0.0081	0.0139	1.2	1.5	3	2.95		2
55LSR-37.1	6/16/2015	12:55	0.01 U	0.152	0.256	0.0073	0.015			4	2.91		1.5
55LSR-37.1	7/21/2015	12:35	0.011	0.116	0.212	0.0062	0.009			1 U	2.96		1.5
55LSR-37.1 (QC)	7/21/2015	12:35	0.014	0.114	0.214	0.0064	0.0083			1 U	2.92	201	1.4
55LSR-37.1	8/18/2015	12:48	0.01 U	0.129	0.263	0.0051	0.0055	1.4	1.4	1 U	3.07		1.4 J
55LSR-37.1	9/22/2015	11:45	0.01 U	0.169	0.273	0.0052	0.0086			1 U	2.89		1.2
55LSR-37.1 (QC)	9/22/2015	11:55	0.01 U	0.171	0.263	0.0052	0.0076			1 U	2.89		1.3
55LSR-37.1	10/20/2015	11:51	0.01 U	0.2	0.266	0.0062	0.0089			1 U	2.83		1.4
55LSR-37.1	11/17/2015	11:55	0.039	0.32	0.433	0.0067	0.0124	1.1	1.3	2	2.85		2.7 J
55LSR-37.1 (QC)	11/17/2015	12:05	0.038	0.32	0.429	0.0073	0.0136	1.2	1.3	2	2.85		2.6 J
55LSR-37.1	1/19/2016	12:50	0.021	0.471	0.546	0.0109 J	0.0135			2	3.16		
55LSR-37.1	2/22/2016	14:00	0.01 U	0.382	0.48	0.0057	0.0169			4 J	3.77 J		
55LSR-37.1	3/16/2016	13:47	0.01 U	0.37	0.463	0.0067	0.0156			3	2.97		
55LSR-23.4	2/17/2015	9:53	0.014	0.309	0.488	0.0086	0.0288	2.9	2.9	11	3.64		
55LSR-23.4	3/17/2015	8:30	0.048	0.394	0.636	0.0137	0.0399 J			15	4.05		
55LSR-23.4	4/21/2015	9:22	0.027	0.306	0.471	0.0103	0.0267			15	3.75		
55LSR-23.4	5/19/2015	9:44	0.014	0.251	0.394	0.0083	0.0184	2.2	2.4	3	3.54		2.1 J
55LSR-23.4 (QC)	5/19/2015	9:44	0.012	0.248	0.4	0.0078	0.0192	2.2	2.4	3	3.57		2.2 J
55LSR-23.4	6/16/2015	8:57	0.011	0.222	0.371	0.0074	0.0148			2	3.72		1.2 J
55LSR-23.4	7/21/2015	9:22	0.011	0.193	0.314	0.0063	0.0101			1 U	3.87		1.1
55LSR-23.4	8/18/2015	9:11	0.013	0.239	0.419	0.005	0.0078	2.1	1.9	1 U	4.12		1.7
55LSR-23.4	9/22/2015	9:10	0.011	0.337	0.485	0.0051	0.0106			1	3.81		1.2
55LSR-23.4	10/20/2015	8:51	0.014	0.446	0.571	0.0057	0.0114			2	3.84		2.4
55LSR-23.4 (QC)	10/20/2015	9:12	0.015	0.449	0.56	0.0059	0.0108			1	3.87		2.3
55LSR-23.4	11/17/2015	8:58	0.013	0.536	0.673	0.0064	0.0126	2.1	2.3	1	3.78		2.3 J
55LSR-23.4	1/19/2016	9:15	0.023	0.54	0.7	0.0142	0.0213			3	4.49		
55LSR-23.4	2/22/2016	9:55	0.017	0.273	0.479	0.008	0.04			17	4.1		
55LSR-23.4	3/16/2016	10:15	0.012	0.199	0.429	0.0084	0.0287			8	3.08		
55LSR-13.5	2/18/2015	12:50	0.011	0.647	0.837	0.0152	0.0392	3.3	3.2	11	3.94		
55LSR-13.5	3/18/2015	13:20	0.022	0.774	0.935	0.0209 J	0.0486			16	4.66		
55LSR-13.5	4/22/2015	14:45	0.02	0.731	0.888	0.0138 J	0.0285			9	4.3		
55LSR-13.5	5/20/2015	9:35	0.018	0.798	0.972	0.0121	0.0223	2	2.3	4	4.34		3.4
55LSR-13.5	6/17/2015	13:05	0.013	0.784	0.924	0.0105	0.0184			2	4.65		1.7
55LSR-13.5	7/22/2015	13:55	0.017	0.872	0.967	0.0101	0.0164			3	4.74		1.4
55LSR-13.5	8/19/2015	9:00	0.025	0.94	1.14	0.008	0.0265	1.6 J	1.5 J	1	5.02		1.4
55LSR-13.5	9/23/2015	13:15	0.01 U	1.06	1.2	0.0062	0.0099			1 U	4.61		1.1
55LSR-13.5	10/21/2015	9:30	0.019	1.19	1.29	0.0075	0.0124 J			1	4.6		1.5
55LSR-13.5	11/19/2015	9:44	0.011	1.15	1.31	0.0112	0.0177	2.3	2.6	2 J	5.66		1.8 J
55LSR-13.5	1/20/2016	9:20	0.017	1.03	1.2	0.0218	0.0321			6	5.4		
55LSR-13.5	2/23/2016	17:15	0.013	0.534	0.717	0.0209	0.0559			14	4.19		
55LSR-13.5	3/17/2016	9:20	0.011	0.386	0.599	0.0204	0.0453			9 J	4.03		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55LSR-01.1	2/17/2015	8:15	0.011	0.803	0.969	0.0206	0.0383	2.6	2.3	14	4.7 J		
55LSR-01.1	3/17/2015	8:00	0.03	0.91	1.14	0.0271	0.0639			28	5.36		
55LSR-01.1	4/21/2015	8:35	0.011	0.946	1.04	0.0123	0.0217			8	5.06		
55LSR-01.1	5/19/2015	8:08	0.01	0.978	1.11	0.0091	0.0186	1.1	1.3	5	5.13		
55LSR-01.1	6/16/2015	8:17	0.01 U	1.07	1.14	0.0084	0.014			4	5.3		
55LSR-01.1	7/21/2015	8:15	0.01 U	1.11	1.16	0.0077	0.0092			3	5.43		
55LSR-01.1	8/18/2015	8:27	0.01 U	1.11	1.28	0.0063	0.0089	1 U	1 U	2	5.62		
55LSR-01.1	9/22/2015	8:45	0.01	1.16	1.25	0.0069	0.01			3	5.1		
55LSR-01.1	10/20/2015	8:52	0.011	1.27	1.29	0.0076	0.0107			3	4.89		
55LSR-01.1	11/17/2015	8:56	0.01 U	1.27	1.32	0.0089	0.0144	1 U	1 U	4	4.92		
55LSR-01.1	1/19/2016	8:55	0.012	1.16	1.27	0.0169	0.024			8	5.44		
55LSR-01.1	2/22/2016	9:00	0.01 U	0.708	0.854	0.025	0.0593			18	4.94		
55LSR-01.1	3/16/2016	8:50	0.01 UJ	0.524 J	0.73 J	0.0251 J	0.0513 J			10	3.8		
55CHA-00.2	9/22/2015	13:35	0.01 U	0.517	0.524	0.0204	0.0342			6	4.67		
55JON-00.5	9/22/2015	14:09	0.01 U	1.44	1.41	0.0167	0.0187			1	3.01		
55SHE-00.6	2/17/2015	12:01	0.01 U	0.905	1.02	0.0052	0.008	1.2	1.1	1	2.31		
55SHE-00.6	3/17/2015	11:57	0.01 UJ	0.917 J	1.01 J	0.0059 J	0.0099 J			1 U	2.31		
55SHE-00.6	4/21/2015	12:31	0.011	0.611	0.712	0.0052 J	0.008			2	2.38		
55SHE-00.6	5/19/2015	13:50	0.029	0.312	0.652	0.0083	0.0974	2.7	7	49	2.3		32.4
55SHE-00.6	6/16/2015	12:20	0.212	0.303	0.74	0.0056	0.0156			3	2.45		8.9
55SHE-00.6	7/21/2015	12:10	0.062	0.331	0.607	0.006	0.0133			6	2.58		8.2
55SHE-00.6	8/18/2015	12:19	0.019	0.256	0.565	0.0049	0.0103	2.6	3.8	6	2.68		8.2
55SHE-00.6	9/22/2015	11:23	0.019	0.33	0.605	0.0037	0.0095			2	2.48 J		4.6
55SHE-00.6	10/20/2015	11:31	0.023	0.411	0.616	0.0049	0.0097			2	2.3		14.2
55SHE-00.6	11/17/2015	11:13	0.099	0.551	0.841	0.0052	0.0167	2.1	2.4	2	2.21		4.8 J
55SHE-00.6	1/19/2016	12:23	0.044	0.901	1.05	0.0063	0.0107			2	2.17		
55SHE-00.6	2/22/2016	13:25	0.01 U	0.874	0.956	0.004 J	0.0106			3	2.53		
55SHE-00.6	3/16/2016	13:30	0.011	0.814	0.892	0.0037	0.009 J			3 J	2.16		
55DRY-00.4	2/17/2015	11:04	0.01 U	0.464	0.607	0.0321	0.0559	4.7	4.7	9	2.64		
55DRY-00.4	3/17/2015	11:21	0.01 UJ	0.484 J	0.662 J	0.0326 J	0.0649			8 J	2.45		
55DRY-00.4	4/21/2015	11:46	0.012	0.552	0.657	0.0215	0.032			5	2.28		
55DRY-00.4	5/19/2015	12:55	0.01 U	0.752	0.862	0.0184	0.0274	2	1.9	4	2.29		
55DRY-00.4	6/16/2015	11:50	0.013	0.906	0.992	0.0208	0.0287			2	2.65		
55DRY-00.4	7/21/2015	11:28	0.012	0.914	0.991	0.0226	0.0301			2	2.92	117	
55DRY-00.4	8/18/2015	11:35	0.011	0.894	1.05	0.0206	0.029	1.2	1.2	3	3.01	119	
55DRY-00.4	9/22/2015	10:50	0.01 U	0.95	1.01	0.0161	0.023 J			1	2.61		
55DRY-00.4	10/20/2015	10:50	0.01	1.08	1.14	0.0174	0.0242			1 U	2.73		
55DRY-00.4	11/17/2015	10:50	0.01 U	1.16	1.24	0.0188	0.031	1.5	1.6	3	2.67		
55DRY-00.4	1/19/2016	11:43	0.014	1.34	1.42	0.0231	0.0292			2	2.82		
55DRY-00.4	2/22/2016	12:35	0.01 U	0.22	0.368	0.0285	0.0759			9 J	2.24		
55DRY-00.4	3/16/2016	12:36	0.01 U	0.177	0.353	0.0267	0.0711			13 J	1.75		
55OTT-00.3	2/18/2015	16:02	0.01 U	1.32	1.47	0.0337	0.0367	2.6	2.2	3	7.56		
55OTT-00.3	3/17/2015	9:25	0.416	1.4	2.09	0.0464	0.0626 J			6	7.59		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55OTT-00.3 (QC)	3/17/2015	9:25	0.445	1.4	2.11	0.0462 J	0.0651			7	7.59		
55OTT-00.3	4/21/2015	11:00	0.01 U	1.37	1.35	0.0284	0.0308			2	7.08		
55OTT-00.3	5/19/2015	11:52	0.01 U	1.5	1.59	0.0216	0.0232	1.3	1.1	2	6.1		
55OTT-00.3	6/16/2015	11:00	0.01 U	1.52	1.57	0.018	0.0178			1	7.48		
55OTT-00.3	7/21/2015	10:52	0.011	1.71	1.68	0.0152	0.019			4	6.71	77.5	
55OTT-00.3	8/18/2015	11:04	0.01 U	1.49	1.61	0.0177	0.02	1.2	1.1	2	7.94	77.1	
55OTT-00.3	9/22/2015	10:23	0.01 U	1.48	1.43	0.0168	0.02			2	7.49		
55OTT-00.3	10/20/2015	10:20	0.01 U	1.5	1.51	0.0187	0.0199			2	7.35		
55OTT-00.3	11/17/2015	10:18	0.01 U	1.49	1.53	0.0225	0.0294	1.9	2	3	7.69		
55OTT-00.3	1/19/2016	10:45	0.01 U	1.35	1.53	0.041	0.0434			2	7.25		
55OTT-00.3 (QC)	1/19/2016	10:45	0.01 U	1.39	1.5	0.0418	0.0428			2	7.2		
55OTT-00.3	2/22/2016	11:31	0.01 U	1.27	1.35	0.0439	0.0619			3	7.22		
55OTT-00.3	3/16/2016	11:25	0.01	1.41	1.62	0.0523 J	0.0763 J			5	5.84 J		
55OTT-00.3 (QC)	3/16/2016	11:25	0.011	1.42	1.63	0.0521	0.0788			4	5.8		
55MOO-02.9	2/17/2015	14:55	0.01 U	0.103	0.363	0.0039	0.014	5.2	5.1	1 U	7.18		
55MOO-02.9	3/17/2015	14:48	0.01 UJ	0.133 J	0.544 J	0.0051	0.0186			2	8.39		
55MOO-02.9	4/21/2015	15:25	0.012 J	0.292 J	0.511 J	0.0077 J	0.0159			3	14.5		
55MOO-02.9	5/19/2015	16:31	0.01 U	0.255	0.448	0.0074	0.0143	3.8	4.1	2 U	15.8		
55MOO-02.9	6/16/2015	15:26	0.01 U	0.232	0.452	0.0083	0.0145			1	15		
55MOO-02.9	7/21/2015	15:44	0.016	0.181	0.397	0.0105	0.0152			1 U	18.2	39.1	
55MOO-02.9	8/18/2015	15:40	0.01	0.166	0.396	0.01	0.0149	3	3.1	1 UJ	19.3	38.4	
55MOO-02.9	9/22/2015	15:40	0.01 U	0.193	0.328	0.0068	0.0104			1 U	18.7		
55MOO-02.9	10/20/2015	14:03	0.01 U	0.236	0.379	0.0088	0.01			1 U	18.7		
55MOO-02.9	11/17/2015	14:48	0.01 U	0.341	0.545	0.0077	0.0188	3.9	4.1	6	17.6		
55MOO-02.9	1/19/2016	15:19	0.011	0.324	0.637	0.0079	0.0136			1 U	14.9 J		
55MOO-02.9	2/23/2016	9:00	0.01 UJ	0.112	0.435	0.006	0.016			1	8.62		
55MOO-02.9	3/17/2016	9:07	0.01 U	0.098	0.465	0.0044	0.0136			2 U	8.47		
55MOO-02.9 (QC)	3/17/2016	9:07	0.01 U	0.105	0.445	0.0044	0.0125			1	0.63		
55WBLS-17.7	2/17/2015	15:47	0.01 U	0.038	0.24	0.0052	0.0157	4.2	4.2	2	4.88		
55WBLS-17.7	3/17/2015	15:40	0.01 UJ	0.012 J	0.237 J	0.0067	0.0161			1	4.5		
55WBLS-17.7	4/21/2015	16:00	0.012	0.01 U	0.228	0.0047 J	0.0133 J			2	4.87		
55WBLS-17.7	5/20/2015	9:01	0.011	0.01 U	0.246	0.0048	0.0156	4.3	4.6	2 U	4.71		1.5
55WBLS-17.7	6/16/2015	15:53	0.01 U	0.01 U	0.241	0.0059	0.014			2	4.87		1.4
55WBLS-17.7	7/21/2015	16:10	0.033	0.01 U	0.262	0.0069	0.0254			2 U	3.93	45.5	2.3
55WBLS-17.7	8/18/2015	16:10	0.01 U	0.01 U	0.296	0.0042	0.0099	4.5	4.6	2 U	5.49 J	34.2 J	1 J
55WBLS-17.7	9/23/2015	8:59	0.01 U	0.01 U	0.266	0.0031	0.0102			1	5.39		1.8
55WBLS-17.7 (QC)	9/23/2015	9:24	0.01 U	0.01 U	0.258	0.0031	0.0103			2 U	5.48 J		1.7
55WBLS-17.7	10/20/2015	14:30	0.01 U	0.01 U	0.21	0.0046	0.0102			1 U	5.63		1.1
55WBLS-17.7	11/17/2015	15:25	0.01 U	0.01 U	0.244	0.005	0.0155	3.7	4	1	5.45		3.1 J
55WBLS-17.7	1/20/2016	9:13	0.014	0.057	0.297	0.0065	0.0139			1 U	4.6		
55WBLS-17.7	2/23/2016	10:15	0.01 U	0.059	0.255	0.005	0.0165			2	5.39		
55WBLS-17.7	3/17/2016	10:50	0.01 U	0.054	0.272	0.0042	0.0149			2 U	5.21		
55WBLS-12.4	9/2/2015	12:00	0.01 J	0.01 UJ	0.237 J	0.0038	0.0105						

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55BUC-00.3	2/18/2015	10:36	0.01 U	0.109	0.181	0.0255	0.0365	2.9	2.6	6	0.53		
55BUC-00.3	3/18/2015	9:50	0.01 U	0.087	0.151	0.0249	0.0354			4	0.42		
55BUC-00.3	4/22/2015	9:43	0.01 U	0.01 U	0.071	0.0233	0.0274			2	0.41		
55BUC-00.3 (QC)	4/22/2015	9:43	0.01 U	0.01 U	0.066	0.0397	0.0272			2	0.46		
55BUC-00.3	5/20/2015	10:55	0.01 U	0.01 U	0.064	0.0273	0.0327	1.8	1.8	2	0.38		
55BUC-00.3	6/17/2015	10:58	0.01 U	0.035	0.11	0.0324	0.0368			2	0.4		
55BUC-00.3	7/22/2015	9:50	0.011	0.029	0.086	0.0277	0.0288			1 U	0.43	5 U	
55BUC-00.3	8/19/2015	10:15	0.01 U	0.01 U	0.068	0.0198	0.0204	1.7 J	1.6	1 U	0.46	34.2	
55BUC-00.3	9/23/2015	10:55	0.01 U	0.01 U	0.068	0.018	0.0205			1 U	0.53		
55BUC-00.3	10/21/2015	10:13	0.01 U	0.01 U	0.051	0.0216	0.0221			1 U	0.72		
55BUC-00.3	11/19/2015	17:15	0.01 UJ	0.197 J	0.323 J	0.02	0.0311	5.4	5.8 J	1 UJ	1.09 J		
55BUC-00.3	1/20/2016	11:07	0.01 U	0.176	0.277	0.0227	0.0358			3	0.63		
55BUC-00.3 (QC)	1/20/2016	11:07	0.01 U	0.177	0.281	0.0228	0.0363			2	0.62		
55BUC-00.3	2/23/2016	12:40	0.01 U	0.174	0.261	0.0281	0.0526			10	0.68		
55BUC-00.3	3/17/2016	12:20	0.01 UJ	0.109 J	0.167 J	0.0265 J	0.0505			16	0.67 J		
55WBLS-11.1	2/18/2015	12:49	0.01 U	0.1	0.238	0.0084	0.019	3.4	3.2	1 U	2.56		
55WBLS-11.1 (QC)	2/18/2015	12:49	0.01 U	0.103	0.239	0.0081	0.0194		3.2	1 U	2.55		
55WBLS-11.1	3/18/2015	11:24	0.01 U	0.053	0.194	0.0062	0.0184			1 U	2.6		
55WBLS-11.1	4/22/2015	12:00	0.011	0.01 U	0.179	0.0058	0.014			1	2.6		
55WBLS-11.1	5/20/2015	12:23	0.013	0.01 U	0.177	0.0096	0.0139	3.2	3.4	2 U	2.26		1.1
55WBLS-11.1	6/17/2015	12:37	0.014	0.01 U	0.191	0.0055	0.0123			1 U	2.32		1.7
55WBLS-11.1	7/22/2015	11:16	0.015	0.01 U	0.203	0.0051	0.0109			2 U	2.34		1.7
55WBLS-11.1	8/19/2015	11:40	0.011	0.01 U	0.283	0.0033	0.0096	4.1 J	4.2	1 U	2.27		2.3
55WBLS-11.1 (QC)	8/19/2015	11:40	0.012	0.01 U	0.273	0.0038	0.0088	4.2	4.1	1	2.23		2.3
55WBLS-11.1	9/23/2015	12:15	0.012	0.01 U	0.276	0.0037	0.0114			2 U	2.14		4.2
55WBLS-11.1	10/21/2015	11:29	0.013	0.01 U	0.227	0.0044	0.0131			2 U	2.04		3.6
55WBLS-11.1	11/19/2015	16:06	0.08 J	0.01 J	0.329 J	0.0086	0.0351 J	3	3.4	2 U	2.25 J		5.8
55WBLS-11.1	1/20/2016	13:08	0.01 U	0.098	0.23	0.0092	0.0145			1 U	2.7		
55WBLS-11.1	2/23/2016	15:03	0.01 U	0.102	0.25	0.0083	0.0221			1	2.64		
55WBLS-11.1	3/17/2016	14:10	0.01 UJ	0.095 J	0.253 J	0.0078	0.0251 J			2	2.53		
55BEAV-00.5	2/18/2015	11:41	0.01 U	0.183	0.335	0.0145	0.0414	4.7	4.7	2 U	0.7		
55BEAV-00.5	3/18/2015	10:24	0.012	0.158	0.296	0.0137	0.0421			3	0.47		
55BEAV-00.5	4/22/2015	10:49	0.012	0.06	0.235	0.0139	0.03			2 U	0.47		
55BEAV-00.5	5/20/2015	11:34	0.01 U	0.046	0.167	0.0146	0.0241	2.8	2.9	2	0.45		
55BEAV-00.5	6/17/2015	11:42	0.01 U	0.112	0.198	0.017	0.0219			3	0.38		
55BEAV-00.5	7/22/2015	10:20	0.01 U	0.065	0.104	0.0179	0.0191			1 U	0.34	5 U	
55BEAV-00.5	8/19/2015	10:46	0.01 U	0.033	0.08	0.0155	0.0189	1.2 J	1.1	3	0.43	28.7	
55BEAV-00.5	9/23/2015	11:25	0.01 U	0.01 U	0.054	0.0119	0.0147			1 U	0.47		
55BEAV-00.5	10/21/2015	10:44	0.01 U	0.01 U	0.04	0.0118	0.0135			1 U	0.56		
55BEAV-00.5	11/19/2015	16:53	0.03	0.091	0.328	0.0133	0.0481 J	3.9	4 J	2 U	0.62		
55BEAV-00.5 (QC)	11/19/2015	16:53	0.029	0.093	0.324	0.0129	0.0476	3.7	3.8	2 UJ	0.65		
55BEAV-00.5	1/20/2016	12:15	0.015	0.195	0.393	0.0159	0.04			2	0.55		
55BEAV-00.5	2/23/2016	13:31	0.01 U	0.135	0.274	0.0208	0.0552			4	0.64		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55BEAV-00.5 (QC)	2/23/2016	13:40	0.01 U	0.131	0.282	0.0212	0.0557			4	0.64		
55BEAV-00.5	3/17/2016	13:00	0.01 U	0.079	0.226	0.0155	0.0443 J			3	0.63 J		
55WBLS-07.7	2/18/2015	9:33	0.01 U	0.097	0.243	0.0077	0.0192	3.5	3.4	2	2.35		
55WBLS-07.7	3/18/2015	8:30	0.01 U	0.056	0.2	0.0071	0.0182			2	2.41		
55WBLS-07.7	4/22/2015	8:56	0.014	0.015	0.192	0.0077	0.0178			3	2.32 J		
55WBLS-07.7	5/20/2015	10:01	0.012	0.021	0.193	0.0086	0.0189	3	3.1	2	2.02		1.2
55WBLS-07.7	6/17/2015	9:40	0.01 U	0.01 U	0.175	0.0073	0.0178			3	2.14		1.1
55WBLS-07.7 (QC)	6/17/2015	9:40	0.01 U	0.01 U	0.172	0.0073	0.0159			3	2.18		1.2
55WBLS-07.7	7/22/2015	8:58	0.01	0.01 U	0.157	0.0057	0.0152			3	1.9	5 U	2.5
55WBLS-07.7	8/19/2015	9:14	0.01 U	0.022	0.186	0.0045	0.0112	5.2	2	1	1.74	82.4	2.3
55WBLS-07.7	9/23/2015	10:00	0.01 U	0.021	0.415	0.0063	0.0495			5	1.82 J		3.8
55WBLS-07.7	10/21/2015	9:20	0.01 U	0.046	0.256	0.0036	0.0232			2 U	1.95		1.4
55WBLS-07.7	11/19/2015	15:08	0.039	0.048	0.298	0.0077	0.0332	3.6 J	3.9	2 UJ	2.28		2.4 J
55WBLS-07.7	1/20/2016	10:15	0.01 U	0.084	0.264	0.0084	0.018			1	2.25		
55WBLS-07.7	2/23/2016	10:46	0.01 U	0.075	0.231	0.0083	0.0253			2	2.29		
55WBLS-07.7	3/17/2016	11:35	0.01 U	0.036	0.213	0.0062	0.0194			2	2.19		
55WBLS-03.1	2/18/2015	14:52	0.01 U	0.085	0.273	0.0057	0.0208	3.4	3.3	2	2.63		
55WBLS-03.1	3/4/2015	10:06	0.01 U	0.021	0.24	0.0052	0.0186			1 UJ	2.77 J		
55WBLS-03.1	3/18/2015	12:48	0.011	0.01 U	0.232	0.0041	0.0188			2	2.89		
55WBLS-03.1 (QC)	3/18/2015	12:48	0.011	0.012	0.22	0.0043	0.0205			2	2.88		
55WBLS-03.1	4/8/2015	12:12	0.01 U	0.01 U	0.251	0.0035	0.0146			2	3.5		
55WBLS-03.1	4/22/2015	13:22	0.013	0.01 U	0.257	0.0039	0.0172			4	3.19		
55WBLS-03.1	5/6/2015	12:10	0.013	0.01 U	0.306	0.0036	0.0206			3	2.94		
55WBLS-03.1	5/20/2015	13:33	0.024	0.01 U	0.326	0.0041	0.02	4.5	5.1	3	3.76		2
55WBLS-03.1 (QC)	5/20/2015	13:33	0.023	0.01 U	0.338	0.0038	0.0183	4.5	4.9	3	3.54		2.1
55WBLS-03.1	6/3/2015	11:32	0.022	0.01 U	0.362	0.003 U	0.0196			2 U	3.2		
55WBLS-03.1	6/17/2015	14:05	0.022	0.01 U	0.323	0.003 U	0.0138			2 U	3.83		3.7
55WBLS-03.1	7/8/2015	12:05	0.013 J	0.021 J	0.391 J	0.003 U	0.0146 J			2 U	3.68 J		
55WBLS-03.1	7/22/2015	12:26	0.024	0.032	0.371	0.0033	0.0153			2 U	3.9	138	2.1
55WBLS-03.1 (QC)	7/22/2015	12:51	0.024	0.034	0.38	0.0036	0.0168			2 U	3.84	40.7	2.2
55WBLS-03.1	8/4/2015	13:00	0.038	0.048	0.538	0.0058	0.0084 J			1	4.73		
55WBLS-03.1	8/19/2015	13:05	0.026	0.052	0.591	0.0045	0.0133	6.9 J	6.8	2	5.03	44.6	3.3
55WBLS-03.1	9/9/2015	11:50	0.191	0.309	0.804	0.0036	0.014 J			3	8.42		
55WBLS-03.1	9/23/2015	13:26	0.014	0.031	0.497	0.003 U	0.0117			1 U	4.4		1.7
55WBLS-03.1	10/7/2015	12:05	0.01 U	0.022	0.446	0.003 U	0.0121			2	4.33 J		
55WBLS-03.1	10/21/2015	12:36	0.017	0.028	0.445	0.003 UJ	0.0163			2 U	3.84		3.3
55WBLS-03.1 (QC)	10/21/2015	13:03	0.019	0.028	0.453	0.003 U	0.0186			2 U	3.87		3.3
55WBLS-03.1	11/5/2015	11:30	0.011	0.126	0.606	0.003 U	0.0182			2	3.76		
55WBLS-03.1	11/19/2015	13:06	0.014	0.188	0.626	0.003 U	0.0173 J	4.8	5.1 J	2 J	3.79		7.3
55WBLS-03.1	12/11/2015	12:42	0.021	0.169	0.502	0.0038 J	0.0183			2 UJ	3.41 J		
55WBLS-03.1	1/5/2016	12:40	0.016	0.122	0.352	0.0048	0.0172			1	3.27		
55WBLS-03.1	1/20/2016	14:50	0.02	0.126	0.375	0.0056	0.0156			1	3.96		
55WBLS-03.1	2/3/2016	12:55	0.021	0.116	0.33	0.0046	0.0182			1 U	3.12		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55WBLS-03.1	2/23/2016	16:32	0.024	0.068	0.338	0.0041	0.0294			2	3.45		
55WBLS-03.1	3/17/2016	15:34	0.01 U	0.031	0.28	0.0044 J	0.0213			3 J	3.31 J		
55BEAR-00.4	2/17/2015	10:14	0.01 U	1.19	1.53	0.0154	0.025	5.9	5.9	2	9.1 J		
55BEAR-00.4	3/17/2015	9:40	0.01 UJ	0.665 J	1.15 J	0.0162	0.0356			5	6.94		
55BEAR-00.4	4/21/2015	10:18	0.011	1.13	1.32	0.0111	0.0248			6	6.51		
55BEAR-00.4	5/19/2015	11:02	0.018	1.11	1.33	0.0172	0.0284	2.9	3	4	5.03		
55BEAR-00.4	6/16/2015	9:50	0.01 U	1.16	1.35	0.0262	0.0401			4	5.36		
55BEAR-00.4 (QC)	6/16/2015	9:50	0.01 U	1.16	1.39	0.0273	0.0381			4	5.35		
55BEAR-00.4	7/21/2015	10:03	0.01 U	0.994	1.18	0.0293	0.0362			3	6.52	154	
55BEAR-00.4	8/18/2015	9:54	0.01 U	0.844	1.13	0.0227	0.0294	2.9	3.1	4	7.7	154	
55BEAR-00.4	9/22/2015	9:35	0.01 U	0.393	0.608	0.0097	0.0155			2	4.64		
55BEAR-00.4	10/20/2015	9:43	0.01 U	0.487	0.677	0.0078	0.0151			3	4.26		
55BEAR-00.4	11/17/2015	9:36	0.01	0.93	1.15	0.0088	0.0184	4	4.3	2	4.89		
55BEAR-00.4	1/19/2016	9:56	0.018	1.12	1.52	0.0331	0.0399			2	8.59		
55BEAR-00.4	2/22/2016	10:21	0.01 UJ	1.31	1.75	0.03	0.0491			1	10		
55BEAR-00.4 (QC)	2/22/2016	10:52	0.01 UJ	1.31	1.78	0.0301	0.0493			1	10		
55BEAR-00.4	3/16/2016	10:32	0.01 U	1.15	1.69	0.0184	0.0329			2	8.07		
55DEE-05.9	2/17/2015	14:55	0.01 U	0.338	0.461	0.0365	0.0647	4.8	4.7	15	1.69 J		
55DEE-05.9	3/17/2015	15:20	0.01 U	0.297	0.438	0.0415	0.0769			22	1.58		
55DEE-05.9	4/21/2015	13:50	0.01 U	0.262	0.341	0.0378	0.0541			8	1.34		
55DEE-05.9	5/19/2015	14:29	0.013	0.397	0.503	0.0414	0.0499	2.7	2.9	4	1.47		
55DEE-05.9	6/16/2015	15:20	0.011	0.585	0.685	0.0504	0.056			3	1.77		
55DEE-05.9	7/21/2015	15:20	0.017	0.656	0.738	0.042	0.0482			1	2.71	190	
55DEE-05.9	8/18/2015	15:00	0.011	0.542	0.707	0.029	0.0343	1.9	4.7	1 U	3.51	74.7	
55DEE-05.9 (QC)	8/18/2015	15:16	0.01	0.545	0.693	0.0291	0.0359	1.7	4.7	1	3.45	74.9	
55DEE-05.9	9/22/2015	14:50	0.01 U	0.902	1	0.0226	0.0259			1 U	2.98		
55DEE-05.9	10/20/2015	14:45	0.01 U	0.929	1.03	0.0163	0.021			1 U	2.85		
55DEE-05.9	11/17/2015	14:25	0.01 U	0.806	0.912	0.0241	0.0332	3	3.2	2	2.38		
55DEE-05.9	1/19/2016	15:25	0.01 U	0.479	0.596	0.0373	0.0491			1	1.88		
55DEE-05.9	2/22/2016	14:45	0.01 U	0.214	0.329	0.0369	0.0855			28	1.41		
55DEE-05.9	3/16/2016	13:20	0.01 U	0.16	0.289	0.0383	0.0936			40 J	1.19		
55LDR-00.1	2/17/2015	15:25	0.01 U	0.116	0.242	0.0352	0.0592	5	4.8	10	1.81		
55LDR-00.1	3/17/2015	15:45	0.01 U	0.095	0.246	0.0381	0.0642			9	2.03		
55LDR-00.1	4/21/2015	13:58	0.01 U	0.035	0.131	0.0347	0.0522			6	1.47		
55LDR-00.1	5/19/2015	14:58	0.012	0.052	0.135	0.0412	0.0542	2.8	2.9	4	1.2		
55LDR-00.1	6/16/2015	15:50	0.01 U	0.101	0.231	0.0541	0.0585			2	1.18		
55LDR-00.1	10/20/2015	14:55	0.01 U	0.01 U	0.089	0.0346	0.0383			1 U	1.72		
55LDR-00.1	11/17/2015	14:50	0.01 U	0.01 U	0.157	0.0296	0.0411	4.5	4.6	1	1.85		
55LDR-00.1 (QC)	11/17/2015	14:50	0.01 U	0.01 U	0.15	0.0293	0.0465	4.5	4.5	1	1.85		
55LDR-00.1	1/19/2016	15:35	0.01 U	0.258	0.418	0.0362 J	0.0513			2	2.33		
55LDR-00.1	2/22/2016	15:15	0.01 U	0.15	0.297	0.0352 J	0.0723			14	2.06		
55LDR-00.1	3/16/2016	14:20	0.01 U	0.116	0.253	0.0361	0.0776			27 J	1.82		
55DEE-00.1	2/17/2015	8:36	0.01 U	0.238	0.368	0.0366	0.0684	5.2	5	19	1.83 J		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55DEE-00.1 (QC)	2/17/2015	8:36	0.01 U	0.237	0.361	0.0367	0.0663		5.1	19	1.8 J		
55DEE-00.1	3/17/2015	7:58	0.01 UJ	0.211 J	0.374 J	0.0422 J	0.0897			34	1.92		
55DEE-00.1	4/21/2015	8:26	0.012 J	0.183 J	0.261 J	0.0359	0.0513			10	1.5		
55DEE-00.1 (QC)	4/21/2015	8:26	0.011 J	0.182 J	0.274 J	0.0354	0.0519			9	1.49		
55DEE-00.1	5/19/2015	8:58	0.011	0.215	0.318	0.0369	0.0481	3	2.9	5	1.51		
55DEE-00.1	6/16/2015	8:19	0.01 U	0.217	0.32	0.0396	0.0425			2	1.83		
55DEE-00.1	7/21/2015	8:51	0.011	1.11	1.17	0.0253	0.026			1	4.4	79.7	
55DEE-00.1	8/18/2015	8:25	0.011	1.12	1.27	0.0216	0.02	1.4	1 U	2	4.54	83.2	
55DEE-00.1	9/22/2015	8:20	0.01 U	1.09	1.11	0.0215	0.0214			1 U	4.56 J		
55DEE-00.1	10/20/2015	8:24	0.01 U	1.02	1.08	0.0213	0.0223			1 U	4.14		
55DEE-00.1	11/17/2015	8:26	0.01 U	0.665	0.724	0.0239	0.0289	2.3	2.4	1	3.24		
55DEE-00.1	1/19/2016	8:36	0.01 U	0.367	0.514	0.0336	0.0462			2	2.13		
55DEE-00.1	2/22/2016	9:13	0.01 U	0.206	0.354	0.0369	0.0886			18	1.72		
55DEE-00.1	3/16/2016	9:10	0.01 U	0.174	0.31	0.0358	0.0838			28	1.53		
55DRA-17.0	2/17/2015	11:35	0.017	0.366	0.585	0.0392	0.0829	5.7	5.6	6	3.41 J		
55DRA-17.0	3/17/2015	11:25	0.017	0.258	0.576	0.0387	0.107			8	4.56		
55DRA-17.0	4/21/2015	11:20	0.01 U	0.013	0.262	0.0199	0.0501			4	3.39		
55DRA-17.0 (QC)	4/21/2015	11:20	0.016	0.013	0.255	0.0203	0.0511			5	3.37		
55DRA-17.0	5/19/2015	10:50	0.039	0.011	0.304	0.036	0.0662	4.8	5.6	3	3.16		
55DRA-17.0	6/16/2015	12:15	0.061	0.03	0.514	0.073	0.16			2	3.26		
55DRA-17.0	7/21/2015	11:05	0.079	0.067	0.335	0.0457	0.0903			2	3.8	334	
55DRA-17.0	8/18/2015	11:16	0.042	0.049	0.472	0.0447	0.0835	4.7	4.8	2	3.64	153	
55DRA-17.0	9/22/2015	11:18	0.01 U	0.01 U	0.469	0.0423	0.233			7	4.24		
55DRA-17.0	10/20/2015	11:40	0.04	0.01 U	0.349	0.0346	0.152			4	3.98		
55DRA-17.0	11/17/2015	11:21	0.052	0.111	0.611	0.0239	0.0935	3.7	5.4	5	6.15		
55DRA-17.0	1/19/2016	11:45	0.031	0.435	0.72	0.0406	0.0721			1 U	5.44		
55DRA-17.0	2/22/2016	12:00	0.021	0.36	0.522	0.0404	0.0935			9	2.44		
55DRA-17.0	3/16/2016	11:30	0.012	0.29	0.486	0.0445	0.0969			12 J	2		
55SPR-00.4	2/17/2015	12:20	0.013	2.75	2.92	0.0229	0.0319	1.7	1.5	6	6.92 J		
55SPR-00.4	3/17/2015	12:10	0.012	2.7	2.68	0.0208	0.038			7	6.92		
55SPR-00.4	4/21/2015	12:10	0.012	2.64	2.7	0.0136	0.0196			3	6.61		
55SPR-00.4	5/19/2015	11:30	0.014	2.51	2.64	0.0142	0.0213	1.3	1.2	4	6.34		
55SPR-00.4	6/16/2015	11:35	0.01 U	2.54	2.59	0.0112	0.015			2	6.19		
55SPR-00.4	7/21/2015	12:05	0.011	2.41	2.44	0.0092	0.0107			1	6.1	260	
55SPR-00.4 (QC)	7/21/2015	12:10	0.011	2.42	2.45	0.0094	0.0117			2 U	6.11	271	
55SPR-00.4	8/18/2015	12:05	0.012	2.37	2.63	0.0077	0.0088	1.3	1.3	2	6.36	117	
55SPR-00.4	9/22/2015	11:57	0.013	2.38	2.66	0.007	0.0116			1	5.72		
55SPR-00.4 (QC)	9/22/2015	11:57	0.017	2.38	2.44	0.0073	0.0112			1 U	5.79		
55SPR-00.4	10/20/2015	12:20	0.011	2.51	2.5	0.0092	0.0102			1 U	5.74		
55SPR-00.4	11/17/2015	12:05	0.013	2.52	2.55	0.0108	0.0199	1.8	2	2	6.47		
55SPR-00.4	1/19/2016	12:15	0.014	2.77	2.69	0.0243	0.0305			1	6.72		
55SPR-00.4 (QC)	1/19/2016	12:20	0.013	2.59	2.75	0.0255 J	0.0302			1	6.68		
55SPR-00.4	2/22/2016	13:05	0.01 U	2.22	2.31	0.0233	0.0435			5	6.28		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55SPR-00.4	3/16/2016	11:45	0.012	2.19	2.27	0.0274 J	0.0549			9	5.18 J		
55DRA-16.4	2/17/2015	10:45	0.011	0.87	1.07	0.0351	0.07	4.7	4.7	4	4.25		
55DRA-16.4	3/17/2015	10:30	0.013	0.78	1.09	0.0347	0.0875			5	5.16		
55DRA-16.4	4/21/2015	10:35	0.012	1	1.19	0.0159	0.0375			4	4.85		
55DRA-16.4	5/19/2015	10:03	0.027	1.46	1.57	0.0232	0.0432	2.5	2.9	3	5.24		
55DRA-16.4	6/16/2015	10:55	0.025	1.51	1.71	0.0357	0.067			2 U	5.1		
55DRA-16.4	7/21/2015	10:30	0.022	1.79	1.87	0.0216	0.03			2 U	5.83	239	
55DRA-16.4	8/18/2015	10:44	0.015	1.96	2.27	0.0157	0.0223	1.7	1.7	3	6.27	124	
55DRA-16.4	9/22/2015	10:37	0.01 U	1.61	1.76	0.0159	0.0387			2 U	5.44		
55DRA-16.4	10/20/2015	10:43	0.021	1.71	1.77	0.0203	0.0356			2	5.42		
55DRA-16.4 (QC)	10/20/2015	11:09	0.02	1.7	1.79	0.02 J	0.0403			3	5.44		
55DRA-16.4	11/17/2015	10:48	0.023	1.58	1.69	0.0169	0.0444	2.3	2.8	4	6.22		
55DRA-16.4	1/19/2016	11:10	0.021	0.938	1.14	0.0355	0.0604			1	5.83		
55DRA-16.4	2/22/2016	11:25	0.017	0.522	0.694	0.0399	0.0902			9	2.84		
55DRA-16.4	3/16/2016	10:50	0.016	0.442	0.684	0.0437 J	0.0936			9	2.34 J		
55BEAV2-00.1	9/23/2015	15:25	0.01 U	3.29	3.48	0.0648	0.0181			3	6.75		
55DRA-13.2	2/17/2015	10:00	0.011	0.922	1.07	0.037	0.068	4.8	4.7	4	5.34		
55DRA-13.2	3/17/2015	9:45	0.01 U	0.738	1.05	0.036	0.0805			7	6.73		
55DRA-13.2	4/21/2015	9:56	0.013	0.867	1.04	0.013	0.0261			2	5.85		
55DRA-13.2	5/19/2015	9:25	0.021	1.16	1.32	0.0274	0.0424	2.8	3	2 U	5.89		
55DRA-13.2	6/16/2015	10:15	0.016	1.37	1.54	0.0414	0.064			3	5.95		
55DRA-13.2	7/21/2015	9:45	0.026	1.48	1.58	0.0334	0.0383			1 U	6.78	404	
55DRA-13.2	8/18/2015	10:06	0.012	1.43	1.65	0.0197	0.0202	1.9	2.1	1 U	7.24	138	
55DRA-13.2	9/22/2015	10:01	0.01 U	1.31	1.42	0.0157	0.0227			1 U	6.6		
55DRA-13.2	10/20/2015	10:03	0.01 U	1.44	1.45	0.0263	0.0325			1	6.94		
55DRA-13.2	11/17/2015	10:08	0.01 U	1.38	1.54	0.0265	0.0397	2.9	3.2	2	7.48		
55DRA-13.2	1/19/2016	10:40	0.019	0.99	1.25	0.0436	0.0719			6	7.07		
55DRA-13.2	2/22/2016	10:30	0.018	0.575	0.821	0.0403	0.0898			8	3.77		
55DRA-13.2	3/16/2016	10:00	0.018	0.483	0.737	0.0436	0.0922 J			11 J	3.3 J		
55WBDR-00.1	2/17/2015	9:00	0.01 U	0.494	0.771	0.046	0.0629	5.7	5.4	3	4.37		
55WBDR-00.1	3/17/2015	8:45	0.01 U	0.371	0.782	0.0555	0.0797			4	4.63		
55WBDR-00.1 (QC)	3/17/2015	8:45	0.01 U	0.375	0.801	0.0553	0.0773			4	4.63		
55WBDR-00.1	4/21/2015	9:10	0.012	0.341	0.541	0.0321	0.0411			5	3.33		
55WBDR-00.1	5/19/2015	8:45	0.016	0.336	0.523	0.0424	0.0541	3.3	3.6	8	2.61		
55WBDR-00.1	6/16/2015	9:05	0.014	0.612	0.754	0.0556	0.0598			1	2.89		
55WBDR-00.1 (QC)	6/16/2015	9:10	0.014	0.61	0.755	0.056	0.0575			1	2.91		
55WBDR-00.1	7/21/2015	9:05	0.015	0.588	0.692	0.0521	0.0553			1	3.08	377	
55WBDR-00.1	8/18/2015	9:24	0.01 U	0.567	0.762	0.0387	0.0402	1.1	1.8	1	3.23	125	
55WBDR-00.1	9/22/2015	9:23	0.01 U	0.529	0.674	0.0302	0.0356			1 U	3.25		
55WBDR-00.1	10/20/2015	9:22	0.01 U	0.654	0.802	0.0365	0.0381			1 U	4.37		
55WBDR-00.1	11/17/2015	9:23	0.01 U	0.666	0.889	0.0412	0.0476	4.3	4.6	18	5.83		
55WBDR-00.1	1/19/2016	10:00	0.01 U	0.57	0.831	0.0508	0.059			1	5.19		
55WBDR-00.1	2/22/2016	9:35	0.01 U	0.322	0.618	0.054	0.0858 J			6	3.08		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55WBDR-00.1	3/16/2016	9:20	0.01 U	0.22	0.557	0.0518 J	0.0861			11	2.32 J		
55MUD-00.7	9/23/2015	14:44	0.01 U	0.08	0.31	0.0142	0.0684			1 U	5.9		
55DRA-04.3	2/17/2015	13:15	0.01 U	1.76	1.99	0.039	0.0584	4.7	4.6	8	5.52 J		
55DRA-04.3	3/17/2015	13:00	0.01 U	1.36	1.65	0.039 J	0.0675			5	6.26		
55DRA-04.3	4/21/2015	12:50	0.016	2	2.22	0.0175	0.0258			2	5.48		
55DRA-04.3	5/19/2015	12:30	0.023	2.41	2.8	0.0305	0.0407	2.6	2.9	2 U	5.13		
55DRA-04.3 (QC)	5/19/2015	12:30	0.023	2.43	2.58	0.0299	0.04	2.7	3	2 U	5.12		
55DRA-04.3	6/16/2015	13:30	0.016	2.95	3.11	0.0407	0.0477			1	5.3		
55DRA-04.3	7/21/2015	13:25	0.018	3.05	3.21	0.0173	0.0254			1 U	5.91	146	
55DRA-04.3	8/18/2015	13:05	0.015	3.43	4.04	0.0215	0.0232	1.8	2	1 U	6.01	153	
55DRA-04.3	9/22/2015	13:04	0.01 U	3.08	3.15	0.0122	0.0174			1	5.47		
55DRA-04.3	10/20/2015	13:01	0.01 U	3.09	3.08	0.0111	0.0138			1 U	5.51 J		
55DRA-04.3	11/17/2015	12:55	0.01 U	2.84	3.01	0.0287	0.0344	3.5	3.7	1 U	7.19		
55DRA-04.3	1/19/2016	13:25	0.011	1.92	2.15	0.0403 J	0.0505			1	6.56		
55DRA-04.3	2/22/2016	13:50	0.012	0.866	1.06	0.0451	0.0883 J			11	4.03		
55DRA-04.3	3/16/2016	12:30	0.014	0.712	0.959	0.0467	0.095			17 J	3.36 J		
55DRA-04.3 (QC)	3/16/2016	12:30	0.01 U	0.711	1.01	0.0458	0.0932			15	3.99		
55DRA-00.3	2/17/2015	14:10	0.01	1.76	1.98	0.0395	0.0573	4.7	4.5	4	5.63		
55DRA-00.3 (QC)	2/17/2015	14:10	0.011	1.75	1.97	0.0401	0.0569	4.8	4.5	4	5.58		
55DRA-00.3	3/17/2015	14:05	0.01 U	1.35	1.6	0.0408 J	0.0659 J			6	6.45		
55DRA-00.3	4/21/2015	13:20	0.013	1.97	2.14	0.017	0.0283			4	5.82		
55DRA-00.3	5/19/2015	13:39	0.013	2.25	2.4	0.0243	0.0377	2.6	3	3	5.47		
55DRA-00.3	6/16/2015	14:20	0.01	2.77	2.91	0.0351	0.0421			3	5.67		
55DRA-00.3	7/21/2015	14:15	0.02	2.93	3.05	0.02	0.0275			2	6.27	145	
55DRA-00.3	8/18/2015	13:48	0.015	2.9	3.51	0.0197	0.0215	2.1	1.9	2	6.41	150	
55DRA-00.3	9/22/2015	13:52	0.01 U	2.91	3.14	0.0114	0.0156			1	5.76		
55DRA-00.3	10/20/2015	13:55	0.01 U	2.99	3.15	0.0092	0.0137			1	5.79		
55DRA-00.3	11/17/2015	13:40	0.01 U	2.81	2.92	0.0253	0.0328	3.5	3.7	2	7.39		
55DRA-00.3	1/19/2016	14:25	0.01 U	1.96	2.26	0.0409 J	0.0494			2	6.87		
55DRA-00.3	2/22/2016	14:05	0.01 U	0.866	1.06	0.0455 J	0.089 J			10	4.16 J		
55DRA-00.3 (QC)	2/22/2016	14:05	0.013	0.859	1.09	0.0459 J	0.0923 J			11	4.15		
55DRA-00.3	3/16/2016	12:55	0.01 U	0.72	0.965	0.0476	0.0956			16 J	3.72		
55SFLD-01.1	2/17/2015	16:05	0.01 U	0.045	0.129	0.0375	0.0527	3.2	3.1	3	1.74		
55SFLD-01.1	3/17/2015	16:30	0.01 U	0.044	0.147	0.0397 J	0.0589			5	1.8		
55SFLD-01.1	4/21/2015	14:20	0.012	0.01 U	0.087	0.0408	0.0539			6	1.17		
55SFLD-01.1	5/19/2015	15:49	0.01 U	0.018	0.077	0.0497	0.0586	2	2.1	3	0.89		
55SFLD-01.1	6/16/2015	16:20	0.01 U	0.057	0.122	0.0606	0.0659			2	0.9		
55SFLD-01.1	7/21/2015	16:05	0.011	0.096	0.176	0.0779	0.0826			2 U	0.95	5 U	
55SFLD-01.1	8/18/2015	16:05	0.012	0.02	0.135	0.0724	0.0896	2.7	3.8	4	0.88	22.1	
55SFLD-01.1	9/22/2015	15:27	0.01 U	0.01 U	0.099	0.0587	0.067			1 U	0.83		
55SFLD-01.1	10/20/2015	16:00	0.01 U	0.01 U	0.08	0.0632	0.069			2 U	1.01		
55SFLD-01.1	11/17/2015	15:40	0.01 U	0.01 U	0.132	0.0496	0.126	5.2	6.2	27	1.77		
55SFLD-01.1	1/20/2016	12:05	0.01 U	0.436	0.608	0.0438	0.075			6	3.04		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55SFLD-01.1	2/23/2016	11:00	0.01 U	0.061	0.141	0.0429 J	0.0611 J			6	1.67		
55SFLD-01.1 (QC)	2/23/2016	11:00	0.01 U	0.06	0.138	0.0428	0.0585			5	1.65		
55SFLD-01.1	3/16/2016	15:20	0.01 U	0.038	0.114	0.0404	0.071			15	1.61		
55LDP-00.1	2/18/2015	12:05	0.01 U	0.239	0.408	0.0454	0.0683	4.9	4.7	7	4.54		
55LDP-00.1	3/18/2015	12:20	0.01 U	0.193	0.4	0.0589	0.121			32	4.24		
55LDP-00.1 (QC)	3/18/2015	12:34	0.01 U	0.19	0.414	0.0572	0.121			29	4.23		
55LDP-00.1	4/22/2015	9:45	0.01 U	0.287	0.426	0.0719	0.0976			7	4.72		
55LDP-00.1 (QC)	4/22/2015	9:45	0.018	0.286	0.431	0.0712	0.099			8	4.33 J		
55LDP-00.1	5/20/2015	10:15	0.011	0.703	0.83	0.0582	0.0708	2.4	2.5	3	8.94		
55LDP-00.1	6/17/2015	12:25	0.01 U	0.917	0.976	0.0346	0.0348			1 U	12.4		
55LDP-00.1	7/22/2015	12:50	0.021	0.893	1.1	0.0309	0.033			1	12.9	218	
55LDP-00.1	8/19/2015	9:42	0.03	0.907	1.07	0.0271	0.03	1.2 J	1 UJ	1 U	13.3	223	
55LDP-00.1	9/23/2015	12:40	0.01 U	0.991	1.05	0.0219	0.0273			1	13		
55LDP-00.1	10/21/2015	10:20	0.01 U	1.09	1.13	0.0168	0.0186 J			1 U	12.5		
55LDP-00.1	11/19/2015	10:01	0.01 U	1.44	1.45	0.023	0.026 J	1 U	1 J	2 J	15		
55LDP-00.1	1/20/2016	10:10	0.01 U	0.573	0.832	0.0734	0.114			7	5.54		
55LDP-00.1	2/23/2016	14:05	0.01 U	0.193	0.337	0.0469	0.0725			8	4.25		
55LDP-00.1	3/17/2016	9:35	0.01 U	0.138	0.285	0.0446	0.079			7	4.1 J		
55DEA-20.2	2/18/2015	9:10	0.01 U	0.046	0.08	0.0255	0.0292	1.3	1.2	3	1.19		
55DEA-20.2 (QC)	2/18/2015	9:10	0.01 U	0.049	0.078	0.0277	0.0272	1.5	1.2	4	1.17		
55DEA-20.2	3/18/2015	10:35	0.01 U	0.044	0.067	0.0248	0.0295			3	1.35		
55DEA-20.2	4/22/2015	13:55	0.01 U	0.01 U	0.048	0.0287	0.0311			3	1.12		
55DEA-20.2	5/20/2015	13:55	0.01 U	0.01 U	0.042	0.034	0.035	1.1	1.1	3	1.15		
55DEA-20.2	6/17/2015	9:10	0.01 U	0.023	0.059	0.0376	0.0359			1	1.25		
55DEA-20.2	7/22/2015	9:30	0.01 U	0.036	0.065	0.0414	0.0403			1	1.39	10.8	
55DEA-20.2 (QC)	7/22/2015	9:35	0.01 U	0.039	0.135	0.0409	0.0401			1 U	1.36	11.1	
55DEA-20.2	8/19/2015	12:50	0.01 U	0.016	0.072	0.0397	0.0394	2	2	1 U	1.54	11.4	
55DEA-20.2	9/23/2015	9:47	0.01 U	0.01 U	0.045	0.036	0.0395			1	1.58		
55DEA-20.2	10/21/2015	13:20	0.01 U	0.01 U	0.034	0.0382 J	0.0398 J			1 U	1.7 J		
55DEA-20.2	11/19/2015	11:51	0.01 U	0.014	0.08	0.0307	0.0358 J	2.2	2.2	1 U	2.56		
55DEA-20.2	1/20/2016	13:30	0.01 U	0.023	0.068	0.0293	0.0319			1	5.09		
55DEA-20.2	2/23/2016	9:30	0.01 U	0.027	0.068	0.0328	0.0337			6	2.27		
55DEA-20.2	3/17/2016	12:45	0.01 UJ	0.027 J	0.054 J	0.0313 J	0.0508			7	2.18		
55DEA-20.2 (QC)	3/17/2016	12:45	0.01 U	0.023	0.049	0.0317 J	0.0433			5	1.61		
55DEA-13.8	2/18/2015	10:40	0.01 U	0.081	0.149	0.032	0.0414	2.6	2.3	7	2.51		
55DEA-13.8	3/18/2015	9:25	0.01 U	0.093	0.165	0.0342 J	0.0602			9	2.95		
55DEA-13.8	4/22/2015	13:25	0.01 U	0.014	0.095	0.0338	0.0431			5	1.85		
55DEA-13.8	5/20/2015	13:00	0.01 U	0.019	0.08	0.0391	0.0459	1.7	1.8	4	1.8		
55DEA-13.8	6/3/2015	9:10					0.0621			7			
55DEA-13.8	6/17/2015	10:00	0.01 U	0.016	0.081	0.0427	0.0444			2	1.99		
55DEA-13.8	7/22/2015	10:50	0.013	0.055	0.109	0.0516	0.0575			1 U	2.04	5 U	
55DEA-13.8	8/19/2015	12:00	0.01 U	0.01 U	0.11	0.0467	0.0576	2.7	2.7	1 U	2.22	16.1	
55DEA-13.8	9/23/2015	10:31	0.01 U	0.01 U	0.077	0.0403	0.0504			1 U	2.15		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55DEA-13.8	10/21/2015	12:40	0.01 UJ	0.01 UJ	0.069 J	0.0491	0.0559 J			1 U	2.19 J		
55DEA-13.8	11/19/2015	11:25	0.01 UJ	0.01 UJ	0.099 J	0.03	0.0383	3.2	3.5	1 UJ	3.65 J		
55DEA-13.8	1/20/2016	11:00	0.01 U	0.429	0.578	0.0459	0.0803			10	6.48		
55DEA-13.8	2/23/2016	10:10	0.01 U	0.098	0.18	0.0405 J	0.0572			8	2.88		
55DEA-13.8	3/17/2016	12:00	0.01 U	0.071	0.134	0.0368	0.0602			12	2.78		
55DEA-09.2	4/22/2015	12:40	0.01 U	0.075	0.146	0.0392	0.0523			7	2.88		
55DEA-09.2	6/3/2015	10:00					0.0981			22			
55DEA-09.2	2/23/2016	11:55	0.01 U	0.173	0.278	0.0473	0.0737			12	3.87		
55DEA-09.2	3/17/2016	11:30	0.01 UJ	0.149 J	0.25 J	0.0441 J	0.077			13 J	3.7		
55DEA-05.9	2/18/2015	11:25	0.01 U	0.128	0.266	0.037	0.0571	3.6	3.5	12	4.21		
55DEA-05.9	3/18/2015	8:50	0.01 U	0.158	0.319	0.0477 J	0.0826			14	5.14		
55DEA-05.9	4/22/2015	11:40	0.01 U	0.01 U	0.199	0.0502	0.0923			12	3.38		
55DEA-05.9	5/20/2015	11:40	0.01 U	0.01 U	0.183	0.0554	0.107	3.6	4.3	9	3.12		
55DEA-05.9 (QC)	5/20/2015	11:40	0.01	0.01 U	0.189	0.0547	0.106	3.7	4.3	9	3.09		
55DEA-05.9	6/3/2015	10:45					0.154			18			
55DEA-05.9	6/17/2015	11:00	0.014	0.01	0.223	0.0748	0.114			7	3.71		
55DEA-05.9 (QC)	6/17/2015	11:05	0.015	0.01 U	0.219	0.0723	0.113			6	3.68		
55DEA-05.9	7/22/2015	11:40	0.026	0.027	0.265	0.0884	0.139			7	3.96	5 U	
55DEA-05.9	8/19/2015	10:40	0.019	0.03	0.344	0.0492	0.08	6	5.8	3	4.92	58.6	
55DEA-05.9 (QC)	8/19/2015	10:55	0.023	0.03	0.309	0.0483	0.0809	6.1	6.2	1	4.89	58.1	
55DEA-05.9	9/23/2015	11:17	0.01 U	0.018	0.26	0.0225	0.0474			2 U	4.1		
55DEA-05.9	10/21/2015	11:25	0.014	0.11	0.255	0.027 J	0.0418			1 U	4.24		
55DEA-05.9 (QC)	10/21/2015	11:30	0.016	0.108	0.247	0.0326	0.0407			1 U	4.27		1.1
55DEA-05.9	11/19/2015	10:55	0.014	0.252	0.472	0.0309	0.057	3.9	4.4	5 J	4.73		
55DEA-05.9 (QC)	11/19/2015	10:55	0.016	0.251	0.448	0.0314	0.0562	3.9	4.2	5 J	4.7		
55DEA-05.9	1/20/2016	11:00	0.015	0.714	0.976	0.0696	0.0975			8	8.14		
55DEA-05.9	2/23/2016	12:45	0.01 U	0.055	0.194	0.0425	0.0596			3	4.42		
55DEA-05.9	3/17/2016	11:15	0.01 U	0.01 U	0.206	0.0292	0.0507			2	4.26		
55DEA-02.6	4/22/2015	11:00	0.01 U	0.022	0.209	0.0508	0.0937			20	3.7		
55DEA-02.6	6/3/2015	11:30					0.255			121			
55DEA-02.6 (QC)	6/3/2015	11:35					0.262			116			
55DEA-02.6	2/23/2016	13:10	0.01 U	0.108	0.254	0.043	0.0688			17	4.62		
55DEA-02.6	3/17/2016	10:30	0.01 U	0.034	0.227	0.0303 J	0.0691 J			33 J	4.46		
55DEA-00.6	2/18/2015	11:50	0.01	0.306	0.448	0.0367	0.0726	3.3	3.2	34	5.28		
55DEA-00.6	3/18/2015	12:00	0.016	0.333	0.497	0.0449	0.101			43	6.09		
55DEA-00.6	4/22/2015	10:33	0.012	0.227	0.374	0.047 J	0.0777			17	4.98		
55DEA-00.6	5/20/2015	10:50	0.014	0.411	0.541	0.043	0.0685	2.3	2.7	7	5.81		
55DEA-00.6	6/3/2015	12:20					0.235			105			
55DEA-00.6	6/17/2015	12:10	0.01 U	0.569	0.664	0.038	0.0517			5	7.25		
55DEA-00.6	7/22/2015	12:35	0.01 U	0.882	0.941	0.0249	0.0268			1	8.79	169	
55DEA-00.6	8/19/2015	10:15	0.03	1.06	1.25	0.0205	0.021	6.9	7.5	1	10	190	
55DEA-00.6	9/23/2015	12:20	0.01 U	1.02	1.05	0.0169	0.022			1	9		
55DEA-00.6 (QC)	9/23/2015	12:20	0.01 U	1.03	1.08	0.0168	0.0194			1	8.98		

Location ID	Date	Time	NH4-N	NO2-3N	TPN	SRP	TP	DOC	TOC	TSS	Cl	Alk	Chl a
55DEA-00.6	10/21/2015	10:52	0.01 U	1.06	1.14	0.0193	0.0212			1	8.98		
55DEA-00.6	11/19/2015	10:27	0.01 UJ	0.855 J	0.937 J	0.0202	0.0284	1.5	1.8	5 J	8.49		
55DEA-00.6	1/20/2016	10:40	0.01 U	0.715	0.932	0.0521	0.0864			15	9.55		
55DEA-00.6 (QC)	1/20/2016	10:40	0.012	0.712	0.839	0.053	0.0844			14	9.61		
55DEA-00.6	2/23/2016	13:45	0.01 U	0.21	0.341	0.0416	0.067			15	5.34		
55DEA-00.6	3/17/2016	10:10	0.01 U	0.116	0.265	0.0303	0.0693			22 J	5.17		
55DAR-00.2	2/18/2015	13:15	0.01 U	7.7	8.31	0.0389	0.0388	1 U	1 U	3	15.5		
55DAR-00.2	3/18/2015	13:40	0.01 U	8.25	9.57	0.0369 J	0.0498			14	15.6		
55DAR-00.2	4/22/2015	9:15	0.011	8.08	7.75	0.0257	0.0299			4	15.6		
55DAR-00.2	5/20/2015	8:55	0.014	7.87	7.97	0.036	0.0382	1 U	1 U	4	15.6		
55DAR-00.2	6/17/2015	13:50	0.01 U	8.09	9.45	0.0418	0.0419			5	15.3		
55DAR-00.2	7/22/2015	14:45	0.01 U	7.98	7.84	0.034	0.0346			2	15.2	212	
55DAR-00.2	8/19/2015	8:06	0.015	7.71	8.64	0.0224	0.0246	1.1 J	1 UJ	2	15.6	216	
55DAR-00.2	9/23/2015	14:00	0.01 U	7.82	8.07	0.0307	0.033			2	13.5		
55DAR-00.2	10/21/2015	8:50	0.01 U	8.1	7.89	0.033 J	0.0337			2	13.1		
55DAR-00.2	11/19/2015	9:12	0.01 U	8.1	8.11	0.0355	0.0429	1 U	1.2	5 J	15.3		
55DAR-00.2	1/20/2016	8:45	0.01	7.81	7.82	0.0482	0.0536			7	13.9		
55DAR-00.2	2/23/2016	14:40	0.01 U	7.63	7.23	0.0587	0.063			10	14.6		
55DAR-00.2	3/17/2016	8:40	0.01 UJ	6.21 J	6.46 J	0.0882	0.121			13	14.9		

Instantaneous Hydrolab® Measurements

Table D-5. Abbreviations and units of measurement used in this section.

Abbreviation	Parameter	Unit of Measurement
Temp	Stream Temperature	°C
Cond	Specific Conductivity	uS/cm
pH	pH	S.U.
DO	Dissolved Oxygen (Hydrolab® probe) [a]	mg/L

[a] We corrected most DO data taken using Hydrolab® probes using Winkler titration data.

Table D-6. Data qualifiers used in this section.

Qualifier	Meaning
J	The measurement result value is an estimate.

Table D-7. Instantaneous Hydrolab® measurements taken during 2015-2016.

Location ID	Date	Time	Temp	pH	Cond		DO	
55LSR-46.7	2/17/2015	13:58	6.18	7.74	229.7		10.92	
55LSR-46.7	3/17/2015	13:55	7.21	7.68	230		10.83	
55LSR-46.7	4/21/2015	14:25	14.21	8.23	232	J	10.79	
55LSR-46.7	5/19/2015	15:45	17.13	8.18	238		10.61	
55LSR-46.7	6/16/2015	14:18	16.61	8.15	239		11.07	
55LSR-46.7	7/21/2015	14:43	17.34	8.50	233		11.72	
55LSR-46.7	8/18/2015	14:46	14.61	8.31	238		12.67	
55LSR-46.7	9/22/2015	14:42	9.92	8.20	247		12.14	
55LSR-46.7	10/20/2015	13:11	9.21	7.86	244		12.07	
55LSR-46.7	11/17/2015	13:53	5.01	7.86	230		10.11	
55LSR-46.7	2/22/2016	15:50	7.06	7.67	222.7		10.69	
55LSR-39.5	2/17/2015	13:05	4.07	7.69	203		11.47	
55LSR-39.5	3/4/2015	9:11	1.99	7.87	215.6		11.88	
55LSR-39.5	3/17/2015	12:57	6.62	7.79	216		10.98	
55LSR-39.5	4/8/2015	10:55	8.81	8.15	214		9.78	
55LSR-39.5	4/21/2015	13:15	14.90	8.08	216	J	9.20	
55LSR-39.5	5/19/2015	14:50	19.52	8.40	217		9.93	
55LSR-39.5	6/3/2015	10:05	17.86	7.72	216		8.43	
55LSR-39.5	6/16/2015	13:25	22.97	8.28	217		9.94	
55LSR-39.5	7/8/2015	10:50	23.35	8.14	206	J	7.80	J
55LSR-39.5	7/21/2015	13:49	23.86	8.36	209		9.99	
55LSR-39.5	8/4/2015	11:25	21.25	8.01	222.5		8.30	
55LSR-39.5	8/18/2015	13:27	21.19	7.78	227		9.53	
55LSR-39.5 (QC)	8/18/2015	14:12	21.25	7.77	226		9.55	
55LSR-39.5	9/22/2015	12:45	14.74	7.85	232		9.04	
55LSR-39.5	10/7/2015	10:40	12.63	7.84	232.2		9.71	J
55LSR-39.5	10/20/2015	12:21	11.54	7.82	238		9.55	
55LSR-39.5	11/5/2015	10:30	6.37	7.83	239			

Location ID	Date	Time	Temp	pH	Cond	DO
55LSR-39.5	11/17/2015	13:03	5.01	7.78	231	10.29
55LSR-39.5	12/11/2015	11:11	2.38	7.41	226	11.30
55LSR-39.5	1/5/2016	11:10	0.72			14.10
55LSR-39.5	2/3/2016	11:34	2.02			11.75
55LSR-39.5	2/22/2016	14:42	4.85	7.76	212.2	11.95
55LSR-37.1	2/17/2015	12:24	4.06	7.71	195	11.90
55LSR-37.1	3/17/2015	12:23	6.84	7.71	206	11.00
55LSR-37.1	4/21/2015	13:00	14.75	8.08	204 J	9.59
55LSR-37.1	5/19/2015	14:15	18.83	8.17	206	9.00
55LSR-37.1	6/16/2015	12:55	21.21	8.19	199	8.88
55LSR-37.1	7/21/2015	12:35	21.81	8.55	192	9.59
55LSR-37.1 (QC)	7/21/2015	13:04	21.88	8.56	192	9.57
55LSR-37.1	8/18/2015	12:48	18.96	8.07	209	10.00
55LSR-37.1	9/22/2015	11:45	13.31	8.02	215	9.92
55LSR-37.1 (QC)	9/22/2015	11:55	13.31	8.02	215	9.90
55LSR-37.1	10/20/2015	11:51	11.10	8.06	221	10.90
55LSR-37.1	11/17/2015	11:55	5.12	8.22	217	11.55
55LSR-37.1 (QC)	11/17/2015	12:05	5.15	8.05	217	11.54
55LSR-37.1	2/22/2016	14:00	5.09	7.77	199.9	11.75
55LSR-31.8	8/18/2015	10:51	16.53	7.99	210	9.87
55LSR-23.4	2/17/2015	9:53	3.35	7.48	140.4	11.74
55LSR-23.4	3/17/2015	8:30	7.66	7.36	172	10.24
55LSR-23.4	4/21/2015	9:22	13.07	7.71	170 J	8.61
55LSR-23.4	5/19/2015	9:44	16.12	7.84	190	8.55
55LSR-23.4 (QC)	5/19/2015	10:11	16.15	7.85	190	8.60
55LSR-23.4	6/16/2015	8:57	18.29	7.96	189	7.70
55LSR-23.4	7/21/2015	9:22	20.06	8.37	205	7.85
55LSR-23.4	8/18/2015	9:11	16.82	7.70	223	7.68
55LSR-23.4	9/22/2015	9:10	9.78	7.74	250	8.81
55LSR-23.4	10/20/2015	8:51	10.42	7.56	228	9.14
55LSR-23.4 (QC)	10/20/2015	9:12	10.43	7.51	228	9.16
55LSR-23.4	11/17/2015	8:58	4.94	7.69	213	11.02
55LSR-23.4	2/22/2016	9:55	3.82	7.54	145.2	11.53
55LSR-13.5	2/18/2015	12:50	3.74	7.65	161.7	11.79
55LSR-13.5	3/18/2015	13:20	8.05	7.70	198.2	10.73
55LSR-13.5	4/22/2015	14:45	14.44	8.14	206	9.94
55LSR-13.5	5/20/2015	9:35	15.41	7.80	235.9	9.06
55LSR-13.5	6/17/2015	13:05	20.43	8.46	236.5	10.35
55LSR-13.5	7/22/2015	13:55	18.27	8.43	276	10.74
55LSR-13.5 (QC)	7/22/2015	13:50	18.25	8.36	276.7	10.70
55LSR-13.5	8/19/2015	9:00	16.72	7.94	271.5	8.24
55LSR-13.5	9/23/2015	13:15	12.35	8.18	269.3	11.27
55LSR-13.5	10/21/2015	9:30	8.87	8.26	279	10.35
55LSR-13.5	11/19/2015	9:44	4.30	8.03	262.3	11.60 J
55LSR-13.5	2/23/2016	17:15	3.63	7.76	148	11.58
55LSR-01.1	2/17/2015	8:15	5.29	7.52	204.6	10.20
55LSR-01.1	3/17/2015	8:00	8.54	7.60	229	9.33
55LSR-01.1	4/21/2015	8:35	11.46	7.72	245	8.34
55LSR-01.1	5/19/2015	8:08	12.88	7.73	265	8.07
55LSR-01.1	6/16/2015	8:17	13.64	8.11	268	7.90
55LSR-01.1	7/21/2015	8:15	14.05	6.92	282	7.77
55LSR-01.1	8/18/2015	8:27	12.64	7.90	280.2	8.11
55LSR-01.1	9/22/2015	8:45	10.94	7.65	281.3	8.57
55LSR-01.1	10/20/2015	8:52	10.52	7.82	289.4	8.96
55LSR-01.1	11/17/2015	8:56	8.76	7.80	284	9.32 J

Location ID	Date	Time	Temp	pH	Cond	DO
55LSR-01.1	2/22/2016	9:00	5.54	7.89 J	184.2	10.21
55CHA-00.2	9/22/2015	13:35	10.95	8.36	184	9.55
55JON-00.5	9/22/2015	14:09	10.46	7.84	164	9.59
55SHE-00.6	2/17/2015	12:01	5.98	8.57	201	14.03
55SHE-00.6	3/17/2015	11:57	8.49	8.41	199	12.36
55SHE-00.6	4/21/2015	12:31	15.80	9.16	171 J	14.04
55SHE-00.6	5/19/2015	13:50	20.10	9.30	159	9.92
55SHE-00.6	6/16/2015	12:20	24.45	8.50	199	7.65
55SHE-00.6	7/21/2015	12:10	24.20	8.71	198	10.47
55SHE-00.6	8/18/2015	12:19	23.22	8.57	201	10.92
55SHE-00.6	9/22/2015	11:25	16.18	8.75	195	10.83
55SHE-00.6	10/20/2015	11:31	12.92	8.60	197	11.60
55SHE-00.6	11/17/2015	11:13	6.82	8.75	204	10.44
55SHE-00.6	2/22/2016	13:25	5.86	8.26	204.5	12.45
55DRY-00.4	2/17/2015	11:04	2.06	7.46	118	12.50
55DRY-00.4	3/17/2015	11:21	6.25	7.48	129	11.10
55DRY-00.4	4/21/2015	11:46	9.98	7.96	154 J	10.09
55DRY-00.4	5/19/2015	12:55	13.47	8.02	203	9.25
55DRY-00.4	6/16/2015	11:50	13.46	7.94	223	9.11
55DRY-00.4	7/21/2015	11:28	14.90	8.19	240	9.03
55DRY-00.4	8/18/2015	11:35	12.65	7.90	249	9.77
55DRY-00.4	9/22/2015	10:50	9.21	7.94	245	10.04
55DRY-00.4	10/20/2015	10:50	9.09	7.97	245	10.57
55DRY-00.4	11/17/2015	10:50	4.36	7.94	227	11.78
55DRY-00.4	2/22/2016	12:35	3.60	7.09	82.2	12.06
55OTT-00.3	2/18/2015	16:02	6.22	7.83	196	11.10
55OTT-00.3	3/17/2015	9:25	6.84	7.67	214	10.94
55OTT-00.3 (QC)	3/17/2015	9:25	6.84	7.67	215	10.96
55OTT-00.3	4/21/2015	11:00	10.05	8.06	202 J	10.08
55OTT-00.3	5/19/2015	11:52	11.93	7.93	205	9.54
55OTT-00.3	6/16/2015	11:00	11.68	7.79	195	9.51
55OTT-00.3	7/21/2015	10:52	11.95	8.13	190	9.77
55OTT-00.3	8/18/2015	11:04	11.28	7.80	197	10.25
55OTT-00.3	9/22/2015	10:23	8.92	7.84	199	10.21
55OTT-00.3	10/20/2015	10:20	9.20	7.94	208	10.65
55OTT-00.3	11/17/2015	10:18	5.99	8.20	205	11.36
55OTT-00.3	2/22/2016	11:31	5.16	7.78	189	11.59
55MOO-02.9	2/17/2015	14:55	4.36	6.87	72.3	10.99
55MOO-02.9	3/17/2015	14:48	6.82	6.94	88.3	10.50
55MOO-02.9	4/21/2015	15:25	13.53	7.43	95 J	8.98
55MOO-02.9	5/19/2015	16:31	15.75	7.55	134	8.43
55MOO-02.9	6/16/2015	15:26	17.45	7.81	134	8.19
55MOO-02.9	7/21/2015	15:44	20.01	7.77	143.2	8.27
55MOO-02.9	8/18/2015	15:40	16.77	7.30	152	8.86
55MOO-02.9	9/22/2015	15:40	11.76	7.60	146	9.37
55MOO-02.9	10/20/2015	14:03	9.38	8.52	146	10.36
55MOO-02.9	11/17/2015	14:48	3.67	8.62	135	11.39
55MOO-02.9	2/23/2016	9:00	1.30	6.76	72.6	11.83
55WBLS-17.7	2/17/2015	15:47	3.67	7.01	78	10.34
55WBLS-17.7	3/17/2015	15:40	6.38	6.71	79.5	10.16
55WBLS-17.7	4/21/2015	16:00	16.45	7.31	84 J	8.59
55WBLS-17.7	5/20/2015	9:01	16.93	7.15		5.53
55WBLS-17.7	6/16/2015	15:53	23.01	7.25	89	6.72
55WBLS-17.7	7/21/2015	16:10	22.81	6.74	101	5.14

Location ID	Date	Time	Temp	pH	Cond		DO	
55WBLS-17.7	8/18/2015	16:10	20.81	6.34	96		6.05	
55WBLS-17.7	9/23/2015	8:59	12.26	7.10	96.3		6.64	
55WBLS-17.7 (QC)	9/23/2015	9:24	12.26	6.88	96.2		6.69	
55WBLS-17.7	10/20/2015	14:30	11.65	7.99	100		7.60	
55WBLS-17.7	11/17/2015	15:25	4.20	7.96	93.5		9.72	
55WBLS-17.7	2/23/2016	10:15	1.46	6.62	78.5		9.88	
55BUC-00.3	2/18/2015	10:36	1.87	7.07	42.8		12.44	
55BUC-00.3	3/18/2015	9:50	4.01	7.11	49		11.71	
55BUC-00.3	4/22/2015	9:43	7.21	7.56	51.3	J	10.83	
55BUC-00.3 (QC)	4/22/2015	10:05	7.22	7.55	51.3	J	10.86	
55BUC-00.3	5/20/2015	10:55	11.55	7.45	59.2		9.41	
55BUC-00.3	6/17/2015	10:58	14.82	7.35	64.1		8.69	
55BUC-00.3	7/22/2015	9:50	14.42	7.38	69.2		8.43	
55BUC-00.3	8/19/2015	10:15	14.66	6.86	83.7		8.68	
55BUC-00.3	9/23/2015	10:55	10.44	7.45	81.4		9.37	
55BUC-00.3	10/21/2015	10:13	6.98	8.40	80.9		10.50	
55BUC-00.3	2/23/2016	12:40	2.33	6.86	40.9		12.37	
55WBLS-11.1	2/18/2015	12:49	3.74	7.06	66		11.34	
55WBLS-11.1 (QC)	2/18/2015	13:28	3.74	7.06	66		11.32	
55WBLS-11.1	3/18/2015	11:24	5.89	7.09	67.1		11.12	
55WBLS-11.1	4/22/2015	12:00	13.69	7.90	69	J	10.00	
55WBLS-11.1	5/20/2015	12:23	20.00	8.16	72.3		8.91	
55WBLS-11.1	6/17/2015	12:37	23.74	8.49	75		8.27	
55WBLS-11.1	7/22/2015	11:16	21.97	8.30	87.3		7.93	
55WBLS-11.1	8/19/2015	11:40	21.63	7.87	105		8.73	
55WBLS-11.1 (QC)	8/19/2015	12:13	21.80	7.88	104		8.67	
55WBLS-11.1	9/23/2015	12:15	14.50	7.86	94.2		9.04	
55WBLS-11.1	10/21/2015	11:29	10.77	7.99	87.7		9.79	
55WBLS-11.1	11/19/2015	16:06	6.06	7.99	77.3		10.55	J
55WBLS-11.1	2/23/2016	15:03	3.50	6.89	65		10.80	
55BEAV-00.5	2/18/2015	11:41	3.42	7.16	43.3		11.90	
55BEAV-00.5	3/18/2015	10:24	5.09	7.21	50.4		11.42	
55BEAV-00.5	4/22/2015	10:49	10.71	7.54	50.8	J	9.85	
55BEAV-00.5	5/20/2015	11:34	12.54	7.27	55.2		9.23	
55BEAV-00.5	6/17/2015	11:42	14.45	7.96	60.2		8.66	
55BEAV-00.5	7/22/2015	10:20	13.67	7.64	56.2		9.08	
55BEAV-00.5	8/19/2015	10:46	13.74	7.17	63.1		9.40	
55BEAV-00.5	9/23/2015	11:25	8.68	7.57	62.7		10.21	
55BEAV-00.5	10/21/2015	10:44	5.85	8.48	65.1		10.92	
55BEAV-00.5	2/23/2016	13:31	2.54	6.85	37.3		12.31	
55BEAV-00.5 (QC)	2/23/2016	13:40	2.54	6.86	37.3		12.30	
55WBLS-07.7	2/18/2015	9:33	2.42	6.96	69.2		10.91	
55WBLS-07.7	3/18/2015	8:30	5.69	6.98	73		10.39	
55WBLS-07.7	4/22/2015	8:56	11.35	7.39	76.8	J	8.70	
55WBLS-07.7	5/20/2015	10:01	16.91	7.20	88.3		7.51	
55WBLS-07.7	6/17/2015	9:40	20.87	7.68	88		6.83	
55WBLS-07.7 (QC)	6/17/2015	10:12	20.95	7.46	88		7.13	
55WBLS-07.7	7/22/2015	8:58	19.20	7.88	134		8.09	
55WBLS-07.7	8/19/2015	9:14	16.20	7.31	171		8.99	
55WBLS-07.7	9/23/2015	10:00	11.48	7.01	172		5.44	
55WBLS-07.7	10/21/2015	9:20	9.49	7.25	147		6.34	
55WBLS-07.7	11/19/2015	15:08	4.34	7.69	91.4		10.12	J
55WBLS-07.7	2/23/2016	10:46	2.26	7.20	65.3		10.78	
55WBLS-03.1	2/18/2015	14:52	5.06	6.88	90.1		10.13	
55WBLS-03.1	3/4/2015	10:06	3.19	7.72	96.1		12.00	

Location ID	Date	Time	Temp	pH	Cond	DO
55WBLS-03.1	3/18/2015	12:48	8.57	7.31	103	10.72
55WBLS-03.1 (QC)	3/18/2015	13:03	8.59	7.31	103	10.71
55WBLS-03.1	4/8/2015	12:12	10.37	8.07	107	11.00
55WBLS-03.1	4/22/2015	13:22	16.25	8.49	99 J	10.29
55WBLS-03.1	5/20/2015	13:33	21.82	8.46	106	8.72
55WBLS-03.1 (QC)	5/20/2015	13:50	21.86	8.46	105	8.73
55WBLS-03.1	6/3/2015	11:32	19.11	7.70	99.2	7.45
55WBLS-03.1	6/17/2015	14:05	25.33	8.54	98	8.63
55WBLS-03.1	7/8/2015	12:05	24.73	7.94	91.5 J	8.60 J
55WBLS-03.1	7/22/2015	12:26	24.01	8.20	90.9	9.71
55WBLS-03.1 (QC)	7/22/2015	12:51	24.23	8.24	90.9	9.83
55WBLS-03.1	8/4/2015	13:00	23.91	8.13	105.5	9.54
55WBLS-03.1	8/19/2015	13:05	22.91	7.62	114	9.92
55WBLS-03.1	9/23/2015	13:26	16.35	7.58	117	8.87
55WBLS-03.1	10/7/2015	12:05	13.93	7.65	116	9.50 J
55WBLS-03.1	10/21/2015	12:36	11.73	7.82	125	8.56
55WBLS-03.1 (QC)	10/21/2015	13:03	11.90	7.60	125	8.56
55WBLS-03.1	11/5/2015	11:30	5.66	7.97	131.4	
55WBLS-03.1	11/19/2015	13:06	4.22	7.47	134	11.01 J
55WBLS-03.1	12/11/2015	12:42	2.49	7.38	128	12.29
55WBLS-03.1	1/5/2016	12:40	1.88			13.00
55WBLS-03.1	2/3/2016	12:55	2.62			13.70
55WBLS-03.1	2/23/2016	16:32	4.84	7.23	113.1	8.70
55BEAR-00.4	2/17/2015	10:14	1.71	7.57	295	12.04
55BEAR-00.4	3/17/2015	9:40	5.46	7.36	274	10.55
55BEAR-00.4	4/21/2015	10:18	11.53	8.00	308 J	9.50
55BEAR-00.4	5/19/2015	11:02	15.09	7.99	312	8.72
55BEAR-00.4	6/16/2015	9:50	15.76	8.01	311	8.45
55BEAR-00.4 (QC)	6/16/2015	10:08	15.81	8.03	311	8.43
55BEAR-00.4	7/21/2015	10:03	17.39	8.22	322	8.43
55BEAR-00.4	8/18/2015	9:53	13.19	7.97	326	9.62
55BEAR-00.4	9/22/2015	9:35	10.78	7.94	319	9.58
55BEAR-00.4	10/20/2015	9:43	9.63	7.89	316	10.27
55BEAR-00.4	11/17/2015	9:36	3.09	7.93	295	12.03
55BEAR-00.4	2/22/2016	10:21	3.08	7.60	277.3	11.45
55BEAR-00.4 (QC)	2/22/2016	10:52	3.10	7.60	277.4	11.45
55DEE-05.9	2/17/2015	14:55	2.58	7.77	60.8	12.04
55DEE-05.9	3/17/2015	15:20	5.52	7.32	64.4	11.12
55DEE-05.9	4/21/2015	13:50	10.06	7.30	66	10.10
55DEE-05.9	5/19/2015	14:29	14.17	7.50	84	9.33
55DEE-05.9	6/16/2015	15:20	16.64	7.80	101	8.27
55DEE-05.9	7/21/2015	15:20	19.00	7.62	145.6	7.23
55DEE-05.9	8/18/2015	15:00	16.82	7.50	168.2	7.64
55DEE-05.9 (QC)	8/18/2015	15:16	16.91	7.42	167.5	7.62
55DEE-05.9	9/22/2015	14:50	11.98	8.13	162.5	8.89
55DEE-05.9	10/20/2015	14:45	10.00	8.30	164.4	9.26
55DEE-05.9	11/17/2015	14:25	5.40	8.00	121	10.68 J
55DEE-05.9	2/22/2016	14:45	4.33	8.24 J	48	11.56
55LDR-00.1	2/17/2015	15:25	2.58	7.24	50.2	11.96
55LDR-00.1	3/17/2015	15:45	5.16	7.21	57	11.28
55LDR-00.1	4/21/2015	13:58	9.10	7.32	53	10.27
55LDR-00.1	5/19/2015	14:58	12.48	7.23	55	9.43
55LDR-00.1	10/20/2015	14:55	9.89	8.26	82.2	8.66
55LDR-00.1	11/17/2015	14:50	5.10	7.76	66.2	10.43 J
55LDR-00.1 (QC)	11/17/2015	14:50	5.11	7.75	66	10.41 J

Location ID	Date	Time	Temp	pH	Cond	DO
55LDR-00.1	2/22/2016	15:15	3.92	7.59 J	50	11.76
55DEE-00.1	2/17/2015	8:36	0.90	7.19	58.6	13.08
55DEE-00.1 (QC)	2/17/2015	9:12	0.92	7.18	58.7	13.02
55DEE-00.1	3/17/2015	7:58	5.04	7.19	67.5	11.54
55DEE-00.1	4/21/2015	8:26	6.94	7.61	66.5 J	10.89
55DEE-00.1 (QC)	4/21/2015	8:42	6.94	7.61	66.4 J	10.87
55DEE-00.1	5/19/2015	8:58	10.93	7.60	82.2	9.74
55DEE-00.1	6/16/2015	8:19	13.17	7.54	101	9.12
55DEE-00.1	7/21/2015	8:51	13.34	8.06	183	9.39
55DEE-00.1	8/18/2015	8:25	10.51	7.72	192	10.28
55DEE-00.1	9/22/2015	8:20	7.41	7.71	193	10.41
55DEE-00.1	10/20/2015	8:24	8.14	7.73	196	9.98
55DEE-00.1	11/17/2015	8:26	4.04	7.92	144	11.45
55DEE-00.1	2/22/2016	9:13	3.04	6.99	51.4	12.55
55DRA-17.0	2/17/2015	11:35	2.95	7.29	122.6	11.29
55DRA-17.0	3/17/2015	11:25	6.42	7.53	167	10.26
55DRA-17.0	4/21/2015	11:20	13.32	8.21	170.9	10.46
55DRA-17.0 (QC)	4/21/2015	11:20	13.34	8.21	170.6	10.44
55DRA-17.0	5/19/2015	10:50	17.99	8.61	209	9.16
55DRA-17.0	6/16/2015	12:15	19.49	7.32	225.4	3.74
55DRA-17.0	7/21/2015	11:05	18.96	7.26	283.8	2.50
55DRA-17.0	8/18/2015	11:16	16.95	7.22	300.3	2.37
55DRA-17.0	9/22/2015	11:18	13.15	7.38	288.6	2.42
55DRA-17.0	10/20/2015	11:40	10.33	7.61	283.7	3.85
55DRA-17.0	11/17/2015	11:21	5.23	7.45	326	6.77 J
55DRA-17.0	2/22/2016	12:00	2.93	7.49 J	81	11.33
55SPR-00.4	2/17/2015	12:20	6.94	7.21	278.2	9.13
55SPR-00.4	3/17/2015	12:10	7.68	7.52	276.3	9.38
55SPR-00.4	4/21/2015	12:10	11.85	7.47	278.6	10.59
55SPR-00.4	5/19/2015	11:30	12.22	7.30	278	9.86
55SPR-00.4	6/16/2015	11:35	12.25	7.58	273.4	8.64
55SPR-00.4	7/21/2015	12:05	12.92	7.29	277.1	8.29
55SPR-00.4 (QC)	7/21/2015	12:10	13.29	7.39	277.5	8.44
55SPR-00.4	8/18/2015	12:05	11.77	7.32	274.7	8.06
55SPR-00.4	9/22/2015	11:57	9.45	7.72	274.3	7.99
55SPR-00.4 (QC)	9/22/2015	11:57	9.50	7.33	274.3	7.97
55SPR-00.4	10/20/2015	12:20	9.38	7.56	282.6	8.59
55SPR-00.4	11/17/2015	12:05	6.28	7.34	283	8.71 J
55SPR-00.4	2/22/2016	13:05	7.23	7.19 J	274.9	9.73
55DRA-16.4	2/17/2015	10:45	3.42	7.37	156.7	11.03
55DRA-16.4	3/17/2015	10:30	6.51	7.60	189.6	10.09
55DRA-16.4	4/21/2015	10:35	11.06	7.77	213.6	10.46
55DRA-16.4	5/19/2015	10:03	12.53	7.50	252	8.32
55DRA-16.4	6/16/2015	10:55	13.94	7.58	250	6.72
55DRA-16.4	7/21/2015	10:30	13.92	7.51	276.2	6.61
55DRA-16.4	8/18/2015	10:44	11.60	7.39	279.9	6.94
55DRA-16.4	9/22/2015	11:37	9.48	7.36	279.1	6.61
55DRA-16.4	10/20/2015	10:43	8.93	7.68	282.9	6.78
55DRA-16.4 (QC)	10/20/2015	11:09	8.93	7.53	282.5	6.92
55DRA-16.4	11/17/2015	10:48	4.83	7.47	291	8.74 J
55DRA-16.4	2/22/2016	11:25	3.05	7.63 J	95.6	11.26
55BEAV2-00.1	9/23/2015	15:25	10.02	7.79	379	9.07
55DRA-13.2	2/17/2015	10:00	2.75	7.51	178.8	11.39
55DRA-13.2	3/17/2015	9:45	6.66	7.55	217.1	10.11
55DRA-13.2	4/21/2015	9:56	10.54	7.61	241.5	9.68

Location ID	Date	Time	Temp	pH		Cond	DO	
55DRA-13.2	5/19/2015	9:25	13.19	7.52		274	8.25	
55DRA-13.2	6/16/2015	10:15	14.50	7.87		273.6	8.06	
55DRA-13.2	7/21/2015	9:45	16.29	7.53		300.4	7.61	
55DRA-13.2	8/18/2015	10:06	13.97	7.77		305.7	8.57	
55DRA-13.2	9/22/2015	10:01	10.22	7.65		306.1	8.76	
55DRA-13.2	10/20/2015	10:03	8.88	7.75		318.6	9.44	
55DRA-13.2	11/17/2015	10:08	4.15	7.63		320	10.86	J
55DRA-13.2	2/22/2016	10:30	2.97	7.65	J	113	11.41	
55WBDR-00.1	2/17/2015	9:00	1.32	7.64		213.1	12.09	
55WBDR-00.1	3/17/2015	8:45	6.00	7.51		209.4	10.44	
55WBDR-00.1 (QC)	3/17/2015	8:45	6.00	7.50		209.6	10.44	
55WBDR-00.1	4/21/2015	9:10	9.09	7.68		254	9.87	
55WBDR-00.1	5/19/2015	8:45	12.22	7.70		257	9.41	
55WBDR-00.1	6/16/2015	9:05	13.09	7.99		255.6	8.57	
55WBDR-00.1 (QC)	6/16/2015	9:10	13.15	7.99		255.8	8.59	
55WBDR-00.1	7/21/2015	9:05	15.89	7.58		269.3	8.04	
55WBDR-00.1	8/18/2015	9:24	13.02	7.90		256.5	9.18	
55WBDR-00.1	9/22/2015	9:23	9.47	7.67		261.7	9.46	
55WBDR-00.1	10/20/2015	9:22	8.13	7.72		288.7	10.07	
55WBDR-00.1	11/17/2015	9:23	3.87	7.66		293	11.36	J
55WBDR-00.1	2/22/2016	9:35	2.69	7.84	J	136	11.54	
55MUD-00.7	9/23/2015	14:44	10.28	7.78		344	9.32	
55DRA-04.3	2/17/2015	13:15	3.14	7.73		234.4	12.13	
55DRA-04.3	3/17/2015	13:00	6.83	7.85		251	10.97	
55DRA-04.3	4/21/2015	12:50	12.36	7.99		294	10.88	
55DRA-04.3	5/19/2015	12:30	14.98	7.93		321	10.59	
55DRA-04.3 (QC)	5/19/2015	12:30	14.98	7.93		321	10.58	
55DRA-04.3	6/16/2015	13:30	17.49	8.37		323.7	10.88	
55DRA-04.3	7/21/2015	13:25	19.40	8.33		338.3	12.31	
55DRA-04.3	8/18/2015	13:05	16.05	8.16		346.4	11.33	
55DRA-04.3	9/22/2015	13:04	11.60	8.15		347.2	12.09	
55DRA-04.3	10/20/2015	13:01	9.76	7.84		354.6	12.41	
55DRA-04.3	11/17/2015	12:55	5.33	7.92		365	12.16	J
55DRA-04.3	2/22/2016	13:50	3.62	7.94	J	144.8	11.96	
55DRA-00.3	2/17/2015	14:10	3.04	7.94		237.1	12.25	
55DRA-00.3 (QC)	2/17/2015	14:10	3.04	7.96		236.3	12.24	
55DRA-00.3	3/17/2015	14:05	7.16	8.04		251.9	11.19	
55DRA-00.3	4/21/2015	13:20	13.59	8.28		295.3	9.99	
55DRA-00.3	5/19/2015	13:39	17.40	8.46		316	9.94	
55DRA-00.3	6/16/2015	14:20	20.20	8.64		319.8	8.85	
55DRA-00.3	7/21/2015	14:15	21.73	8.49		338.4	8.06	
55DRA-00.3	8/18/2015	13:48	18.03	8.37		336.9	9.14	
55DRA-00.3	9/22/2015	13:52	12.53	8.19		343.4	10.43	
55DRA-00.3	10/20/2015	13:55	10.20	8.23		354	10.87	
55DRA-00.3	11/17/2015	13:40	5.76	8.25		364	11.82	J
55DRA-00.3	2/22/2016	14:05	3.84	7.90	J	146.9	12.25	
55DRA-00.3 (QC)	2/22/2016	14:05	3.84	7.89	J	146.4	12.25	
55SFLD-01.1	2/17/2015	16:05	3.01	7.26		37.9	11.89	
55SFLD-01.1	3/17/2015	16:30	5.56	7.76		45.8	11.18	
55SFLD-01.1	4/21/2015	14:20	9.47	7.05		40	10.25	
55SFLD-01.1	5/19/2015	15:49	12.44	7.57		41	9.48	
55SFLD-01.1	6/16/2015	16:20	15.27	7.49		42	8.41	
55SFLD-01.1	7/21/2015	16:05	18.15	7.41		52.2	8.11	
55SFLD-01.1	8/18/2015	16:05	16.92	7.78		51.2	8.58	
55SFLD-01.1	9/22/2015	15:27	11.88	8.17		44.2	9.23	

Location ID	Date	Time	Temp	pH		Cond	DO	
55SFLD-01.1	10/20/2015	16:00	10.18	8.50		55.1	9.23	
55SFLD-01.1	11/17/2015	15:40	5.40	7.58		52.7	10.85	J
55SFLD-01.1	2/23/2016	11:00	2.74	7.32	J	38	12.37	
55SFLD-01.1 (QC)	2/23/2016	11:00	2.77	7.32	J	38	12.36	
55LDP-00.1	2/18/2015	12:05	2.34	7.54		122.5	12.49	
55LDP-00.1	3/18/2015	12:35	7.38	7.51		126.2	10.90	
55LDP-00.1 (QC)	3/18/2015	12:35	7.43	7.50		125.3	10.88	
55LDP-00.1	4/22/2015	9:45	10.23	7.73		171	10.03	
55LDP-00.1 (QC)	4/22/2015	9:45	10.25	7.74		171	10.06	
55LDP-00.1	5/20/2015	10:15	12.20	7.90		321.2	10.03	
55LDP-00.1	6/17/2015	12:25	15.41	8.41		440.8	9.64	
55LDP-00.1	7/22/2015	12:50	15.46	8.20		458.2	9.28	
55LDP-00.1	8/19/2015	9:42	12.15	8.11		456.8	9.93	
55LDP-00.1	9/23/2015	12:40	10.16	8.22		470.5	10.57	
55LDP-00.1	10/21/2015	10:20	7.04	8.04		473.4	11.35	
55LDP-00.1	11/19/2015	10:01	4.97	8.03		475	11.57	J
55LDP-00.1	2/23/2016	14:05	3.63	7.71	J	99	12.49	
55DEA-20.2	2/18/2015	9:10	2.76	7.55		21.1	11.72	
55DEA-20.2 (QC)	2/18/2015	9:10	2.77	7.47		21.4	11.72	
55DEA-20.2	3/18/2015	10:35	4.29	7.26		23.5	11.38	
55DEA-20.2	4/22/2015	13:55	7.55	6.97		24	10.34	
55DEA-20.2	5/20/2015	13:55	11.24	7.49		25.2	9.58	
55DEA-20.2	6/17/2015	9:10	10.56	7.35		22.3	9.31	
55DEA-20.2	7/22/2015	9:30	11.18	7.33		31.4	9.23	
55DEA-20.2 (QC)	7/22/2015	9:35	11.18	7.42		31.3	9.21	
55DEA-20.2	8/19/2015	12:50	13.36	7.52		32.7	9.00	
55DEA-20.2	9/23/2015	9:47	7.69	8.25		27.4	10.22	
55DEA-20.2	10/21/2015	13:20	7.16	8.40		36.6	10.55	
55DEA-20.2	11/19/2015	11:51	1.86	7.43		37.7	12.08	J
55DEA-20.2	2/23/2016	9:30	2.19	7.80	J	26.6	12.16	
55DEA-13.8	2/18/2015	10:40	2.43	6.97		37.2	12.26	
55DEA-13.8	3/18/2015	9:25	5.17	7.16		45.7	11.47	
55DEA-13.8	4/22/2015	13:25	8.52	7.01		39	10.72	
55DEA-13.8	5/20/2015	13:00	12.93	7.55		39.1	9.87	
55DEA-13.8	6/3/2015	9:10	11.13	7.94		54.8	10.29	J
55DEA-13.8	6/17/2015	10:00	14.20	7.71		40.7	9.17	
55DEA-13.8	7/22/2015	10:50	15.35	7.48		43.1	8.96	
55DEA-13.8	8/19/2015	12:00	15.73	7.36		45	8.73	
55DEA-13.8	9/23/2015	10:31	8.14	7.70		39.4	10.09	
55DEA-13.8	10/21/2015	12:40	6.60	8.85		50	10.68	
55DEA-13.8	11/19/2015	11:25	2.11	7.73		51.4	12.42	J
55DEA-13.8	2/23/2016	10:10	2.23	7.38	J	42	12.59	
55DEA-09.2	4/22/2015	12:40	9.67	7.25		69.6	10.56	
55DEA-09.2	6/3/2015	10:00	12.36	7.40		109.4	9.52	J
55DEA-09.2	2/23/2016	11:55	2.41	7.13	J	63	12.24	
55DEA-05.9	2/18/2015	11:25	2.12	6.75		86.4	10.09	
55DEA-05.9	3/18/2015	8:50	5.97	7.50		113.3	7.74	
55DEA-05.9	4/22/2015	11:40	11.64	6.97		108	8.69	
55DEA-05.9	5/20/2015	11:40	15.57	7.39		114.6	8.00	
55DEA-05.9 (QC)	5/20/2015	11:40	15.72	7.22		114.6	8.07	
55DEA-05.9	6/3/2015	10:45	14.55	7.09		125.6	6.53	J
55DEA-05.9	6/17/2015	11:00	20.50	7.44		112.3	6.19	
55DEA-05.9 (QC)	6/17/2015	11:05	20.53	7.39		11.7	6.21	
55DEA-05.9	7/22/2015	11:40	20.75	7.20		123.8	5.08	
55DEA-05.9	8/19/2015	10:40	15.67	7.27		137.1	4.95	

Location ID	Date	Time	Temp	pH		Cond	DO	
55DEA-05.9 (QC)	8/19/2015	10:55	15.68	7.23		136.7	5.56	
55DEA-05.9	9/23/2015	11:17	10.43	7.73		128	7.52	
55DEA-05.9	10/21/2015	11:25	7.93	8.33		152.8	9.33	
55DEA-05.9 (QC)	10/21/2015	11:30	7.93	8.30		152.9	9.36	
55DEA-05.9	11/19/2015	10:55	3.27	8.30		99.3	10.96	J
55DEA-05.9 (QC)	11/19/2015	10:55	3.27	8.11		99.3	10.90	J
55DEA-05.9	2/23/2016	12:45	3.56	7.16	J	84.5	11.64	
55DEA-02.6	4/22/2015	11:00	12.61	7.55		117	9.70	
55DEA-02.6	6/3/2015	11:30	15.50	7.44		134.4	9.10	J
55DEA-02.6 (QC)	6/3/2015	11:35	15.50	7.43		134.5	9.13	J
55DEA-02.6	2/23/2016	13:10	2.67	7.48	J	90.7	12.07	
55DEA-00.6	2/18/2015	11:50	3.42	7.29		136.7	12.00	
55DEA-00.6	3/18/2015	12:00	7.18	7.74		158.2	11.06	
55DEA-00.6	4/22/2015	10:33	12.56	7.89		176.8	9.76	
55DEA-00.6	5/20/2015	10:50	14.57	7.93		236.7	9.50	
55DEA-00.6	6/3/2015	12:20	15.37	7.81		192.4	9.32	J
55DEA-00.6	6/17/2015	12:10	16.72	8.26		287.3	8.94	
55DEA-00.6	7/22/2015	12:35	14.69	7.93		371.7	9.48	
55DEA-00.6	8/19/2015	10:15	11.56	8.04		402.5	10.02	
55DEA-00.6	9/23/2015	12:20	10.39	8.00		393.5	10.40	
55DEA-00.6 (QC)	9/23/2015	12:20	10.42	7.98		393.3	10.38	
55DEA-00.6	10/21/2015	10:52	8.34	8.25		390.4	11.06	
55DEA-00.6	11/19/2015	10:27	6.14	8.02		308	11.35	J
55DEA-00.6	2/23/2016	13:45	3.86	7.71	J	120.5	12.20	
55DAR-00.2	2/18/2015	13:15	6.50	8.27		506.4	11.22	
55DAR-00.2	3/18/2015	13:40	10.18	8.37		506.8	10.45	
55DAR-00.2	4/22/2015	9:15	9.85	8.14		512	10.29	
55DAR-00.2	5/20/2015	8:55	11.27	8.05		514.7	10.07	
55DAR-00.2	6/17/2015	13:50	13.16	8.41		504.7	8.90	
55DAR-00.2	7/22/2015	14:45	15.15	8.29		510.6	9.00	
55DAR-00.2	8/19/2015	8:06	11.66	8.12		506.8	9.72	
55DAR-00.2	9/23/2015	14:00	10.91	8.23		511.9	10.16	
55DAR-00.2	10/21/2015	8:50	7.45	8.02		516.4	11.13	
55DAR-00.2	11/19/2015	9:12	5.71	8.14		516	11.50	J
55DAR-00.2	2/23/2016	14:40	6.58	8.22	J	470.3	11.36	

Flow Data

Table D-9. Data qualifiers used in this section.

Qualifier	Meaning
J	The measurement result value is an estimate.

Table D-10. Flow methods used.

Method	Description
Wading	Wading flow measurement calculated using mid-section method
ADCP	StreamPro® Acoustic Doppler Current Profiler
Culvert	Partially full circular culvert flow calculated from measured geometry and velocity
Rating Curve	Flow calculated from water level measurement using stage-discharge rating curve
Observed Dry	Stream observed to be dry

Table D-11. Flow measurements taken during 2013.

Location ID	Date	Start time	End time	Flow (cfs)	Method
55LSR-39.5	8/14/2013	11:25	11:43	39	Wading
55LSR-31.8	8/14/2013	14:53	15:42	76	Wading
55LSR-25.4	8/13/2013			83	Wading
55LSR-23.4	8/13/2013	11:35	13:02	79	Wading
55LSR-18.0	8/13/2013	15:12	15:57	117	Wading
55LSR-16.0	8/13/2013			125	Wading
55LSR-13.5	8/13/2013			124	Wading
55LSR-07.5	8/12/2013	12:52	13:36	335	Wading
55DRY-00.4	8/14/2013	12:10	12:29	3.0	Wading
55OTT-00.3	8/14/2013	13:28	13:54	8.3	Wading
55WBLS-03.1	8/14/2013	14:15	14:34	16	Wading
55BEA-00.4	8/14/2013	16:52	17:09	1.5	Wading
55DEE-00.1	8/13/2013			0.13	Wading
55DRA-00.3	8/13/2013	13:40	14:11	19	Wading
55DEA-00.2	8/13/2013			13	Wading
55DAR-00.2	8/14/2013	17:49	18:04	3.8	Wading

Table D-12. Flow measurements taken during 2015-2016.

Location ID	Date	Start time	End time	Flow (cfs)	Method
55LSR-46.7	2/17/2015	13:58	14:32	28	Wading
55LSR-46.7	3/17/2015	13:51	14:23	29	Wading
55LSR-46.7	4/21/2015	14:23	14:55	28	Wading
55LSR-46.7	5/19/2015	15:37	16:09	27	Wading
55LSR-46.7	6/16/2015	14:18	14:59	23	Wading
55LSR-46.7	7/21/2015	14:43	15:18	22	Wading
55LSR-46.7	8/18/2015	14:46	15:16	22	Wading
55LSR-46.7	9/22/2015	14:42		19	Wading
55LSR-46.7	10/20/2015	13:11	13:38	20	Wading
55LSR-46.7	11/17/2015	13:53	14:20	23	Wading
55LSR-46.7	1/19/2016	14:21	14:53	24	Wading
55LSR-46.7	2/22/2016	15:50	16:13	27	Wading
55LSR-46.7	3/16/2016	15:05	15:49	30	Wading
55LSR-39.5	2/17/2015	13:05	13:32	49	Wading
55LSR-39.5	3/17/2015	12:57	13:20	51	Wading
55LSR-39.5	4/21/2015	13:15	13:55	47	Wading
55LSR-39.5	5/19/2015	14:50	15:13	40	Wading
55LSR-39.5	6/16/2015	13:25	13:50	36	Wading
55LSR-39.5	7/21/2015	13:49	14:11	33	Wading
55LSR-39.5	8/18/2015	13:27	13:50	32	Wading
55LSR-39.5 (QC)	8/18/2015	13:50	14:14	31	Wading
55LSR-39.5	9/22/2015	12:43		33	Wading
55LSR-39.5	10/20/2015	12:21	12:43	35	Wading
55LSR-39.5	11/17/2015	13:03	13:28	32	Wading
55LSR-39.5	1/19/2016	13:29	13:54	36	Wading
55LSR-39.5	2/22/2016	14:49	15:24	52	Wading
55LSR-37.1	2/17/2015	12:22	12:49	57	Wading
55LSR-37.1	3/17/2015	12:23	12:40	55	Wading
55LSR-37.1	4/21/2015	11:55	13:16	50	Wading
55LSR-37.1	5/19/2015	14:15	14:34	46	Wading
55LSR-37.1	6/16/2015	12:44	13:08	40	Wading
55LSR-37.1	7/21/2015	12:35	13:00	33	Wading
55LSR-37.1 (QC)	7/21/2015	13:01	13:28	32	Wading
55LSR-37.1	8/18/2015	12:48	13:08	32	Wading
55LSR-37.1	9/22/2015	11:43		34	Wading
55LSR-37.1 (QC)	9/22/2015	12:07		33	Wading
55LSR-37.1	10/20/2015	11:51	12:08	32	Wading
55LSR-37.1	11/17/2015	11:59	12:20	41	Wading
55LSR-37.1 (QC)	11/17/2015	12:20	12:41	41	Wading
55LSR-37.1	1/19/2016	12:43	13:08	42	Wading
55LSR-37.1	2/22/2016	13:50	14:11	60	Wading
55LSR-37.1	3/16/2016	13:47	14:17	71	Wading
55LSR-23.4	2/18/2015	10:34	10:43	263	ADCP
55LSR-23.4	3/17/2015	8:44	9:20	158	Wading
55LSR-23.4	4/8/2015	10:06		161	Rating curve
55LSR-23.4	4/21/2015	9:22	9:56	132	Wading
55LSR-23.4	5/19/2015	9:44	10:13	86	Wading
55LSR-23.4 (QC)	5/19/2015	10:13	10:41	89	Wading
55LSR-23.4	6/3/2015	9:27		100	Rating curve
55LSR-23.4	6/16/2015	8:57	9:31	77	Wading
55LSR-23.4	7/8/2015	10:10		57 J	Rating curve
55LSR-23.4	7/21/2015	9:22	9:40	50	Wading

Location ID	Date	Start time	End time	Flow (cfs)	Method
55LSR-23.4	8/4/2015	10:50		54 J	Rating curve
55LSR-23.4	8/18/2015	9:11	9:30	49	Wading
55LSR-23.4	9/22/2015	8:50		54	Wading
55LSR-23.4	10/7/2015	10:01		55 J	Rating curve
55LSR-23.4	10/20/2015	8:51	9:08	52	Wading
55LSR-23.4 (QC)	10/20/2015	9:08	9:27	56	Wading
55LSR-23.4	11/5/2015	9:50		67 J	Rating curve
55LSR-23.4	11/17/2015	8:58	9:21	75	Wading
55LSR-23.4	12/11/2015	10:24		147	Rating curve
55LSR-23.4	1/19/2016	9:06	9:38	120	Wading
55LSR-23.4	2/3/2016	10:53		191	Rating curve
55LSR-23.4	2/17/2016	10:08		188	Rating curve
55LSR-23.4	2/22/2016	9:55		286	Rating curve
55LSR-23.4	2/22/2016	10:56	11:09	301	ADCP
55LSR-23.4	3/16/2016	10:15		484	Rating curve
55LSR-23.4	3/16/2016	11:03	11:12	477	ADCP
55LSR-13.5	2/18/2015	13:01	13:10	380	ADCP
55LSR-13.5	3/4/2015	14:19		228	Rating curve
55LSR-13.5	3/18/2015	9:48	9:57	293	ADCP
55LSR-13.5	3/18/2015	13:20		302	Rating curve
55LSR-13.5	4/8/2015	14:04		276	Rating curve
55LSR-13.5	4/22/2015	14:37	15:15	202	Wading
55LSR-13.5	5/6/2015			162	Rating curve
55LSR-13.5	5/20/2015	9:40	10:00	132	Wading
55LSR-13.5	6/3/2015	12:48		186	Rating curve
55LSR-13.5	6/17/2015	13:08	13:32	111	Wading
55LSR-13.5	7/8/2015	13:19		83	Rating curve
55LSR-13.5	7/22/2015	14:00	14:22	78	Wading
55LSR-13.5	8/4/2015	14:35		75	Rating curve
55LSR-13.5	8/19/2015	9:07	9:35	79	Wading
55LSR-13.5	9/9/2015	13:11		84	Rating curve
55LSR-13.5	9/23/2015	13:22	13:47	93	Wading
55LSR-13.5	10/7/2015	13:42		94	Rating curve
55LSR-13.5	10/21/2015	9:35	10:02	96	Wading
55LSR-13.5	11/5/2015	12:46		114	Rating curve
55LSR-13.5	11/19/2015	9:44		134	Rating curve
55LSR-13.5	1/5/2016	15:00		289	Rating curve
55LSR-13.5	1/20/2016	9:33	10:02	249	Wading
55LSR-13.5	2/3/2016	14:38		324	Rating curve
55LSR-13.5	2/17/2016	13:20		427	Rating curve
55LSR-13.5	2/22/2016	12:39	12:46	520	ADCP
55LSR-13.5	2/23/2016	17:15		508	Rating curve
55LSR-13.5	3/16/2016	12:33	12:39	785	ADCP
55LSR-13.5	3/17/2016	9:20		739	Rating curve
55LSR-01.1	2/17/2015	8:15		844	Rating curve
55LSR-01.1	2/18/2015	14:04	14:14	738	ADCP
55LSR-01.1	3/17/2015	8:00		749	Rating curve
55LSR-01.1	3/18/2015	8:32	8:51	649	ADCP
55LSR-01.1	4/21/2015	8:35		575	Rating curve
55LSR-01.1	4/21/2015	11:42	11:50	534	ADCP
55LSR-01.1	5/19/2015	8:08		441	Rating curve
55LSR-01.1	6/2/2015	8:37	8:53	587	ADCP
55LSR-01.1	6/17/2015	8:17		429	Rating curve
55LSR-01.1	7/9/2015	8:59	9:10	410	ADCP

Location ID	Date	Start time	End time	Flow (cfs)		Method
55LSR-01.1	7/21/2015	8:15		425	J	Rating curve
55LSR-01.1	8/18/2015	8:27		356		Rating curve
55LSR-01.1	9/22/2015	8:45		378		Rating curve
55LSR-01.1	10/8/2015	9:12	9:25	352		ADCP
55LSR-01.1	10/20/2015	8:52		353		Rating curve
55LSR-01.1	11/17/2015	8:56		375		Rating curve
55LSR-01.1	12/1/2015	9:29	9:37	379		ADCP
55LSR-01.1	1/13/2016	9:14	9:24	452		ADCP
55LSR-01.1	2/22/2016	9:00		972		Rating curve
55LSR-01.1	2/24/2016	10:43	10:52	840		ADCP
55LSR-01.1	3/16/2016	8:50		1420	J	Rating curve
55LSR-01.1	4/7/2016	8:54	9:05	922		ADCP
55CHA-00.2	9/22/2015	13:33		0.13		Wading
55JON-00.5	9/22/2015	14:09		0.23		Wading
55REFL-NOUT	7/21/2015	12:00		0.55		Culvert
55REFL-NOUT	8/18/2015	12:15		0.38		Culvert
55REFL-NOUT	9/22/2015	11:17		0.17		Culvert
55REFL-NOUT	10/20/2015	11:23		0.43		Culvert
55REFL-NOUT	11/17/2015	11:17		0.29		Culvert
55REFL-NOUT	1/19/2016	12:14	12:16	0.79		Culvert
55REFL-NOUT	3/16/2016	13:17	13:22	0.86		Culvert
55SHE-00.6	2/17/2015	12:01		0.49		Culvert
55SHE-00.6	3/17/2015	11:57		1.1		Culvert
55SHE-00.6	4/21/2015	12:31		6.9		Culvert
55SHE-00.6	5/19/2015	13:50		0.15		Culvert
55SHE-00.6	6/16/2015	12:14		2.8		Culvert
55SHE-00.6	7/21/2015	12:15		2.2		Culvert
55SHE-00.6	8/18/2015	12:19		1.8		Culvert
55SHE-00.6	9/22/2015	11:27		2.7		Culvert
55SHE-00.6	10/20/2015	11:31		3.2		Culvert
55SHE-00.6	11/17/2015	11:13		4.1		Culvert
55SHE-00.6	1/19/2016	12:23		2.6		Culvert
55SHE-00.6	2/22/2016	13:25		2.6		Culvert
55SHE-00.6	3/16/2016	13:27		2.4		Culvert
55DRY-00.4	2/17/2015	11:04	11:30	6.9		Wading
55DRY-00.4	3/17/2015	11:21	11:41	6.6		Wading
55DRY-00.4	4/8/2015	10:34		6.6	J	Rating curve
55DRY-00.4	4/21/2015	11:46	12:10	4.9		Wading
55DRY-00.4	5/6/2015			3.4	J	Rating curve
55DRY-00.4	5/19/2015	12:55	13:19	2.5		Wading
55DRY-00.4	6/3/2015	9:49		3.3	J	Rating curve
55DRY-00.4	6/16/2015	11:39	11:59	1.8		Wading
55DRY-00.4	7/8/2015	10:31		1.7	J	Rating curve
55DRY-00.4	7/21/2015	11:28	11:48	1.4		Wading
55DRY-00.4	8/4/2015	11:10		1.5	J	Rating curve
55DRY-00.4	8/18/2015	11:35	11:56	1.5		Wading
55DRY-00.4	9/9/2015	10:26		1.7	J	Rating curve
55DRY-00.4	9/22/2015	10:45		1.5		Wading
55DRY-00.4	10/7/2015	10:22		1.6	J	Rating curve
55DRY-00.4	10/20/2015	10:50	11:12	1.6		Wading
55DRY-00.4	11/5/2015	10:08		1.8	J	Rating curve
55DRY-00.4	11/17/2015	10:50	11:04	1.9		Wading
55DRY-00.4	12/11/2015	10:49		2	J	Rating curve
55DRY-00.4	1/19/2016	11:43	12:04	2		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55DRY-00.4	2/3/2016	11:16		8.4	J	Rating curve
55DRY-00.4	2/17/2016	10:36		13	J	Rating curve
55DRY-00.4	2/22/2016	12:25	13:10	14		Wading
55DRY-00.4	3/16/2016	12:36	13:07	22		Wading
55DRY-00.4	4/6/2016	9:50		9.6	J	Rating curve
55OTT-02.0	10/6/2015		11:13	1.9		Wading
55OTT-02.0	4/6/2016	9:08	9:32	5.1		Wading
55OTT-00.3	2/18/2015	16:02	16:23	11		Wading
55OTT-00.3	3/17/2015	10:25	10:45	10		Wading
55OTT-00.3 (QC)	3/17/2015	10:45	11:03	10		Wading
55OTT-00.3	4/21/2015	11:00	11:22	9.3		Wading
55OTT-00.3	5/19/2015	11:52	12:16	7.2		Wading
55OTT-00.3	6/16/2015	11:00	11:22	7.3		Wading
55OTT-00.3	7/21/2015	10:52	11:12	5.8		Wading
55OTT-00.3	8/18/2015	11:04	11:22	6.3		Wading
55OTT-00.3	9/22/2015	10:14		6.2		Wading
55OTT-00.3	10/6/2015	13:46	14:01	6.1		Wading
55OTT-00.3	10/20/2015	10:20	10:39	7.5		Wading
55OTT-00.3	11/17/2015	10:18	10:35	8.2		Wading
55OTT-00.3	1/19/2016	10:40	11:01	9.3		Wading
55OTT-00.3 (QC)	1/19/2016	11:01	11:23	9.2		Wading
55OTT-00.3	2/22/2016	11:32	11:58	10		Wading
55OTT-00.3	3/16/2016	11:16	11:47	11		Wading
55OTT-00.3 (QC)	3/16/2016	11:47	12:18	12		Wading
55MOO-02.9	2/17/2015	14:55	15:23	12		Wading
55MOO-02.9	3/4/2015	11:00		6	J	Rating curve
55MOO-02.9	3/17/2015	14:48	15:11	9.1		Wading
55MOO-02.9	4/8/2015	11:33		7.5	J	Rating curve
55MOO-02.9	4/21/2015	15:23		2.3		Culvert
55MOO-02.9	5/6/2015			2.2	J	Rating curve
55MOO-02.9	5/19/2015	16:31		1.6		Culvert
55MOO-02.9	6/3/2015	10:45		4	J	Rating curve
55MOO-02.9	6/16/2015	15:26		1.1		Culvert
55MOO-02.9	7/8/2015	11:34		0.57	J	Rating curve
55MOO-02.9	7/21/2015	15:41		0.49		Culvert
55MOO-02.9	8/4/2015	12:03		0.57	J	Rating curve
55MOO-02.9	8/18/2015	15:40		0.6		Culvert
55MOO-02.9	9/9/2015	11:16		0.73	J	Rating curve
55MOO-02.9	9/22/2015	15:38		0.85		Culvert
55MOO-02.9	10/7/2015	11:15		0.6	J	Rating curve
55MOO-02.9	10/20/2015	14:03		0.86		Culvert
55MOO-02.9	11/5/2015	11:00		0.77	J	Rating curve
55MOO-02.9	11/17/2015	14:48		2.9		Culvert
55MOO-02.9	12/11/2015	11:59		3.1	J	Rating curve
55MOO-02.9	1/5/2016	11:59		1.5	J	Rating curve
55MOO-02.9	1/19/2016	15:19		2.3		Culvert
55MOO-02.9	2/3/2016	12:19		4.5	J	Rating curve
55MOO-02.9	2/17/2016	11:24		11	J	Rating curve
55MOO-02.9	2/23/2016	8:54	9:24	11		Wading
55MOO-02.9	3/17/2016	9:07	9:38	19		Wading
55MOO-02.9 (QC)	3/17/2016	9:39	10:10	18		Wading
55WBLS-17.7	2/17/2015	15:46	16:12	43		Wading
55WBLS-17.7	3/17/2015	15:37	16:09	30		Wading
55WBLS-17.7	4/21/2015	15:54	16:13	21		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55WBLS-17.7	5/20/2015	9:01	9:33	8.7		Wading
55WBLS-17.7	6/16/2015	15:55	16:16	13		Wading
55WBLS-17.7	7/21/2015	16:10	16:22	0.14		Wading
55WBLS-17.7	8/18/2015	16:10	16:27	4.1		Wading
55WBLS-17.7	9/23/2015	8:47	9:09	2.2		Wading
55WBLS-17.7 (QC)	9/23/2015	9:09	9:30	2.1		Wading
55WBLS-17.7	10/20/2015	14:30	14:45	3		Wading
55WBLS-17.7	11/17/2015	15:25	15:48	10		Wading
55WBLS-17.7	1/20/2016	9:13	9:43	13		Wading
55WBLS-17.7	2/17/2016	11:42		34		Rating curve
55WBLS-17.7	2/23/2016	9:51	10:21	62		Wading
55WBLS-17.7	3/17/2016	10:45	11:08	71		Wading
55BUC-00.3	2/18/2015	10:36	10:58	23		Wading
55BUC-00.3	3/18/2015	9:45		15		Wading
55BUC-00.3	4/22/2015	9:43	10:08	10		Wading
55BUC-00.3 (QC)	4/22/2015	10:09	10:31	10		Wading
55BUC-00.3	5/20/2015	10:55	11:17	4.8		Wading
55BUC-00.3	6/17/2015	10:58	11:21	3.7		Wading
55BUC-00.3	7/22/2015	9:50	10:05	0.7		Wading
55BUC-00.3	8/19/2015	10:15	10:30	0.39		Wading
55BUC-00.3	9/23/2015	10:49	11:05	0.56		Wading
55BUC-00.3	10/21/2015	10:13	10:27	0.9		Wading
55BUC-00.3	11/19/2015	17:15		2.7	J	Rating curve
55BUC-00.3	1/20/2016	11:07	11:25	11		Wading
55BUC-00.3 (QC)	1/20/2016	11:26	11:44	11		Wading
55BUC-00.3	2/23/2016	12:40	13:12	47		Wading
55BUC-00.3	3/17/2016	12:17	12:44	76		Wading
55WBLS-11.1	2/18/2015	12:45	13:17	102		Wading
55WBLS-11.1 (QC)	2/18/2015	13:17	13:48	96		Wading
55WBLS-11.1	3/18/2015	11:24	11:57	65		Wading
55WBLS-11.1	4/22/2015	11:51	12:21	42		Wading
55WBLS-11.1	5/20/2015	12:23	12:45	17		Wading
55WBLS-11.1	6/17/2015	12:37	13:01	18		Wading
55WBLS-11.1	7/22/2015	11:16	11:32	1.6		Wading
55WBLS-11.1	8/19/2015	11:40	11:58	1.2		Wading
55WBLS-11.1 (QC)	8/19/2015	11:58	12:13	1.1		Wading
55WBLS-11.1	9/23/2015	12:03	12:30	1.9		Wading
55WBLS-11.1	10/21/2015	11:29	11:45	2.9		Wading
55WBLS-11.1	11/19/2015	16:06		20	J	Rating curve
55WBLS-11.1	1/20/2016	13:08	13:51	36		Wading
55WBLS-11.1	2/23/2016	15:03	15:47	153		Wading
55WBLS-11.1	3/17/2016	14:05	14:49	204		Wading
55BEAV-00.5	2/18/2015	11:41	12:02	8.5		Wading
55BEAV-00.5	3/18/2015	10:24	10:43	4.8		Wading
55BEAV-00.5	4/22/2015	10:49	11:02	3.2		Wading
55BEAV-00.5	5/20/2015	11:34	11:49	0.85		Wading
55BEAV-00.5	6/17/2015	11:42	11:55	0.46		Wading
55BEAV-00.5	7/22/2015	10:20	10:30	0.16		Wading
55BEAV-00.5	8/19/2015	10:46	10:55	0.11		Wading
55BEAV-00.5	9/23/2015	11:20	11:31	0.14		Wading
55BEAV-00.5	10/21/2015	10:44	10:54	0.15		Wading
55BEAV-00.5	11/19/2015	16:53		2.4	J	Rating curve
55BEAV-00.5	1/20/2016	12:08	12:30	4.2		Wading
55BEAV-00.5	2/23/2016	13:31	13:57	27		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55BEAV-00.5 (QC)	2/23/2016	13:59	14:24	26		Wading
55BEAV-00.5	3/17/2016	13:00	13:26	34		Wading
55WBLS-07.7	2/18/2015	9:36	9:56	111		Wading
55WBLS-07.7	3/18/2015	8:45	9:09	68		Wading
55WBLS-07.7	4/22/2015	8:56	9:10	47		Wading
55WBLS-07.7	5/19/2015	10:01	10:25	19		Wading
55WBLS-07.7	6/17/2015	9:43	10:03	21		Wading
55WBLS-07.7 (QC)	6/17/2015	10:03	10:22	22		Wading
55WBLS-07.7	7/22/2015	8:58	9:19	3.1		Wading
55WBLS-07.7	8/19/2015	9:14	9:42	2.5		Wading
55WBLS-07.7	9/23/2015	9:39	10:19	3.6		Wading
55WBLS-07.7	10/21/2015	9:20	9:45	4.4		Wading
55WBLS-07.7	11/19/2015	15:08		23	J	Rating curve
55WBLS-07.7	1/20/2016	10:08	10:37	42		Wading
55WBLS-07.7	2/23/2016	11:08	11:52	198		Wading
55FAN-00.3	6/3/2015	11:11		0.47		Culvert
55FAN-00.3	3/17/2016	11:45	11:51	15		Culvert
55WBLS-03.1	2/18/2015	14:52	15:36	140		Wading
55WBLS-03.1	3/4/2015	10:05	10:30	71		Wading
55WBLS-03.1	3/18/2015	12:48	13:17	61		Wading
55WBLS-03.1 (QC)	3/18/2015	13:17	13:44	62		Wading
55WBLS-03.1	4/8/2015	12:12	12:45	67		Wading
55WBLS-03.1	4/20/2015	11:30		28		ADCP
55WBLS-03.1	4/22/2015	13:24	13:52	53		Wading
55WBLS-03.1	5/6/2015	11:15		37		Wading
55WBLS-03.1	5/6/2015	12:18	12:59	37		Wading
55WBLS-03.1	5/20/2015	13:33	13:46	24		Wading
55WBLS-03.1 (QC)	5/20/2015	13:46	13:57	21		Wading
55WBLS-03.1	6/2/2015	10:15		25		ADCP
55WBLS-03.1	6/17/2015	13:59	14:16	18		Wading
55WBLS-03.1	7/9/2015	11:30		5.4		Wading
55WBLS-03.1	7/22/2015	12:26	12:41	3.1		Wading
55WBLS-03.1 (QC)	7/22/2015	12:44	12:59	3.4		Wading
55WBLS-03.1	8/4/2015	13:05	13:30	2		Wading
55WBLS-03.1	8/20/2015	11:30		1.2		Wading
55WBLS-03.1	9/23/2015	13:25	13:52	4		Wading
55WBLS-03.1	10/8/2015	11:15		5.3		Wading
55WBLS-03.1	10/21/2015	12:36	12:50	5.5		Wading
55WBLS-03.1 (QC)	10/21/2015	12:50	13:03	5.5		Wading
55WBLS-03.1	11/19/2015	13:06	13:19	24		Wading
55WBLS-03.1	12/1/2015	12:15		20		ADCP
55WBLS-03.1	1/5/2016	12:45	13:10	36		Wading
55WBLS-03.1	1/13/2016	12:30		37		ADCP
55WBLS-03.1	1/20/2016	14:43	15:16	43		Wading
55WBLS-03.1	2/22/2016	10:00		183		ADCP
55WBLS-03.1	3/16/2016	9:15		315		ADCP
55WBLS-03.1	4/7/2016	11:30		173		ADCP
55BEAR-03.7	10/18/2015			2.2		Wading
55BEAR-03.7	4/6/2016	10:28	10:48	4.7		Wading
55BEAR-00.4	2/17/2015	10:14	10:32	6.6		Wading
55BEAR-00.4	3/4/2015	12:55		3.4	J	Rating curve
55BEAR-00.4	3/17/2015	9:35	10:00	7.2		Wading
55BEAR-00.4	4/8/2015	10:18		4.8	J	Rating curve
55BEAR-00.4	4/21/2015	10:18	10:39	3.6		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55BEAR-00.4	5/6/2015			2.5	J	Rating curve
55BEAR-00.4	5/19/2015	11:02	11:23	1.7		Wading
55BEAR-00.4	6/3/2015	9:37		3.6	J	Rating curve
55BEAR-00.4	6/16/2015	9:50	10:13	0.82		Wading
55BEAR-00.4 (QC)	6/16/2015	10:15	10:35	0.82		Wading
55BEAR-00.4	7/8/2015	10:20		0.54	J	Rating curve
55BEAR-00.4	7/21/2015	10:03	10:22	0.33		Wading
55BEAR-00.4	8/18/2015	10:07	10:24	0.3		Wading
55BEAR-00.4	9/9/2015	10:11		0.56	J	Rating curve
55BEAR-00.4	9/22/2015	9:30		1		Wading
55BEAR-00.4	10/7/2015	10:12		1.2	J	Rating curve
55BEAR-00.4	10/20/2015	9:43	10:03	2		Wading
55BEAR-00.4	11/5/2015	9:58		2.2	J	Rating curve
55BEAR-00.4	11/17/2015	9:36	9:55	3.2		Wading
55BEAR-00.4	12/11/2015	10:35		7.9	J	Rating curve
55BEAR-00.4	1/19/2016	9:56	10:19	7.6		Wading
55BEAR-00.4	2/3/2016	11:02		7.7	J	Rating curve
55BEAR-00.4	2/17/2016	10:23		6.6	J	Rating curve
55BEAR-00.4	2/22/2016	10:21	10:50	9.3		Wading
55BEAR-00.4 (QC)	2/22/2016	10:51	11:12	9.3		Wading
55BEAR-00.4	3/16/2016	10:32	10:54	11		Wading
55BEAR-00.4	4/6/2016	10:15		6.4	J	Rating curve
55DEE-05.9	2/17/2015	14:55	15:15	12		Wading
55DEE-05.9	3/17/2015	15:18	15:39	9.3		Wading
55DEE-05.9	5/19/2015	14:33	14:53	3.6		Wading
55DEE-05.9	6/16/2015	15:20	15:40	1.6		Wading
55DEE-05.9	7/21/2015	15:22	15:35	0.3		Wading
55DEE-05.9	8/18/2015	15:08	15:22	0.21		Wading
55DEE-05.9 (QC)	8/18/2015	15:22	15:34	0.20		Wading
55DEE-05.9	9/22/2015	14:49	15:02	0.43		Wading
55DEE-05.9	10/20/2015	14:51	15:05	0.95		Wading
55DEE-05.9	11/17/2015	14:25	14:41	1.8		Wading
55DEE-05.9	1/19/2016	15:28	15:50	5.6		Wading
55DEE-05.9	2/22/2016	14:50	15:13	36		Wading
55DEE-05.9	3/16/2016	13:23	14:20	40		Wading
55LDR-00.1	2/17/2015	15:20	15:42	9.7		Wading
55LDR-00.1	3/17/2015	15:42	16:04	7.7		Wading
55LDR-00.1	5/19/2015	15:02	15:18	1.8		Wading
55LDR-00.1	6/16/2015	15:50		0.83		Wading
55LDR-00.1	7/21/2015	15:40		0		Observed dry
55LDR-00.1	8/18/2015	15:23		0		Observed dry
55LDR-00.1	9/22/2015	15:03		0		Observed dry
55LDR-00.1	10/20/2015	15:09	15:23	0.12		Wading
55LDR-00.1	11/17/2015	14:50	15:03	0.68		Wading
55LDR-00.1 (QC)	11/17/2015	15:03		0.65		Wading
55LDR-00.1	1/19/2016	15:53	16:15	4.5		Wading
55LDR-00.1	2/22/2016	15:16	15:36	19		Wading
55LDR-00.1	3/16/2016	14:24	14:55	26		Wading
55DEE-03.2	10/14/2015	12:19	12:40	0.52		Wading
55DEE-03.2	4/5/2016	14:48	15:25	38		Wading
55DEE-00.1	2/17/2015	8:42		24	J	Rating curve
55DEE-00.1	3/17/2015	7:58		22	J	Rating curve
55DEE-00.1	4/8/2015	9:55		21	J	Rating curve
55DEE-00.1	4/21/2015	8:26	8:44	16		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55DEE-00.1 (QC)	4/21/2015	8:44		17		Wading
55DEE-00.1	5/19/2015	8:58	9:19	6.4		Wading
55DEE-00.1	6/16/2015	8:19	8:36	2.2		Wading
55DEE-00.1	7/8/2015	10:00		0.19	J	Rating curve
55DEE-00.1	7/21/2015	8:51	9:06	0.17		Wading
55DEE-00.1	8/4/2015	10:42		0.07	J	Rating curve
55DEE-00.1	8/18/2015	8:44	8:54	0.07	J	Wading
55DEE-00.1	9/9/2015	9:43		0.04	J	Rating curve
55DEE-00.1	9/22/2015	8:20	8:32	0.06	J	Wading
55DEE-00.1	10/7/2015	9:55		0.05	J	Rating curve
55DEE-00.1	10/20/2015	8:24	8:33	0.06	J	Wading
55DEE-00.1	11/5/2015	9:42		0.05	J	Rating curve
55DEE-00.1	12/11/2015	10:17		6.7	J	Rating curve
55DEE-00.1	12/14/2015	9:07	9:25	3.9		Wading
55DEE-00.1	1/5/2016	10:20		0.25	J	Rating curve
55DEE-00.1	1/19/2016	8:36	8:50	6.4		Wading
55DEE-00.1	1/29/2016	10:49	11:37	61		Wading
55DEE-00.1	2/3/2016	10:08	10:36	18		Wading
55DEE-00.1	2/22/2016	9:13	9:44	51		Wading
55DEE-00.1	3/1/2016	14:40		21	J	Rating curve
55DEE-00.1	3/16/2016	9:07	9:51	65		Wading
55DEE-00.1	4/5/2016	15:40		36	J	Rating curve
55DEE-00.1	5/20/2016	14:00		5.2	J	Rating curve
55DRA-17.0	2/17/2015	11:42	12:04	16		Wading
55DRA-17.0	3/4/2015	11:50		3.9	J	Rating curve
55DRA-17.0	3/17/2015	11:34	11:53	16		Wading
55DRA-17.0	4/8/2015	13:14		9.1	J	Rating curve
55DRA-17.0	4/21/2015	11:31		5.3	J	Rating curve
55DRA-17.0	5/6/2015			3.4	J	Rating curve
55DRA-17.0	5/19/2015	10:54	11:15	2.7		Wading
55DRA-17.0	6/3/2015	12:03		5.9	J	Rating curve
55DRA-17.0	6/16/2015	12:28		2.3		Wading
55DRA-17.0	7/8/2015	12:34		1.4	J	Rating curve
55DRA-17.0	7/21/2015	11:30	11:53	0.58		Wading
55DRA-17.0	8/4/2015	12:55		0.2	J	Rating curve
55DRA-17.0	8/18/2015	11:29	11:48	0.3		Wading
55DRA-17.0	9/9/2015	12:27		0.26	J	Rating curve
55DRA-17.0	9/22/2015	11:28	11:46	1.4		Wading
55DRA-17.0	10/7/2015	13:03		1.2	J	Rating curve
55DRA-17.0	10/20/2015	11:47	12:06	1.1		Wading
55DRA-17.0	11/5/2015	12:03		1.4	J	Rating curve
55DRA-17.0	11/17/2015	11:29	11:49	2.6		Wading
55DRA-17.0	12/11/2015	13:18		11	J	Rating curve
55DRA-17.0	1/19/2016	11:50	12:07	11		Wading
55DRA-17.0	2/3/2016	13:26		22	J	Rating curve
55DRA-17.0	2/17/2016	12:38		54	J	Rating curve
55DRA-17.0	2/22/2016	12:10	12:36	44		Wading
55DRA-17.0	3/16/2016	13:20	13:28	83		ADCP
55SPR-00.4	2/17/2015	12:25	12:43	4.2		Wading
55SPR-00.4	3/4/2015	11:40		3.7		Rating curve
55SPR-00.4	3/17/2015	12:15	12:32	4.4		Wading
55SPR-00.4	4/8/2015	13:09		3.7		Rating curve
55SPR-00.4	4/21/2015	12:21		3.6		Rating curve
55SPR-00.4	5/6/2015			3.4		Rating curve

Location ID	Date	Start time	End time	Flow (cfs)		Method
55SPR-00.4	5/19/2015	11:31	11:51	3.6		Wading
55SPR-00.4	6/3/2015	12:01		3.6		Rating curve
55SPR-00.4	6/16/2015	11:40		2.6		Wading
55SPR-00.4	7/8/2015	12:29		2.5		Rating curve
55SPR-00.4	7/21/2015	12:20	12:45	2.3		Wading
55SPR-00.4 (QC)	7/21/2015	12:45	13:00	2.4		Wading
55SPR-00.4	8/4/2015	12:50		1.7		Rating curve
55SPR-00.4	8/18/2015	12:12	12:32	2		Wading
55SPR-00.4	9/9/2015	12:19		2.2		Rating curve
55SPR-00.4	9/22/2015	12:04	12:18	2.1		Wading
55SPR-00.4 (QC)	9/22/2015	12:19	12:33	2.2		Wading
55SPR-00.4	10/20/2015	12:24	12:45	2.2		Wading
55SPR-00.4	11/17/2015	12:10	12:30	3.4		Wading
55SPR-00.4	1/5/2016	13:38		2.7		Rating curve
55SPR-00.4	1/19/2016	12:24	12:40	3.6		Wading
55SPR-00.4	2/3/2016	13:18		3.7		Rating curve
55SPR-00.4	2/17/2016	12:32		6.2		Rating curve
55SPR-00.4	2/22/2016	13:05	13:26	5.6		Wading
55SPR-00.4	3/16/2016	11:50	12:11	8		Wading
55DRA-16.4	2/17/2015	10:46	11:16	22		Wading
55DRA-16.4	3/4/2015	12:00		11	J	Rating curve
55DRA-16.4	3/17/2015	10:38	11:06	23		Wading
55DRA-16.4	4/8/2015	13:19		19	J	Rating curve
55DRA-16.4	4/21/2015	10:44	11:06	11		Wading
55DRA-16.4	5/6/2015			6.6	J	Rating curve
55DRA-16.4	5/19/2015	10:09	10:28	8.4		Wading
55DRA-16.4	6/3/2015	12:09		14	J	Rating curve
55DRA-16.4	6/16/2015	11:05	11:23	5.1		Wading
55DRA-16.4	7/8/2015	12:39		4.3	J	Rating curve
55DRA-16.4	7/21/2015	10:35	10:52	3.2		Wading
55DRA-16.4	8/4/2015	13:00		2.8	J	Rating curve
55DRA-16.4	8/18/2015	10:55	11:12	2.5		Wading
55DRA-16.4	9/9/2015	12:36		3.1	J	Rating curve
55DRA-16.4	9/22/2015	10:45	11:02	3.8		Wading
55DRA-16.4	10/7/2015	13:07		4.2	J	Rating curve
55DRA-16.4	10/20/2015	10:49	11:10	3.9		Wading
55DRA-16.4 (QC)	10/20/2015	11:10	11:27	3.8		Wading
55DRA-16.4	11/5/2015	12:10		4.5	J	Rating curve
55DRA-16.4	11/17/2015	10:48	11:09	6		Wading
55DRA-16.4	12/11/2015	13:24		18	J	Rating curve
55DRA-16.4	1/5/2016	13:50		7.3	J	Rating curve
55DRA-16.4	1/19/2016	11:15	11:35	16		Wading
55DRA-16.4	2/3/2016	13:32		30	J	Rating curve
55DRA-16.4	2/17/2016	12:41		72	J	Rating curve
55DRA-16.4	2/22/2016	11:30	11:48	72		Wading
55DRA-16.4	3/16/2016	10:57	11:17	94		Wading
55BEAV2-00.1	9/23/2015	15:25	15:43	0.76		Wading
55DRA-13.2	2/17/2015	10:05	10:24	30		Wading
55DRA-13.2	3/17/2015	9:42	10:05	34		Wading
55DRA-13.2	4/21/2015	10:05	10:24	15		Wading
55DRA-13.2	5/12/2015	13:09	13:25	11		Wading
55DRA-13.2	5/19/2015	9:33	9:49	9.8		Wading
55DRA-13.2	6/16/2015	10:22	10:42	6.7		Wading
55DRA-13.2	7/21/2015	9:53	10:13	4.3		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55DRA-13.2	8/18/2015	10:17	10:37	3.4		Wading
55DRA-13.2	9/22/2015	10:06	10:25	4.8		Wading
55DRA-13.2	10/20/2015	10:12	10:27	5.4		Wading
55DRA-13.2	11/17/2015	10:08	10:27	7.6		Wading
55DRA-13.2	1/19/2016	10:43	11:00	23		Wading
55DRA-13.2	2/22/2016	10:36	11:06	72		Wading
55DRA-13.2	3/16/2016	10:05	10:37	100		Wading
55WBDR-00.1	2/17/2015	9:05	9:30	13		Wading
55WBDR-00.1	3/4/2015	12:10		9.2	J	Rating curve
55WBDR-00.1	3/17/2015	8:47	9:08	21		Wading
55WBDR-00.1 (QC)	3/17/2015	9:08	9:30	21		Wading
55WBDR-00.1	4/8/2015	13:28		14	J	Rating curve
55WBDR-00.1	4/21/2015	9:28	9:43	8.2		Wading
55WBDR-00.1	5/6/2015			5.8	J	Rating curve
55WBDR-00.1	5/19/2015	8:49	9:07	5.9		Wading
55WBDR-00.1	6/3/2015	12:16		12	J	Rating curve
55WBDR-00.1	6/16/2015	9:12		3.7		Wading
55WBDR-00.1 (QC)	6/16/2015	9:30	9:48	3.7		Wading
55WBDR-00.1	7/8/2015	12:46		3	J	Rating curve
55WBDR-00.1	7/21/2015	9:10	9:35	2.1		Wading
55WBDR-00.1	8/4/2015	14:04		2.2	J	Rating curve
55WBDR-00.1	8/18/2015	9:33	9:53	2.4		Wading
55WBDR-00.1	9/9/2015	12:42		4.4	J	Rating curve
55WBDR-00.1	9/22/2015	9:30	9:53	4		Wading
55WBDR-00.1	10/7/2015	13:15		4.6	J	Rating curve
55WBDR-00.1	10/20/2015	9:31	9:54	5.4		Wading
55WBDR-00.1	11/5/2015	12:16		5.4	J	Rating curve
55WBDR-00.1	11/17/2015	9:30	9:50	8.2		Wading
55WBDR-00.1	12/11/2015	13:34		23	J	Rating curve
55WBDR-00.1	1/19/2016	10:03	10:28	15		Wading
55WBDR-00.1	2/3/2016	13:40		14	J	Rating curve
55WBDR-00.1	2/17/2016	12:50		43	J	Rating curve
55WBDR-00.1	2/22/2016	9:46	10:12	31		Wading
55WBDR-00.1	3/16/2016	9:26	9:54	46		Wading
55MUD-00.7	9/23/2015	14:41	14:54	0.87		Wading
55DRA-05.4	5/14/2015	14:45	15:01	27		Wading
55DRA-05.4	4/6/2016	11:18	11:45	81		Wading
55DRA-04.3	2/17/2015	13:15	13:42	54		Wading
55DRA-04.3	3/4/2015	12:26		33	J	Rating curve
55DRA-04.3	3/17/2015	13:06	13:36	67		Wading
55DRA-04.3	4/8/2015	13:39		42	J	Rating curve
55DRA-04.3	4/21/2015	12:50		32	J	Rating curve
55DRA-04.3	5/6/2015			21	J	Rating curve
55DRA-04.3	5/19/2015	12:30		22		Wading
55DRA-04.3 (QC)	5/19/2015		13:07	23		Wading
55DRA-04.3	6/3/2015	12:26		36	J	Rating curve
55DRA-04.3	6/16/2015	13:31		15		Wading
55DRA-04.3	7/8/2015	12:56		16	J	Rating curve
55DRA-04.3	7/21/2015	13:34	13:51	11		Wading
55DRA-04.3	8/4/2015	14:13		12	J	Rating curve
55DRA-04.3	8/18/2015	13:10	13:32	11		Wading
55DRA-04.3	9/22/2015	13:08	13:26	14		Wading
55DRA-04.3	10/7/2015	13:21		16	J	Rating curve
55DRA-04.3	10/20/2015	13:09	13:30	19		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55DRA-04.3	11/5/2015	12:22		19	J	Rating curve
55DRA-04.3	11/17/2015	12:55		23		Wading
55DRA-04.3	12/11/2015	13:45		47	J	Rating curve
55DRA-04.3	1/19/2016	13:41	14:00	48		Wading
55DRA-04.3	2/3/2016	13:51		51	J	Rating curve
55DRA-04.3	2/17/2016	13:00		123	J	Rating curve
55DRA-04.3	2/22/2016	13:21	13:31	138		ADCP
55DRA-04.3	3/16/2016	14:03	14:10	140		ADCP
55DRA-00.3	2/18/2015	11:34		56		Wading
55DRA-00.3	3/5/2015	11:43		31		Wading
55DRA-00.3	3/17/2015	14:24	14:46	75		Wading
55DRA-00.3	4/21/2015	13:02		32		Wading
55DRA-00.3	5/12/2015	9:38	9:53	24		Wading
55DRA-00.3	5/19/2015	13:43	14:03	23		Wading
55DRA-00.3	6/2/2015	11:23		65		Wading
55DRA-00.3	6/16/2015	14:30	14:46	16		Wading
55DRA-00.3	7/9/2015	11:15		13		Wading
55DRA-00.3	7/21/2015	14:28	14:45	13		Wading
55DRA-00.3	8/18/2015	14:00	14:21	12		Wading
55DRA-00.3	8/20/2015	11:20		11		Wading
55DRA-00.3	9/22/2015	14:00	14:18	14		Wading
55DRA-00.3	10/8/2015	11:15		14		Wading
55DRA-00.3	10/20/2015	14:00	14:20	19		Wading
55DRA-00.3	11/17/2015	13:42	13:56	25		Wading
55DRA-00.3	12/14/2015	9:42	10:10	40		Wading
55DRA-00.3	1/13/2016	11:15		34		Wading
55DRA-00.3	1/19/2016	14:35	14:56	52		Wading
55DRA-00.3	1/29/2016	12:24	13:03	147		Wading
55DRA-00.3	2/22/2016	12:30		137		ADCP
55DRA-00.3	3/16/2016	11:15		158		ADCP
55DRA-00.3	4/7/2016	11:00		86		ADCP
55SFLD-03.0	10/5/2015	12:19	12:32	0.10		Wading
55SFLD-03.0	4/5/2016	13:13	13:46	11		Wading
55SFLD-01.1	2/17/2015	16:10	16:28	5.8		Wading
55SFLD-01.1	3/17/2015	16:35	16:52	4.8		Wading
55SFLD-01.1	5/19/2015	15:50	16:10	1.2		Wading
55SFLD-01.1	6/16/2015	16:26	16:45	0.52		Wading
55SFLD-01.1	7/21/2015	16:10	16:32	0.1	J	Wading
55SFLD-01.1	8/18/2015	15:56	16:12	0.033	J	Wading
55SFLD-01.1	9/22/2015	15:32	15:42	0.1		Wading
55SFLD-01.1	10/20/2015	16:07	16:22	0.23		Wading
55SFLD-01.1	11/17/2015	15:40		1		Wading
55SFLD-01.1	1/20/2016	12:08	12:23	8.1		Wading
55SFLD-01.1	2/23/2016	11:05	11:27	9.9		Wading
55SFLD-01.1 (QC)	2/23/2016	11:30	11:55	11		Wading
55SFLD-01.1	3/16/2016	15:20	15:44	18		Wading
55SFLD-01.1	4/5/2016	14:02	14:28	14		Wading
55LDP-00.1	2/18/2015	12:10	12:33	12		Wading
55LDP-00.1	3/18/2015	12:20	12:40	22		Wading
55LDP-00.1 (QC)	3/18/2015	12:40	13:02	23		Wading
55LDP-00.1	4/22/2015	9:48	10:08	6.5		Wading
55LDP-00.1 (QC)	4/22/2015	10:08	10:25	7		Wading
55LDP-00.1	5/20/2015	10:21	10:43	2		Wading
55LDP-00.1	6/17/2015	12:31	12:44	0.88		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55LDP-00.1	7/22/2015	13:00	13:17	0.92		Wading
55LDP-00.1	8/19/2015	9:50	10:07	0.89		Wading
55LDP-00.1	9/23/2015	12:45	13:00	0.91		Wading
55LDP-00.1	10/21/2015	10:28	10:43	1.1		Wading
55LDP-00.1	11/19/2015	10:01	10:19	0.88		Wading
55LDP-00.1	1/20/2016	10:13	10:31	14		Wading
55LDP-00.1	2/23/2016	14:08	14:35	21		Wading
55LDP-00.1	3/17/2016	9:40	10:01	32		Wading
55DEA-20.2	2/18/2015	9:21	9:55	18		Wading
55DEA-20.2 (QC)	2/18/2015	9:55	10:15	18		Wading
55DEA-20.2	3/18/2015	10:39	11:01	12		Wading
55DEA-20.2	4/22/2015	13:58	14:17	8.7		Wading
55DEA-20.2	5/20/2015	14:01	14:20	4.5		Wading
55DEA-20.2	5/26/2015			4.2		Wading
55DEA-20.2	6/17/2015	9:17	9:36	3		Wading
55DEA-20.2	7/22/2015	9:43	10:05	1.4		Wading
55DEA-20.2 (QC)	7/22/2015	10:06	10:24	1.4		Wading
55DEA-20.2	8/19/2015	12:54	13:16	0.73		Wading
55DEA-20.2	9/23/2015	9:50	10:07	0.61		Wading
55DEA-20.2	10/21/2015	13:23	13:44	0.97		Wading
55DEA-20.2	11/19/2015	11:51	12:10	1.4		Wading
55DEA-20.2	1/20/2016	13:31	13:46	2.9		Wading
55DEA-20.2	2/23/2016	9:35	9:56	11		Wading
55DEA-20.2	3/17/2016	12:50	13:09	24		Wading
55DEA-20.2 (QC)	3/17/2016	13:10	13:30	26		Wading
55DEA-13.8	2/18/2015	10:40	10:58	38		Wading
55DEA-13.8	3/4/2015	13:30		32	J	Rating curve
55DEA-13.8	3/18/2015	9:32	9:54	41		Wading
55DEA-13.8	4/8/2015	9:07		32	J	Rating curve
55DEA-13.8	4/22/2015	13:25		21.5	J	Culvert
55DEA-13.8	5/6/2015			13	J	Rating curve
55DEA-13.8	5/20/2015	13:06	13:24	8.1		Wading
55DEA-13.8	6/3/2015	9:18	9:38	9.5		Wading
55DEA-13.8	6/17/2015	10:13	10:31	4		Wading
55DEA-13.8	7/8/2015	9:21		1.8	J	Rating curve
55DEA-13.8	7/22/2015	11:00	11:18	1.6		Wading
55DEA-13.8	8/4/2015	10:10		0.91	J	Rating curve
55DEA-13.8	8/19/2015	12:08	12:24	0.63		Wading
55DEA-13.8	9/9/2015	9:11		1.2	J	Rating curve
55DEA-13.8	9/23/2015	10:41	11:02	0.82		Wading
55DEA-13.8	10/7/2015	9:15		0.64	J	Rating curve
55DEA-13.8	10/21/2015	12:45	13:05	1.1		Wading
55DEA-13.8	11/5/2015	9:15		1.7	J	Rating curve
55DEA-13.8	11/19/2015	11:25		2.2	J	Rating curve
55DEA-13.8	12/11/2015	9:39		12	J	Rating curve
55DEA-13.8	1/5/2016	9:40		7.7	J	Rating curve
55DEA-13.8	1/20/2016	12:48	13:06	29		Wading
55DEA-13.8	2/3/2016	9:20		19	J	Rating curve
55DEA-13.8	2/17/2016	9:18		53	J	Rating curve
55DEA-13.8	2/23/2016	10:22	10:50	56		Wading
55DEA-13.8	3/17/2016	12:08	12:27	73		Wading
55DEA-09.2	4/22/2015	12:46	13:07	25		Wading
55DEA-09.2	5/21/2015	12:30	12:48	9.6		Wading
55DEA-09.2	6/3/2015	10:07	10:24	14		Wading

Location ID	Date	Start time	End time	Flow (cfs)		Method
55DEA-09.2	2/23/2016	12:00	12:35	57		Wading
55DEA-09.2	3/16/2016	8:59	9:05	111		ADCP
55DEA-05.9	2/18/2015	8:48	8:56	50		ADCP
55DEA-05.9	3/18/2015	10:32	10:46	62		ADCP
55DEA-05.9	4/8/2015	8:51		41	J	Rating curve
55DEA-05.9	4/22/2015	11:42	12:11	28		Wading
55DEA-05.9	5/6/2015			14	J	Rating curve
55DEA-05.9	5/20/2015	11:55	12:12	11		Wading
55DEA-05.9 (QC)	5/20/2015	12:12	12:30	10		Wading
55DEA-05.9	6/3/2015	10:46	11:10	21		Wading
55DEA-05.9	6/17/2015	11:07	11:25	4.9		Wading
55DEA-05.9 (QC)	6/17/2015	11:26	11:42	4.7		Wading
55DEA-05.9	7/8/2015	9:07		1.7	J	Rating curve
55DEA-05.9	7/22/2015	11:51	12:20	1.2		Wading
55DEA-05.9	8/4/2015	9:55		0.57	J	Rating curve
55DEA-05.9	8/19/2015	11:02	11:20	0.39		Wading
55DEA-05.9 (QC)	8/19/2015	11:20	11:36	0.38		Wading
55DEA-05.9	9/9/2015	9:00		1.6	J	Rating curve
55DEA-05.9	9/23/2015	11:24		0.64		Wading
55DEA-05.9	10/7/2015	9:01		1.1	J	Rating curve
55DEA-05.9	10/21/2015	11:33	11:53	1.4		Wading
55DEA-05.9	11/19/2015	10:55		2.7	J	Rating curve
55DEA-05.9	12/11/2015	9:25		17	J	Rating curve
55DEA-05.9	1/20/2016	11:06	11:35	31		Wading
55DEA-05.9	2/3/2016	9:03		49	J	Rating curve
55DEA-05.9	2/17/2016	8:56		68	J	Rating curve
55DEA-05.9	2/22/2016	9:06	9:20	75		ADCP
55DEA-05.9	2/23/2016	12:45		70	J	Rating curve
55DEA-05.9	3/16/2016	9:29	9:37	105		ADCP
55DEA-05.9	3/17/2016	11:15		103	J	Rating curve
55DEA-02.6	4/22/2015	11:01	11:22	29		Wading
55DEA-02.6	6/3/2015	11:32	11:52	26		Wading
55DEA-02.6	2/23/2016	13:15	13:34	71		Wading
55DEA-02.6	3/17/2016	10:30	11:00	98		Wading
55SBD-00.5	1/5/2016	14:39	14:45	0.49		Wading
55SBD-00.5	2/3/2016	14:10	14:25	0.23		Wading
55SBD-00.5	4/7/2016	10:34	10:52	1.6		Wading
55DEA-00.2	3/5/2015	11:00		30		ADCP
55DEA-00.2	4/21/2015	10:00		42		ADCP
55DEA-00.2	6/2/2015	9:35		36		Wading
55DEA-00.2	7/9/2015	10:00		7.7		Wading
55DEA-00.2	8/20/2015	10:19		6.9		Wading
55DEA-00.2	10/8/2015	10:00		6.3		Wading
55DEA-00.2	12/1/2015	11:30		7		ADCP
55DEA-00.2	1/13/2016	11:15		15		ADCP
55DEA-00.2	2/24/2016	11:30		84		ADCP
55DEA-00.2	4/7/2016	9:30		109		ADCP
55DAR-00.2	2/18/2015	13:19	13:35	3.4		Wading
55DAR-00.2	3/18/2015	13:38	13:55	2.4		Wading
55DAR-00.2	4/22/2015	9:15	9:29	2.7		Wading
55DAR-00.2	5/20/2015	8:57	9:13	2.6		Wading
55DAR-00.2	6/17/2015	13:55	14:05	2.8		Wading
55DAR-00.2	7/22/2015	14:49	15:04	2.3		Wading
55DAR-00.2	8/19/2015	8:11	8:26	2.4		Wading

Location ID	Date	Start time	End time	Flow (cfs)	Method
55DAR-00.2	9/23/2015	14:02	14:16	2.6	Wading
55DAR-00.2	10/21/2015	9:00	9:13	2.2	Wading
55DAR-00.2	11/19/2015	9:12	9:29	2.7	Wading
55DAR-00.2	1/20/2016	8:49	9:02	3	Wading
55DAR-00.2	2/23/2016	14:40	14:56	3.4	Wading
55DAR-00.2	3/17/2016	8:45	9:06	5.2	Wading

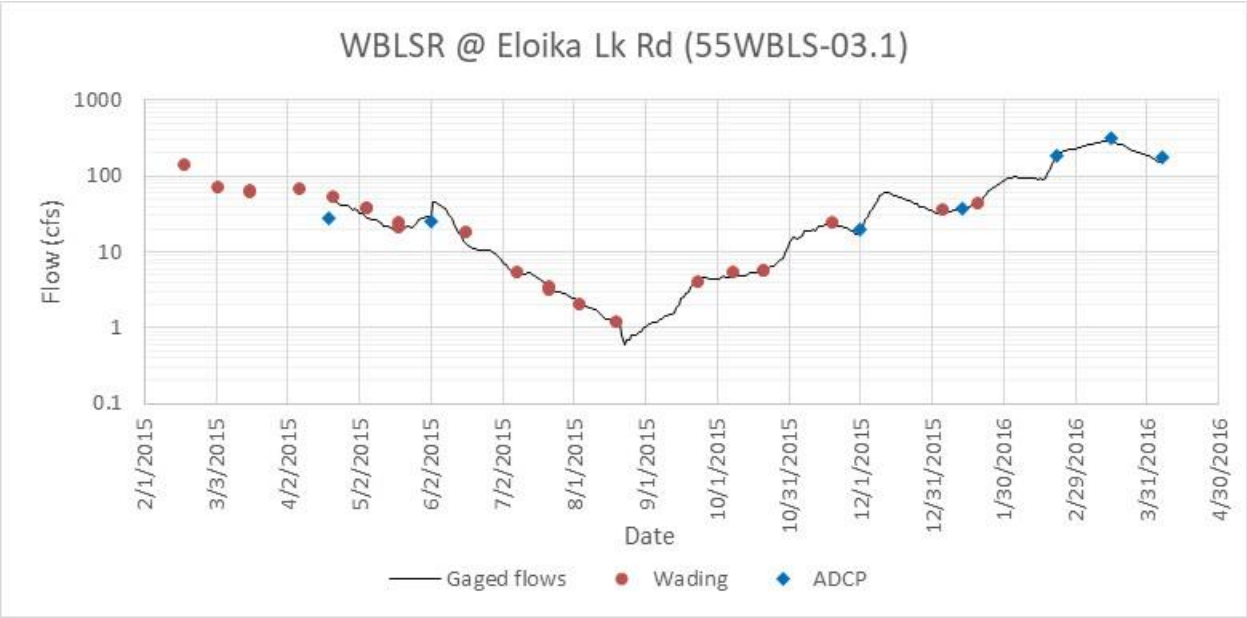


Figure D-1. Continuous and instantaneous flows at West Branch Little Spokane River at Eloika Lake Rd. (55WBLS-03.1) gage station.

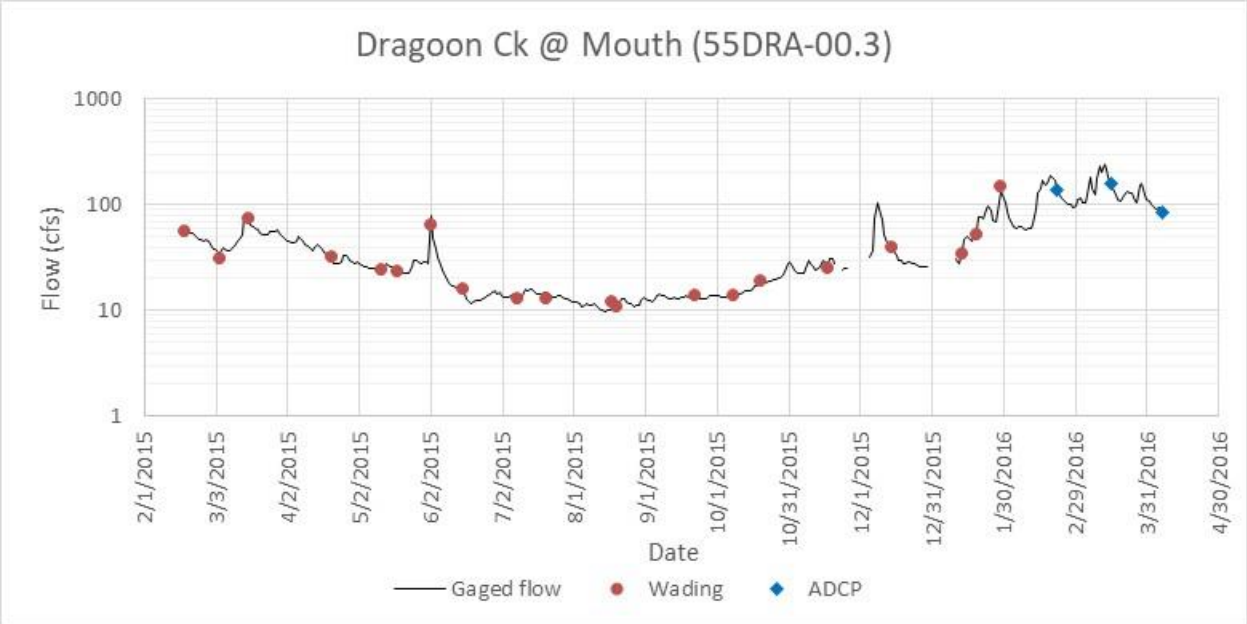


Figure D-2. Continuous and instantaneous flows at Dragoon Creek at Mouth (55DRA-00.3) gage station.

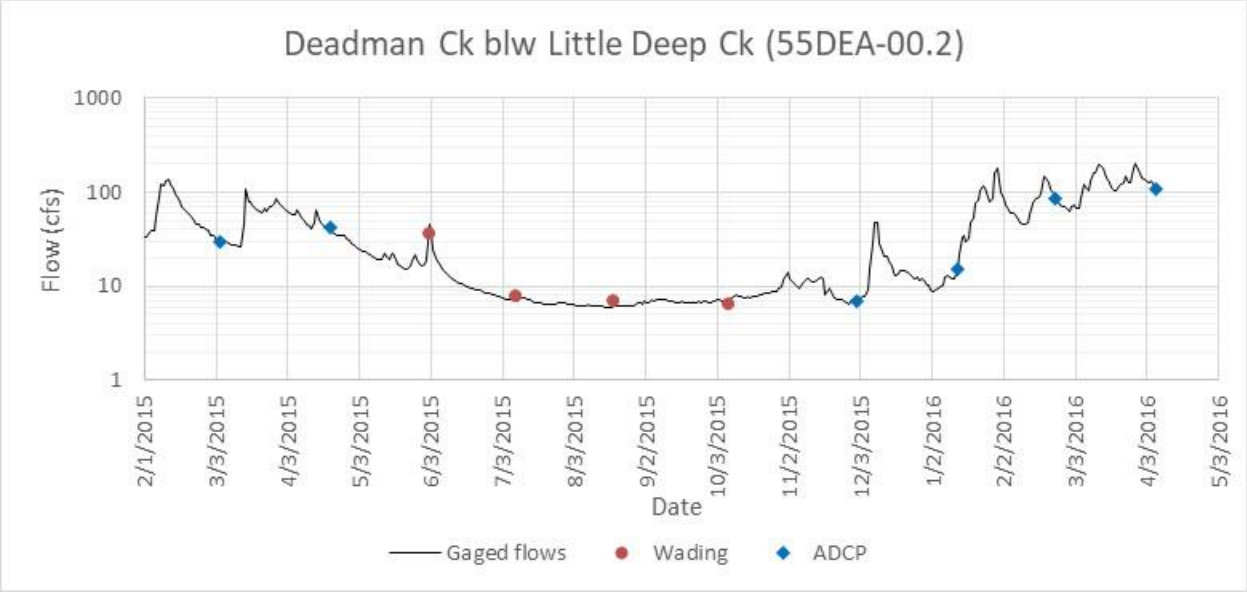


Figure D-3. Continuous and instantaneous flows at Deadman Creek below Little Deep Creek (55DEA-00.2) gage station.

Continuous Hydrolab® Data

Table D-13. Summary of dissolved oxygen and pH results from continuous Hydrolab® data.

Note: This table includes data from 2010 as well as 2013 and 2015.
*For multiple-day deployments, we show the range of daily minimum and maximum. We show values that fail to meet numeric criteria (DO < 9.5 mg/L, pH > 8.5[3]) in **bold**.*

Location ID	Sampling Location	Survey Date	Dissolved Oxygen		pH	
			Min	Max	Min	Max
55LSR-46.7	LSR @ Scotia	Jul 28-30, 2015	**6.45 - 6.82**	12.04 - 12.07	7.53 - 7.55	8.46 - **8.52**
		Aug 25-27, 2015	**6.68 - 6.78**	12.5 - 12.6	7.6 - 7.64	**8.66 - 8.68**
55LSR-39.5	LSR @ Frideger Rd	Jul 26-28, 2010	**3.56 - 3.83**	**9** - 9.79	7.16 - 7.17	7.87 - 8
		Aug 23-25, 2010	**5.47 - 5.73**	10.82 - 10.86	7.6 - 7.61	8.43 - 8.45
		Jul 21-25, 2015	**4.35 - 4.63**	9.81 - 10.09	7.41 - 7.47	8.31 - 8.36
		Aug 18-21, 2015	**4.45 - 4.76**	**8.4 - 9.32**	7.42 - 7.46	7.92 - 8.09
55LSR-37.1	LSR @ Elk	Aug 13-14, 2013	**7.32 J**	**9.47 J**	7.86	
		Jul 21-28, 2015	**7.06 - 7.67**	9.75 - 10.27	7.62 - 7.68	8.53 - **8.66**
		Aug 18-25, 2015	**7.02 - 7.62**	9.79 - 10.32	7.73 - 7.79	8.43 - **8.55**
55LSR-33.2	LSR @ E Eloika Rd	Aug 14-15, 2013	**7.78 - 7.89 J**	9.71 J	7.9	8.39
55LSR-31.8	LSR @ Deer Park-Milan Rd	Jul 26-29, 2010	**6.21 - 6.74**	**9.05** - 9.84	7.76 - 8.04	**8.64 - 8.84**
		Aug 23-26, 2010	**7.12 - 7.45**	10.94 - 11.52	7.52 - 7.56	8.38 - 8.46
		Aug 14-15, 2013	**7.42 J**	**9.46 J**	7.81	8.32
		Jul 21-28, 2015	**6.35 - 7.34**	11 - 11.68	7.71 - 7.81	**8.72 - 8.83**
		Aug 18-25, 2015	**6.97 - 7.74**	10.16 - 11.21	7.77 - 7.85	8.43 - **8.62**
55LSR-23.4	LSR @ Chattaroy	Jul 26-28, 2010	**5.55 - 6.36**	**9.48** - 9.98	7.74 - 7.81	**8.56 - 8.69**
		Aug 23-25, 2010	**7.37 - 7.54**	11.32 - 11.4	8.02 - 8.07	**8.68 - 8.75**
		Aug 14-15, 2013	**6.89 J**	10.28 - 10.4 J	7.98	8.49
		Jul 21-28, 2015	**6.75 - 7.42**	10.52 - 11.74	8.19 - **8.51**	**8.64 - 8.78**
		Aug 18-25, 2015	**6.38 - 7.44**	10.62 - 12.01	7.88 - 8.07	**8.52 - 8.79**
55LSR-19.8	LSR @ Colbert Landfill outfall	Aug 13, 2013	**7.26 J**		7.99	
55LSR-16.0	LSR @ E Colbert Rd	Aug 13, 2013		10.14 J		
55LSR-13.5	LSR @ N LSR Dr	Jul 26-28, 2010	**6.37 - 6.89**	**9.45** - 9.99	7.86 - 7.9	8.49 - **8.57**
		Aug 23-27, 2010	**7.88 - 8.17**	10.65 - 10.95	8.01 - 8.06	**8.56 - 8.57**
		Aug 13-14, 2013	**7.44 J**	10.12 J	7.97	8.48
		Jul 22-28, 2015	**7.13 - 7.79**	10.28 - 10.88	8.02 - 8.13	**8.56 - 8.66**
		Aug 19-25, 2015	**7.2 - 8.06**	10.39 - 11.75	7.98 - 8.02 J	8.43 - **8.55** J
55LSR-11.0	LSR @ Dartford USGS gage	Jul 28-30, 2010	**7.13 - 7.44 J**	**9.32** - 9.91 J	7.64 - 7.73	8.12 - 8.25
		Aug 25-27, 2010	**8.34 - 8.46**	10.2	8.11 - 8.12	8.5
55LSR-03.9	LSR @ Rutter Pkwy (Painted Rocks)	Aug 12, 2013		**9.32 J**		
55LSR-01.1	LSR @ Mouth	Jul 28-30, 2010	**7.89 - 8.32**	9.88 - 10.21	7.85	8.24 - 8.27
		Aug 25-27, 2010	**8.12 - 8.2**	10.03 - 10.08	7.77 - 7.78	8.08 - 8.11
		Aug 12, 2013				8.37
		Jul 22-28, 2015	**7.82 - 8.11**	10.04 - 10.34	8 - 8.06	8.43 - 8.47
		Aug 25-26, 2015	**8.03**	10.72	7.92	8.38
55DRY-00.4	Dry Ck @ Mouth	Jul 26-28, 2010	**9.01 - 9.18**	9.76 - 9.83	8.01	8.19 - 8.2
		Aug 23-25, 2010	9.84 - 9.92	10.47 - 10.74	7.98 - 7.99	8.05 - 8.09
		Jul 28-29, 2015	**9.18**	10.21	8.12	8.22
		Aug 25-26, 2015	**8.93**	9.77	8.21	8.29
55OTT-01.4	Otter Ck @ 2nd Valley Rd xing	Jul 28-29, 2015	**8.95**	10.54	7.93	8.2
		Aug 25-26, 2015	**8.67**	9.76	7.72	7.93
55OTT-00.3	Otter Ck @ Mouth	Jul 26-28, 2010	**8.94 - 9.26**	9.8 - 9.98	8.01	8.2 - 8.24
		Aug 23-25, 2010	9.86 - 9.93	10.54 - 10.73	7.53 - 7.62	7.87
		Jul 28-29, 2015	9.79	10.46	8	8.39
		Aug 25-26, 2015	9.81	10.47	7.97	8.25
55MOO-02.9	Moon Ck @ Hwy 211	Jul 28-29, 2015	**8.57**		7.36	7.6
		Aug 25-26, 2015	**8.45**	9.6	7.35	7.61
55WBLS-17.7	WBLSR @ Harworth Rd.	Jul 28-29, 2015	**3.87**	**6.69**	6.6	
		Aug 25-27, 2015	**5.57 - 5.77**	**6.55 - 6.65**	6.6 - 6.63	6.7
55BUC-00.3	Buck Ck @ Mouth	Jul 29-30, 2015	**8.16**	**8.96**	7.24	7.49
		Aug 26, 2015	**7.48**	**9.17**	7.23	

[3] pH values below 6.5 would also fail to meet criteria, however we did not observe any pH values less than 6.5 during this project.

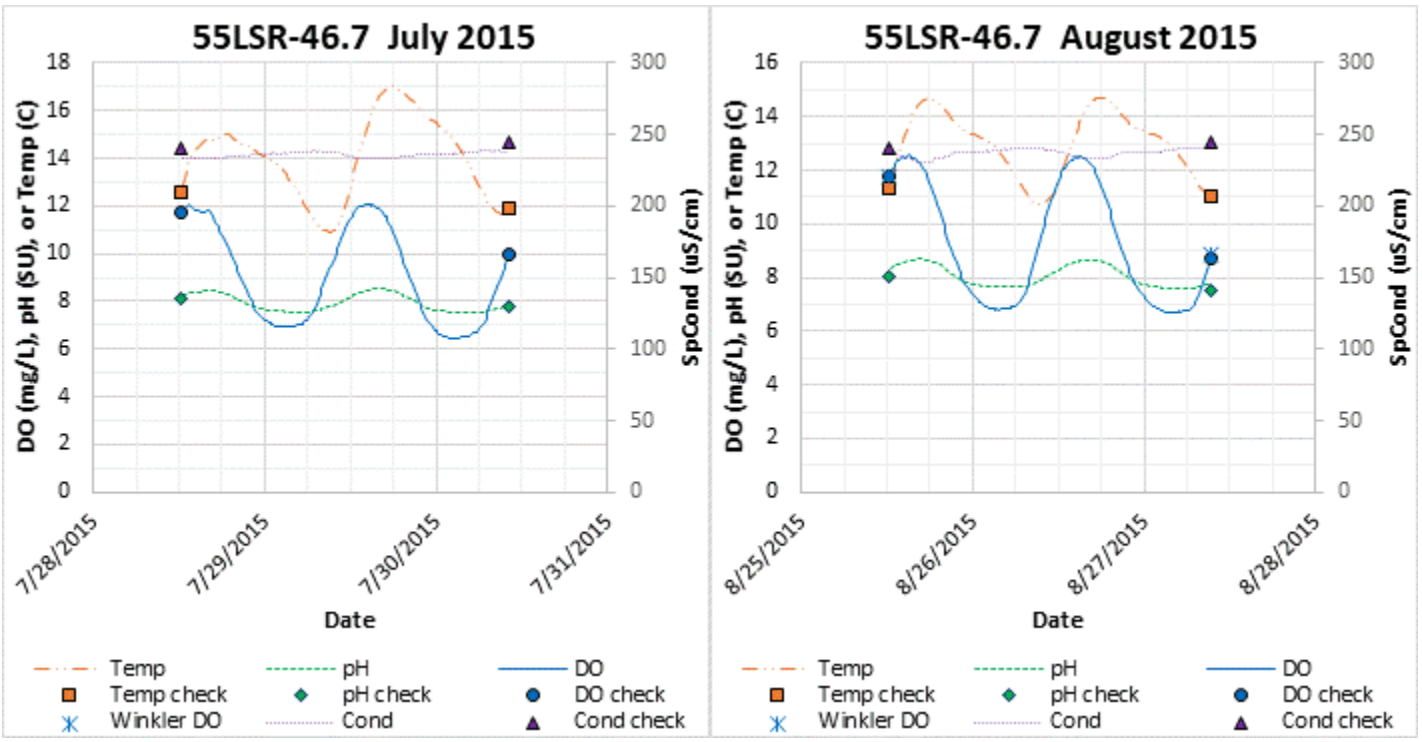
Location ID	Sampling Location	Survey Date	Dissolved Oxygen		pH	
			Min	Max	Min	Max
55WBLS-07.7	WBLSR @ Fan Lk Rd	Jul 29-30, 2015	**9.29**	10.95	7.73	8.19
		Aug 25-27, 2015	**9.07 - 9.24**	10.05 - 10.13	7.72 - 7.73	7.91
55WBLS-03.1	WBLSR @ Eloika Lk Rd	Jul 29-30, 2015	**4.87**	10.2	6.8	7.99
		Aug 26-27, 2015	**1.59**	10.36	6.69	7.47
55BEAR-00.4	Bear Ck @ Mouth	Jul 28-29, 2015	**8.67**	9.55	8.13	8.22
		Aug 25-26, 2015	**8.59**	9.58	8.15	8.33
55DEE-05.9	Deer Ck abv Little Deer Ck	Jul 21-27, 2015	**6.94 - 8.1**	**8.08 - 8.77**	7.29 - 7.46	7.46 - 7.65
		Aug 18-24, 2015	**6.28 - 6.66**	**7.68 - 8.68**	7.1 - 7.2	7.33 - 7.48
55DEE-01.4	Deer Ck @ Elk-Chattaroy Rd	Jul 28-29, 2015	**8.09**	**9.39** - 9.55	7.7	8.03
55DEE-00.1	Deer Ck @ Mouth	Jul 27-28, 2010			7.17 - 7.21	7.42
		Aug 23-25, 2010	**8.81 - 8.89**	10.23 - 10.47	7.49	7.66
		Jul 28-29, 2015	**8.8**	10.48	7.95	**8.58**
		Aug 25-26, 2015	**8.81**	10.14	7.94	8.33
55DRA-19.6	Dragoon Ck @ Mongomery Rd	Aug 26-28, 2015	**5.98 - 6.41**	**8.83 - 9.31**	7.54	7.72 - 7.79
55DRA-17.0	Dragoon Ck @ Dahl Rd	Jul 30, 2015	**3.26**	**4.24**	7.23	7.28
		Aug 26-28, 2015	**2.26 - 2.47**	**4.2**	7.12	7.19
55SPR-00.4	Spring Ck @ Spring Ck Rd	Jul 29-31, 2015	**5.82 - 5.92**	**8.83**	7.35	7.53 - 7.54
		Aug 26-28, 2015	**5.45 - 5.55**	**8.99 - 9.12**	7.06 - 7.07	7.29 - 7.31
55DRA-16.4	Dragoon Ck @ Hwy 395 nr Deer Park	Jul 29-31, 2015	**6.02 - 6.23**	**8.67 - 8.68**	7.49 - 7.5	7.68
		Aug 26-28, 2015	**6.09 - 6.19**	**9.43 - 9.49**	7.45 - 7.46	7.69 - 7.71
55DRA-13.2	Dragoon Ck abv WB Dragoon Ck	Jul 29-31, 2015	**6.98 - 7.21**	10.38 - 10.63	7.74 - 7.76	8.16 - 8.18
		Aug 26-28, 2015	**6.96 - 7.03**	10.81 - 10.92	7.8 - 7.83	8.35 - 8.36
55WBDR-00.1	WB Dragoon Ck @ Mouth	Jul 29-31, 2015	**7.92 - 8.16**	9.7	7.94	8.31
		Aug 26-28, 2015	**8.05 - 8.16**	10.28	7.75	8.16 - 8.17
55DRA-04.3	Dragoon Ck @ North Rd	Jul 29-31, 2015	**6.53 - 6.81**	12.19 - 12.37	7.85 - 7.87	**8.54 - 8.56**
		Aug 26-28, 2015	**7.2 - 7.22**	12.17 - 12.23	7.82 - 7.84	**8.56 - 8.61**
55DRA-00.3	Dragoon Ck @ Mouth	Jul 28-30, 2010	**8.24 - 8.5**	**9.33**	8.12	8.46 - 8.47
		Aug 25-27, 2010	**8.87 - 8.89**	10	8.12 - 8.17	8.32 - 8.38
		Jul 29-31, 2015	**8.01 - 8.27**	9.61	8.15 - 8.16	8.48
55SFLD-01.1	SF Little Deep Ck @ Day-Mt Spokane Rd	Jul 28-29, 2015	**8.52**	**9.46**	7.03	7.24
		Aug 25, 2015	**7.68**	**9.32**	7.3	
55LDP-00.1	Little Deep Ck @ Shady Slope Rd	Jul 28-29, 2015	**8.65**	10.34	8.2	8.42
		Aug 25-26, 2015	**8.42**	10.19	8.09	8.33
55LDP-00.0	Little Deep Ck @ Mouth	Jul 28-29, 2010	**7.73 - 7.87**	**9.15**	8.18	8.4 - 8.43
		Aug 25-26, 2010	**8.49 - 8.53**	10.73	8.25	8.45 - **8.52**
55DEA-20.2	Deadman Ck @ Park Bdy	Aug 27-28, 2015	**8.43**	**9.19**	7.13	7.36
55DEA-13.8	Deadman Ck @ Holcomb Rd	Jul 30-31, 2015	**7.41**	**9.01**	7.03	7.33
		Aug 27-28, 2015	**7.36**	**8.78**	6.98 J	
55DEA-09.2	Deadman Ck @ Heglar Rd	Jul 30-31, 2015	**7.03**	**8.84**	7.47	
		Aug 27-28, 2015	**6.59**	10.12	7.47	8.35
55DEA-05.9	Deadman Ck @ Bruce Rd	Jul 30-31, 2015	**5.09**	**6.01**		
		Aug 27-28, 2015	**4.89**	**5.91**	7.14	7.23
55DEA-00.6	Deadman Ck @ Shady Slope Rd	Jul 30-31, 2015	**8.96**	10.21	8	8.28
		Aug 27-28, 2015	**9.02**	9.93	8.03	8.23
55DEA-00.2	Deadman Ck blw Little Deep Ck	Jul 28-30, 2010	**8.19 - 8.27**	**9.02**	8.05 - 8.06	8.3 - 8.31
		Aug 25-26, 2010	**8.94 - 8.95**	10.31	8.05 - 8.06	8.27 - 8.33
55DAR-00.2	Dartford Ck @ Mouth	Jul 29-30, 2010	9.91 J	10.42 - 10.8 J	8.32 - 8.35	8.44
		Aug 25-27, 2010	9.58	9.96 - 10.34	8.41 - 8.47	8.44 - **8.55**
		Aug 25-26, 2015	**9.23**	10.04	8.38	**8.54**

J = value qualified as an estimate. (See Appendix E, “Data quality”)

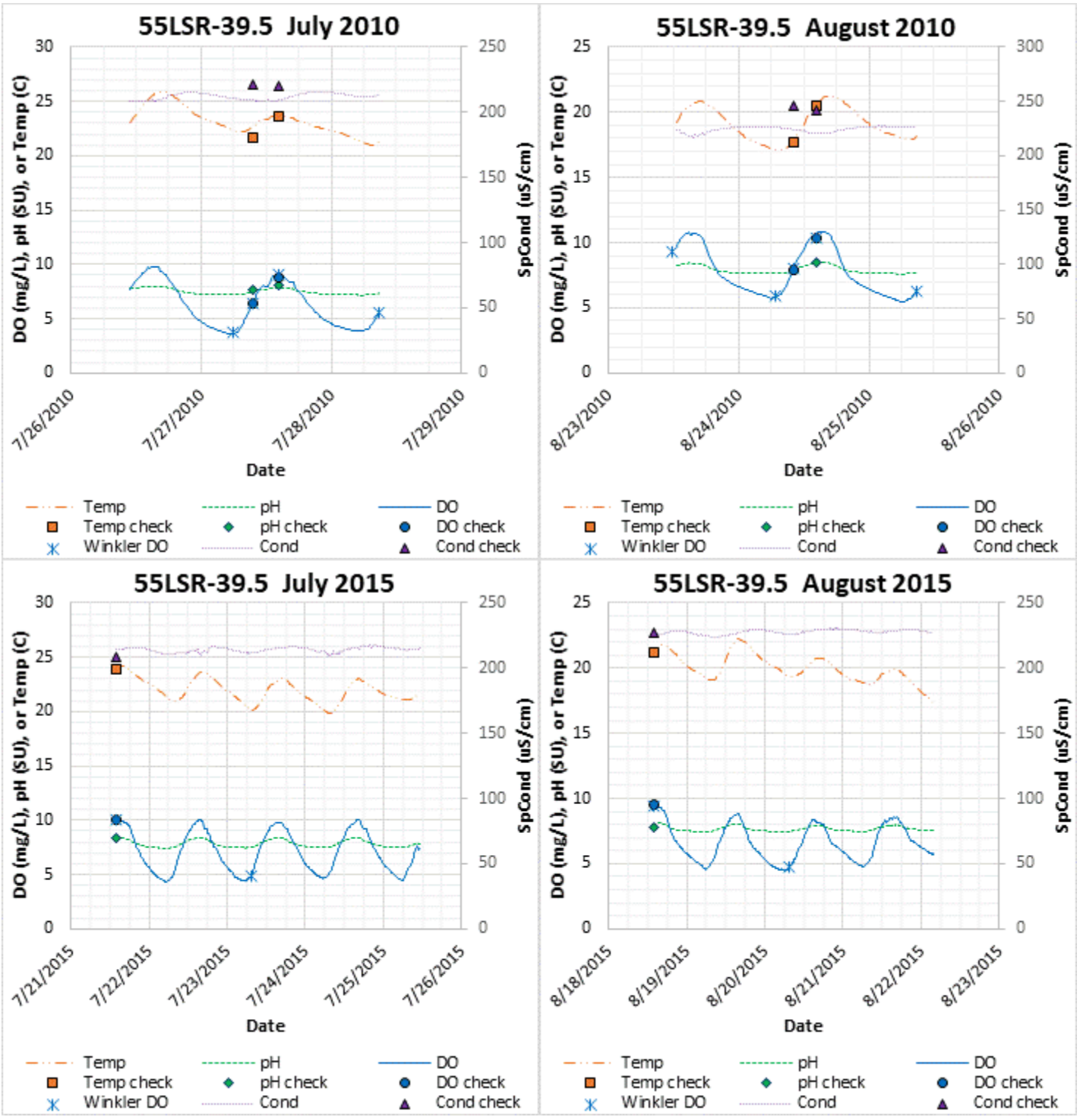
Figure D-4 (Following pages). Continuous Hydrolab® Plots.

Note: We presented continuous Hydrolab® data from 2010 in the previously published data summary report (Stuart, 2012). However, for ease of presentation and comparison, we present all continuous Hydrolab® data from 2010, 2013, and 2015 here.

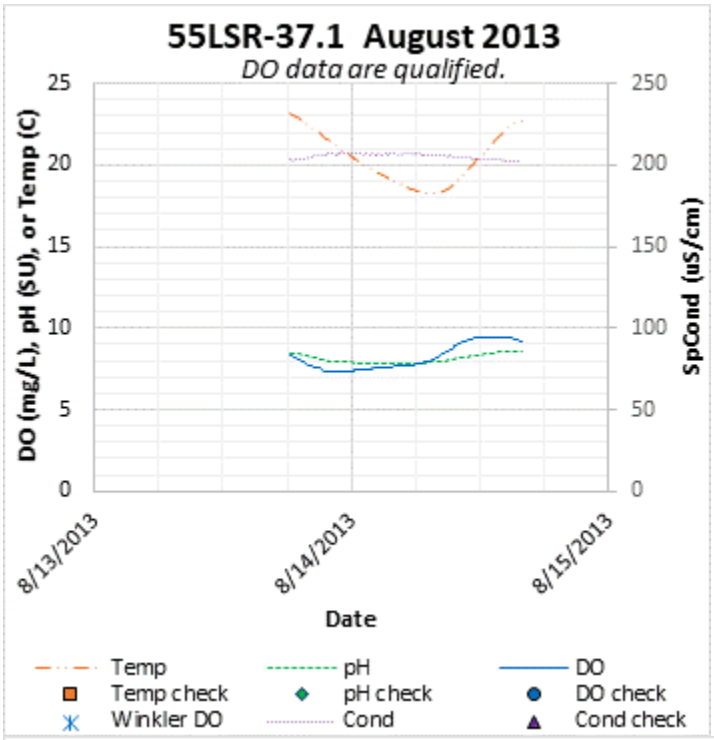
55LSR-46.7 (Little Spokane River @ Scotia)

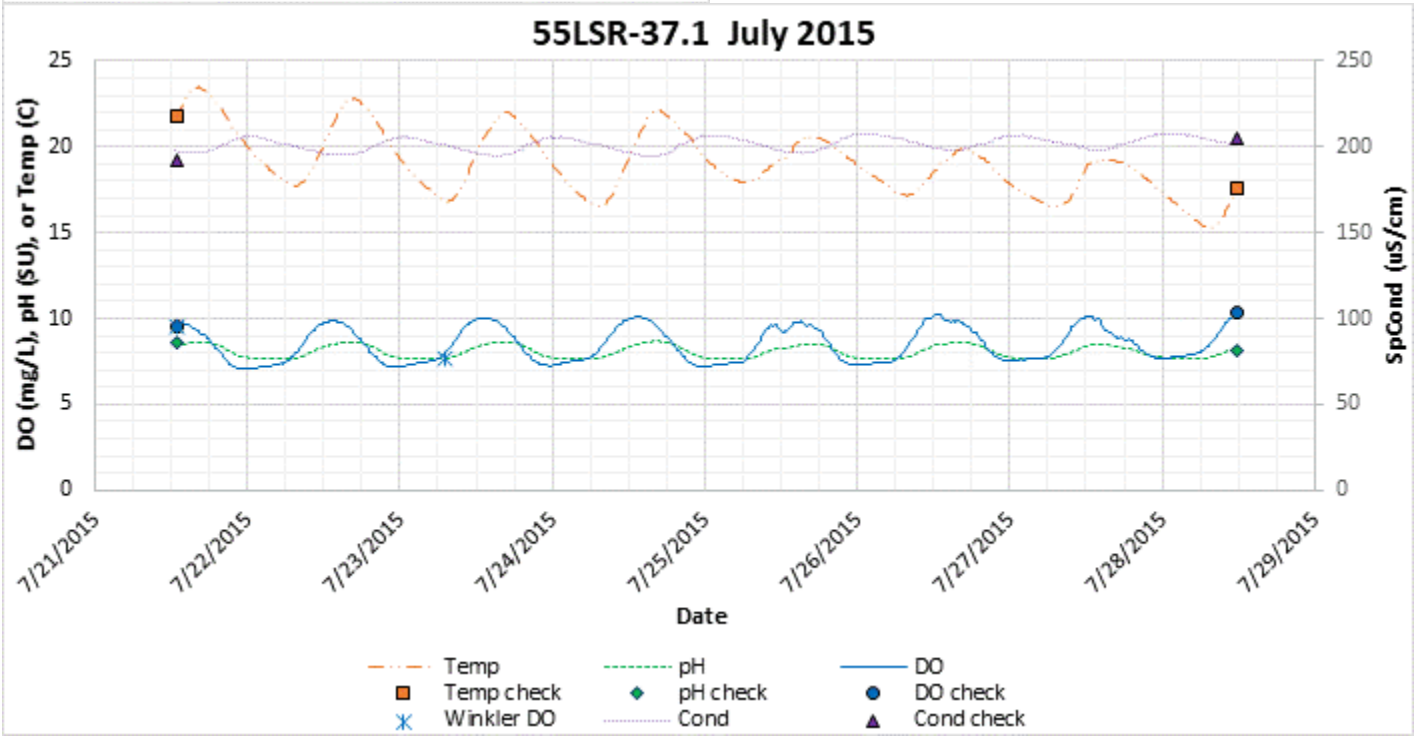


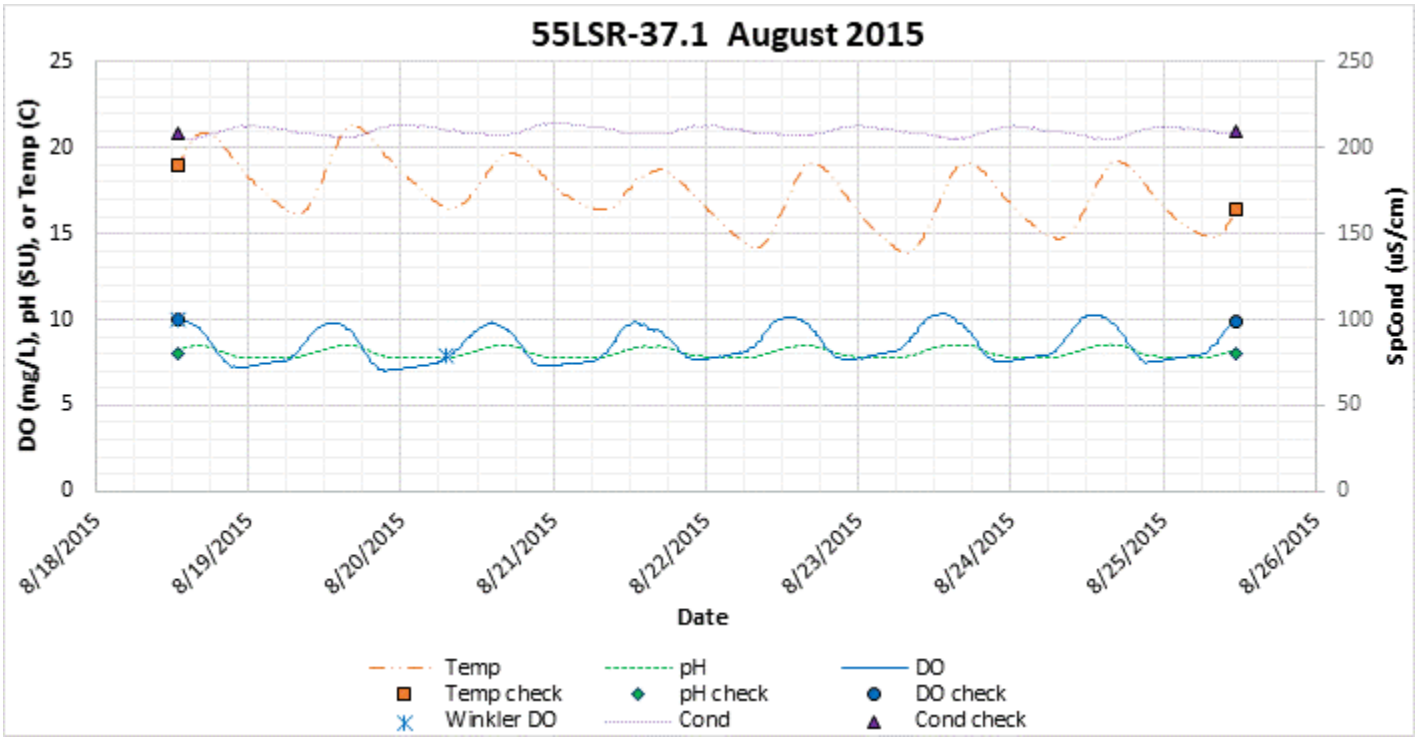
55LSR-39.5 (Little Spokane River @ Frideger Rd)



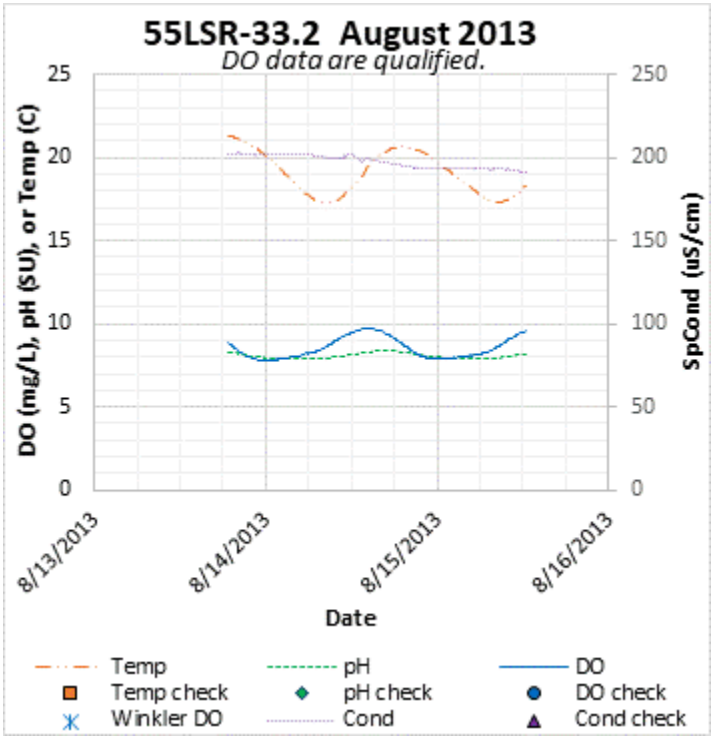
55LSR-37.1 (Little Spokane River @ Elk)



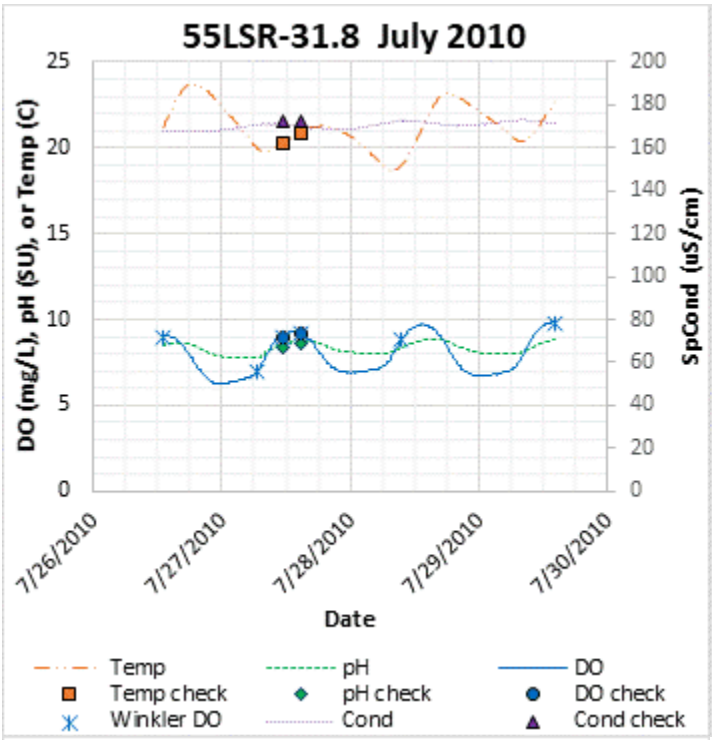


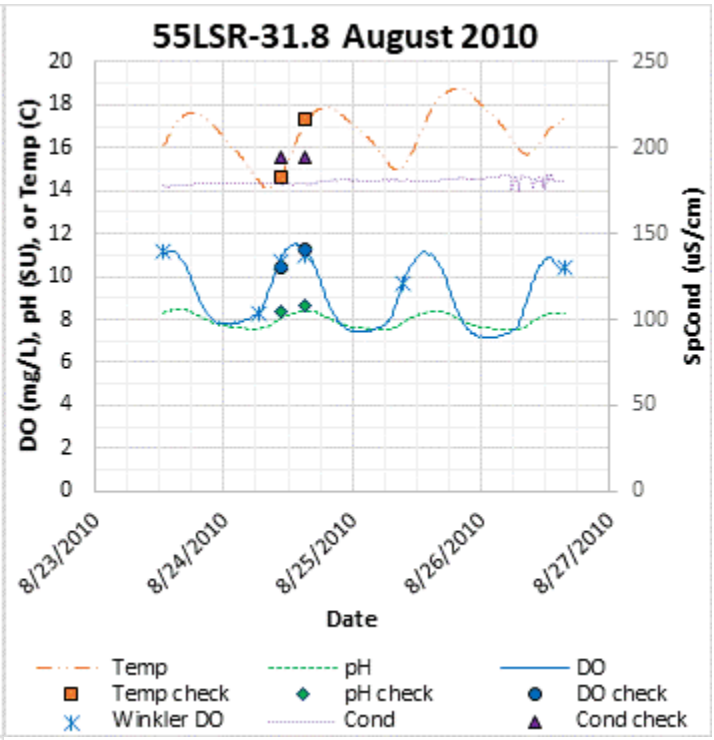


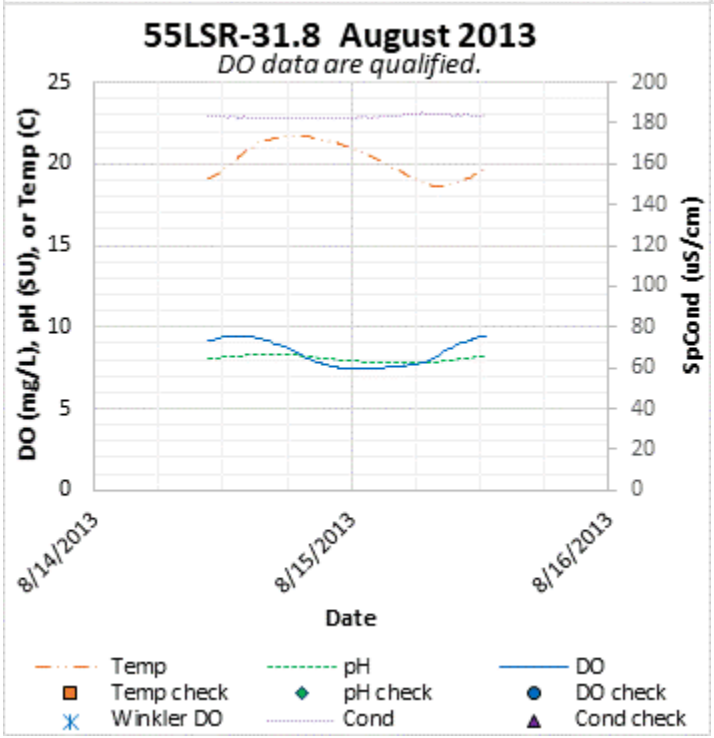
55LSR-33.2 (Little Spokane River @ E Eloika Rd)

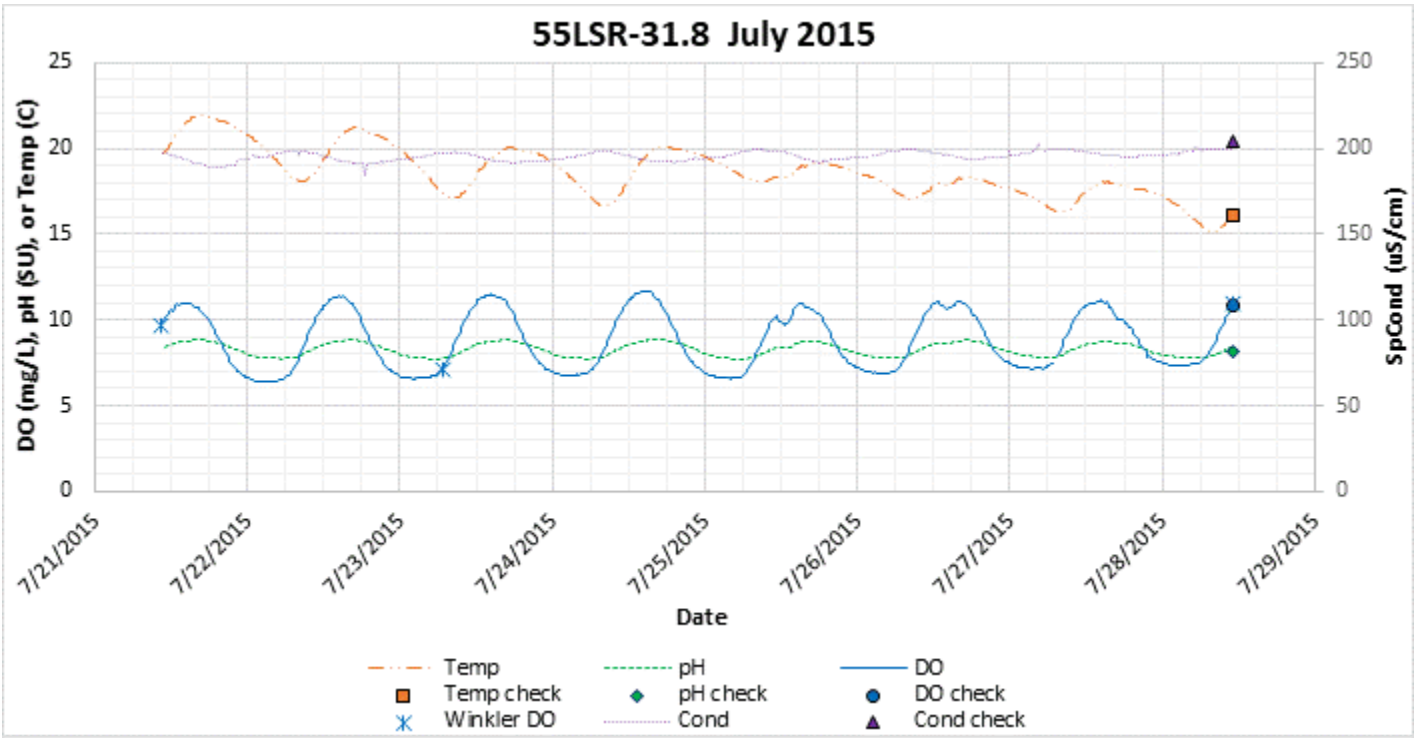


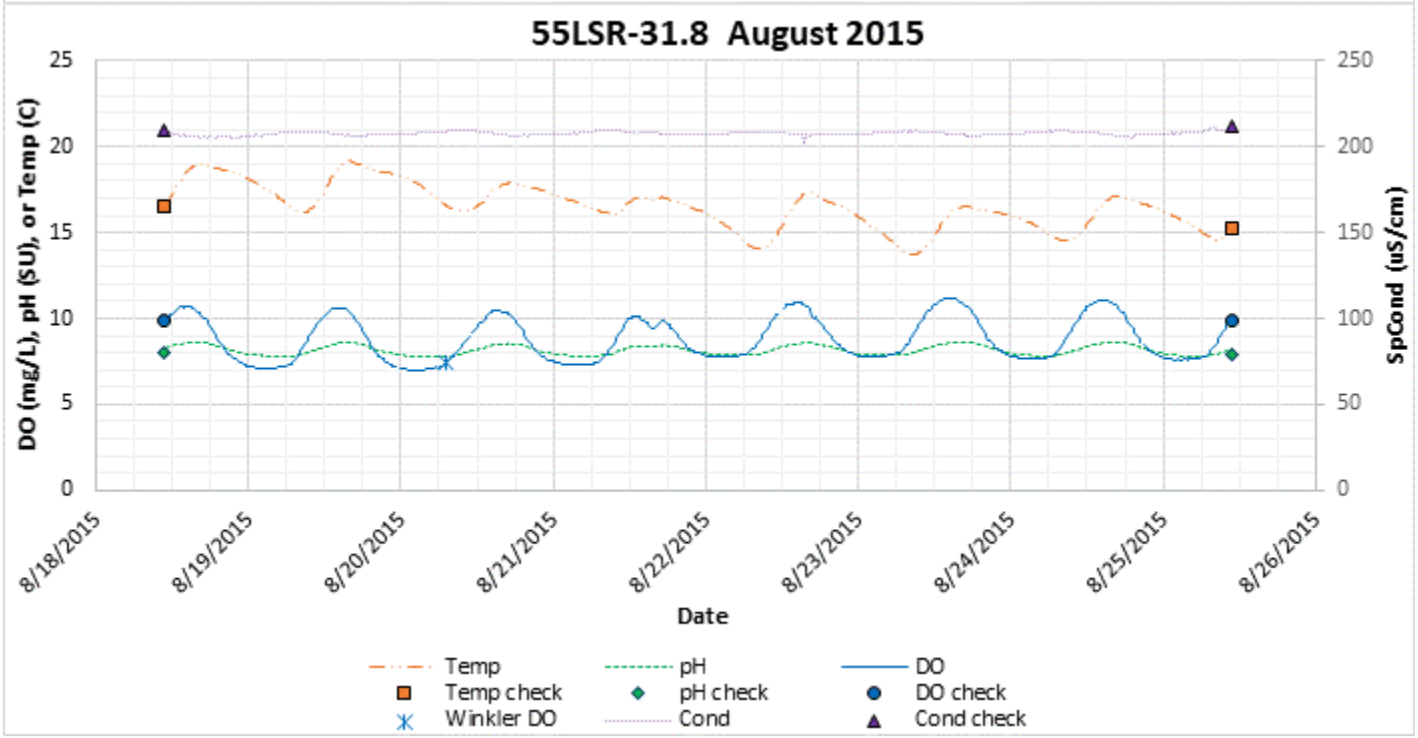
55LSR-31.8 (Little Spokane River @ Deer Park-Milan Rd)



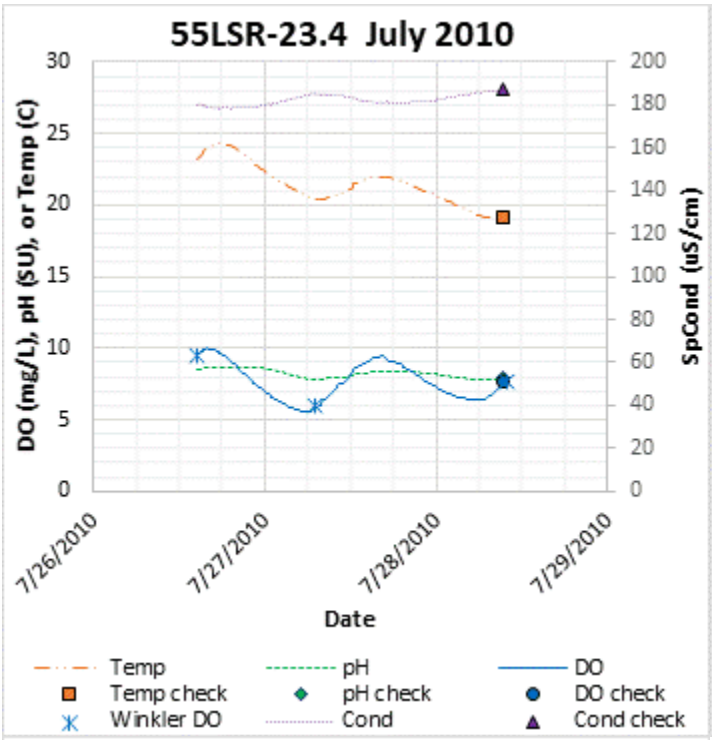


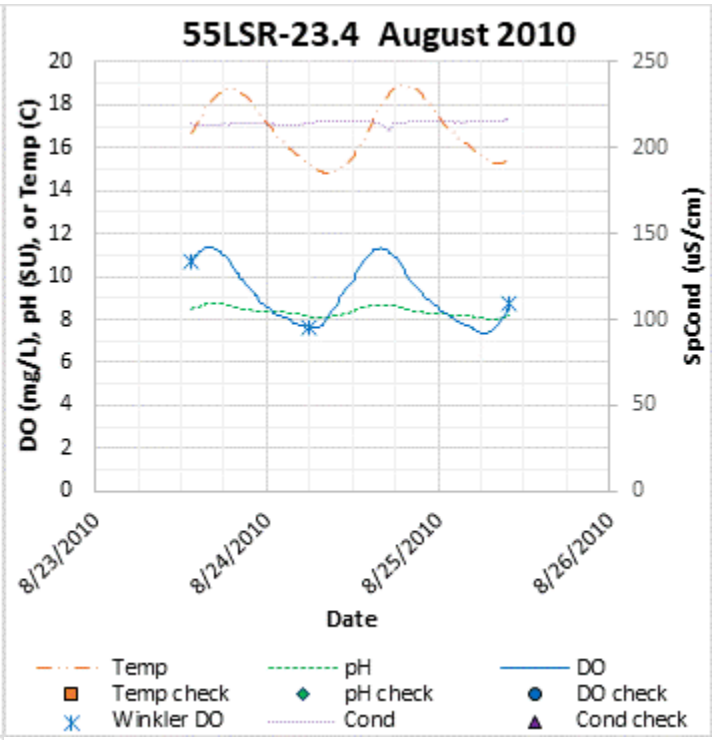


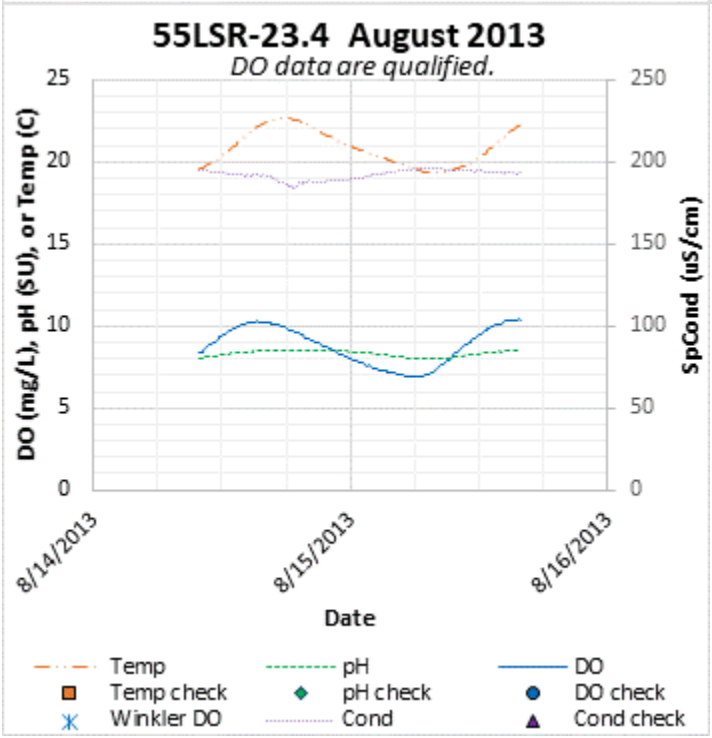

55LSR-31.8 July 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
0
5
10
15
20
25
0
50
100
150
200
250
7/21/2015
7/22/2015
7/23/2015
7/24/2015
7/25/2015
7/26/2015
7/27/2015
7/28/2015
7/29/2015
Date
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

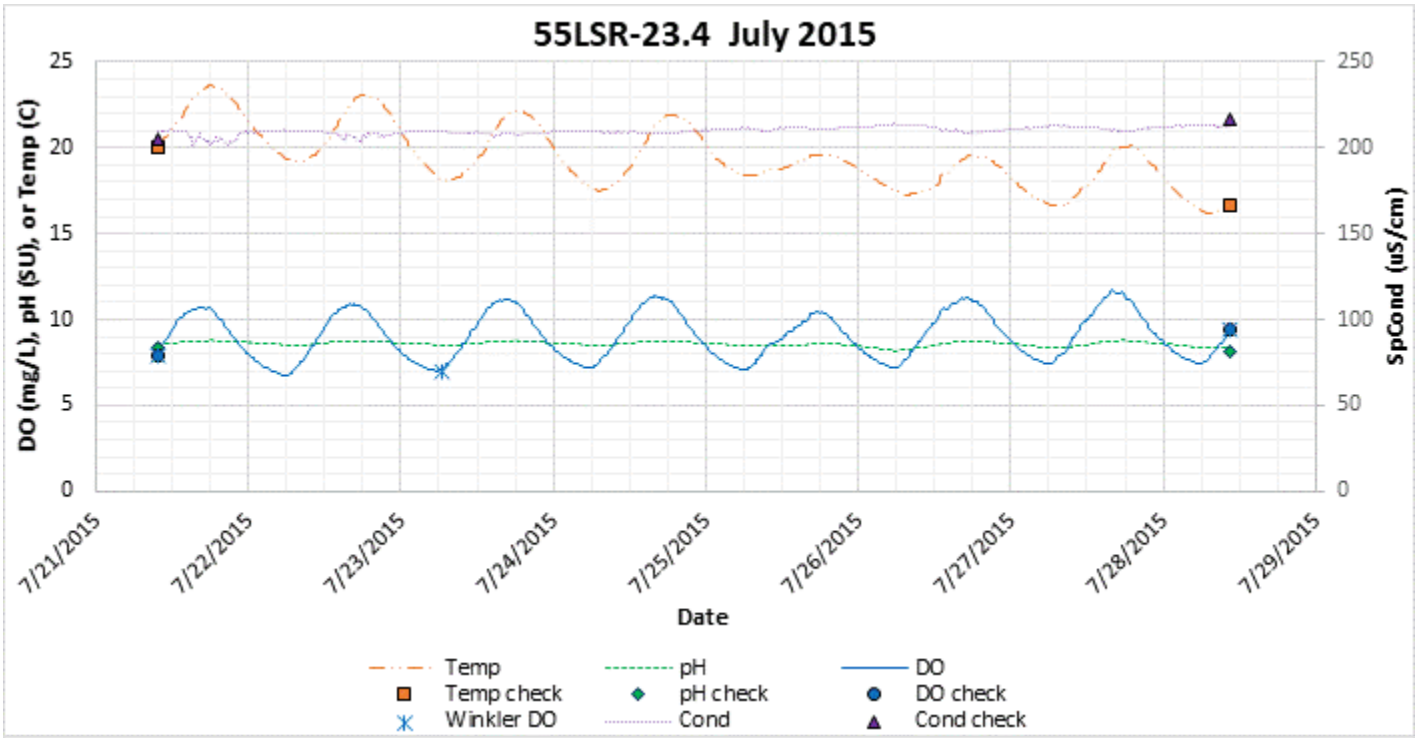

55LSR-31.8 August 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
0
5
10
15
20
25
0
50
100
150
200
250
8/18/2015
8/19/2015
8/20/2015
8/21/2015
8/22/2015
8/23/2015
8/24/2015
8/25/2015
8/26/2015
Date
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

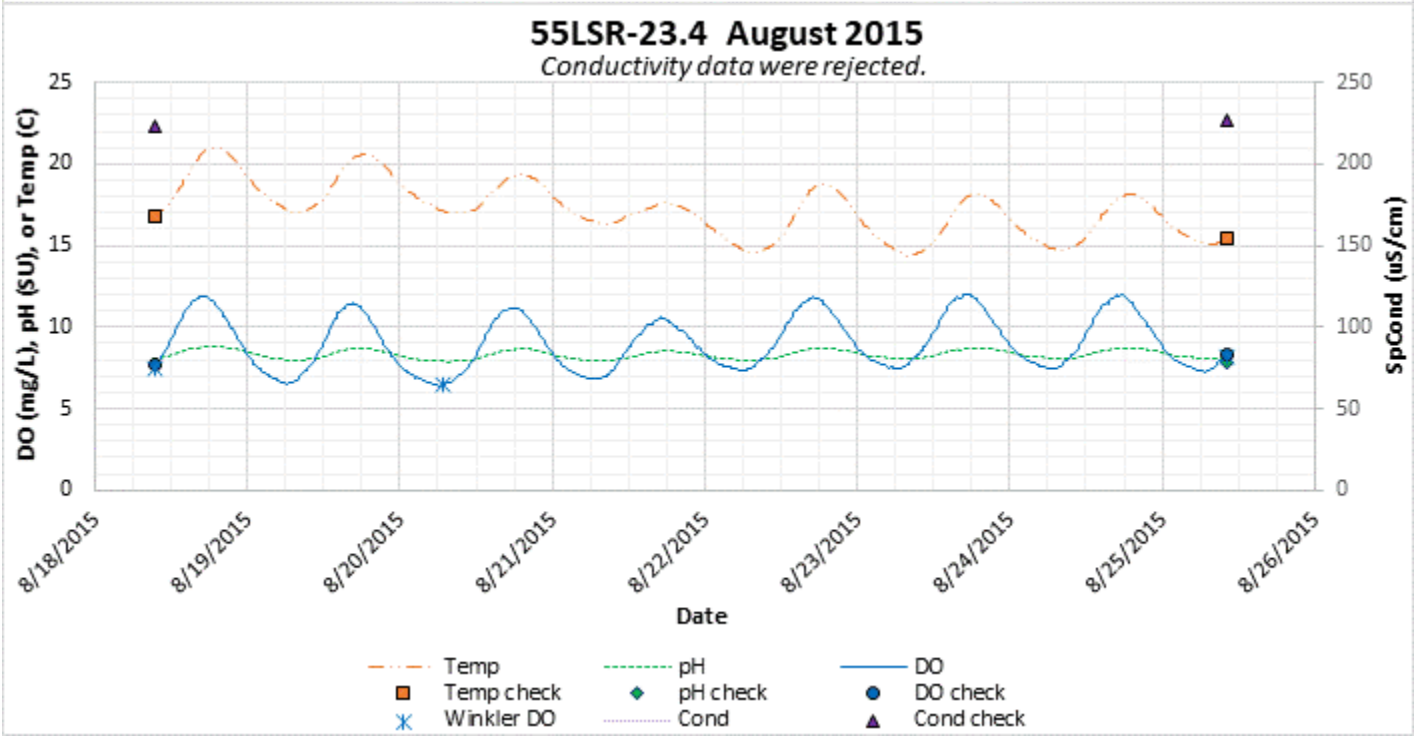
55LSR-23.4 (Little Spokane River @ Chattaroy)



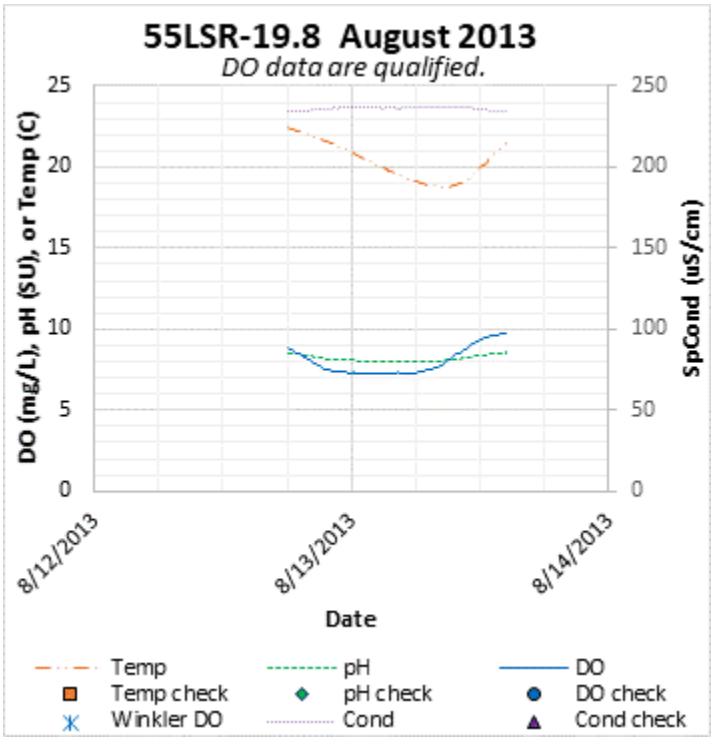




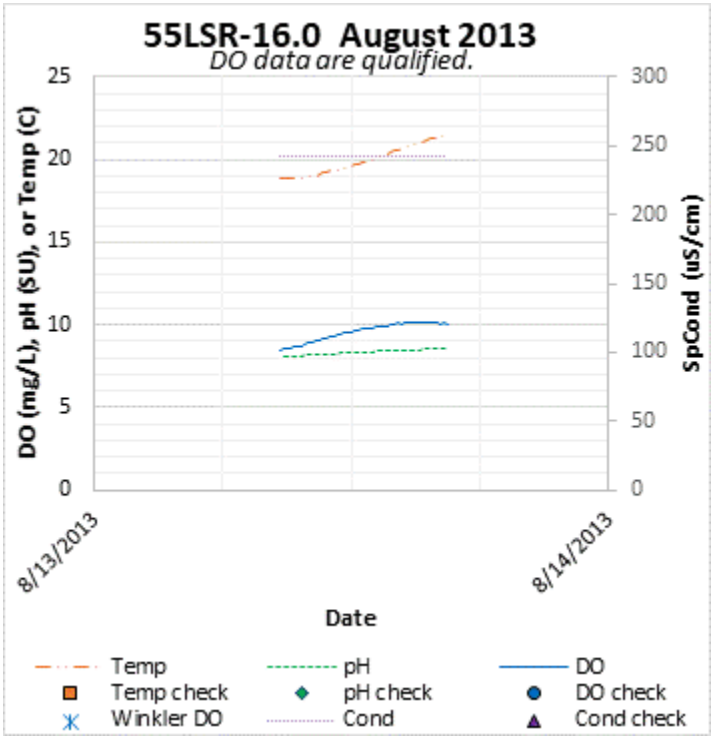

55LSR-23.4 July 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
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10
15
20
25
0
50
100
150
200
250
7/21/2015
7/22/2015
7/23/2015
7/24/2015
7/25/2015
7/26/2015
7/27/2015
7/28/2015
7/29/2015
Date
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check


55LSR-23.4 August 2015
Conductivity data were rejected.
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
0
5
10
15
20
25
0
50
100
150
200
250
8/18/2015
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8/20/2015
8/21/2015
8/22/2015
8/23/2015
8/24/2015
8/25/2015
8/26/2015
Date
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

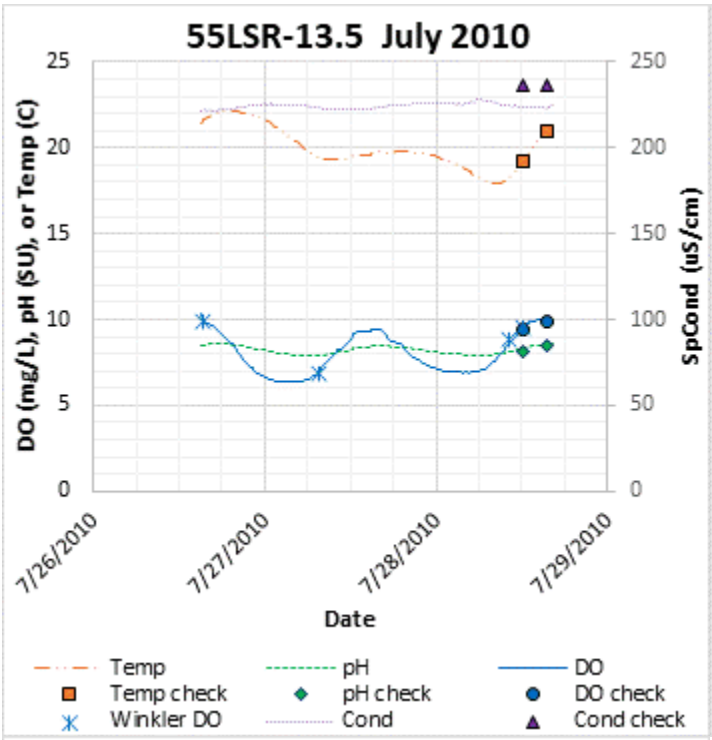
55LSR-19.8 (Little Spokane River @ Colbert Landfill outfall)

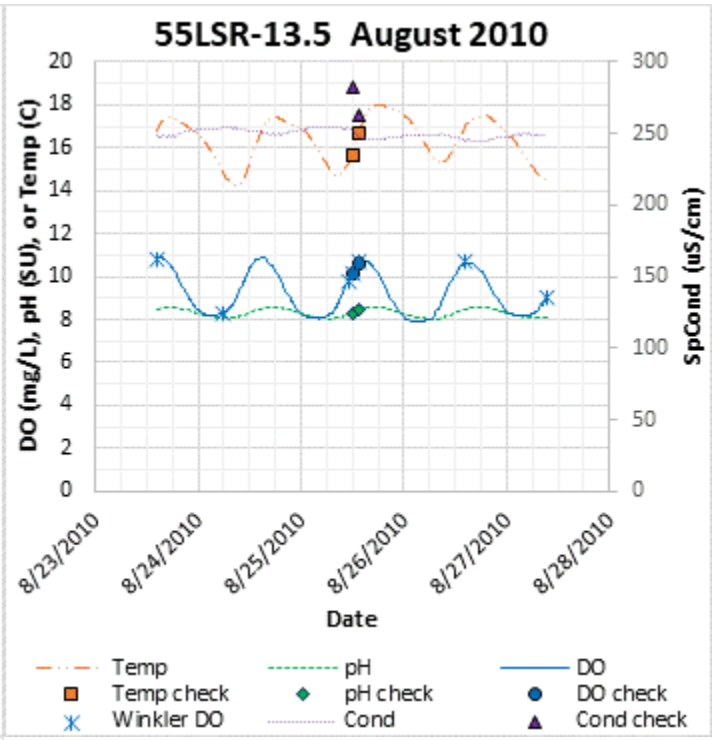


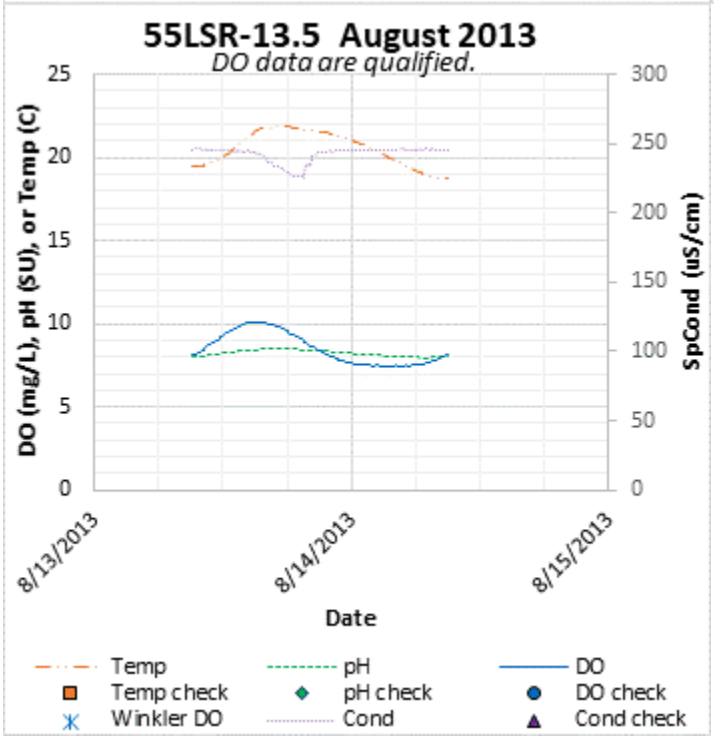
55LSR-16.0 (Little Spokane River @ Colbert Rd)

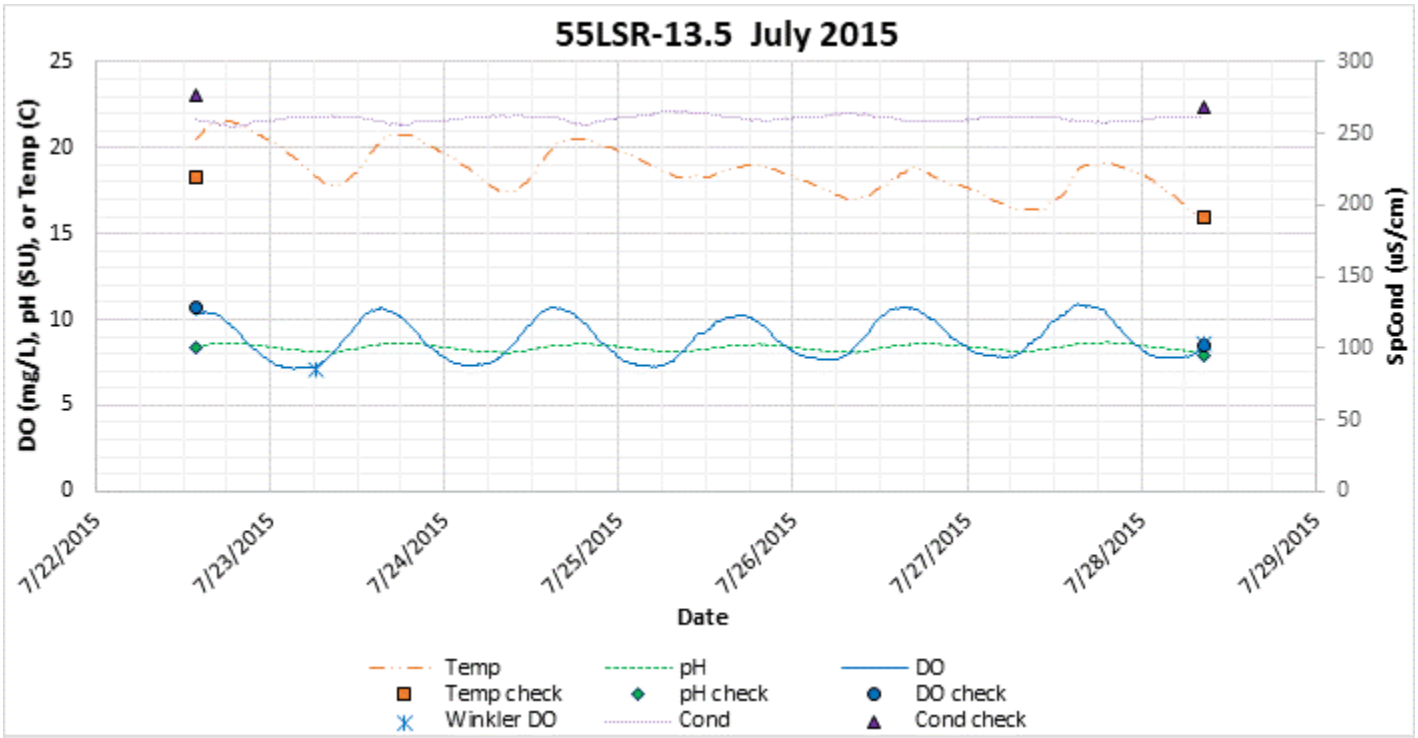


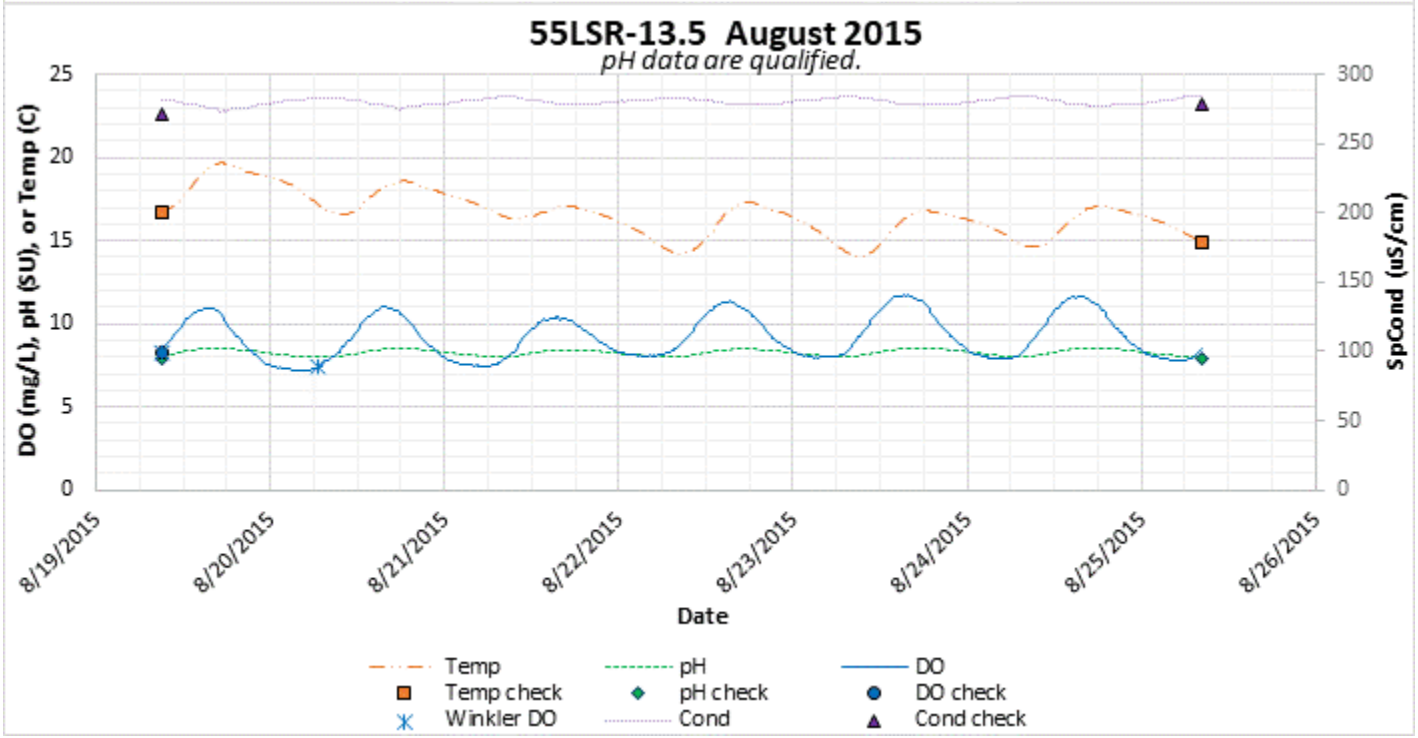
55LSR-13.5 (Little Spokane River @ N Little Spokane River Dr)



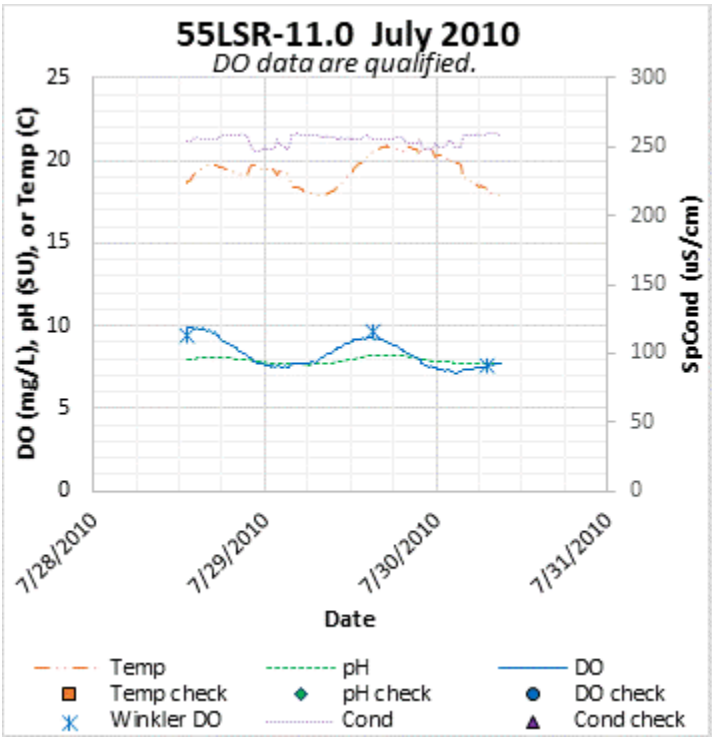


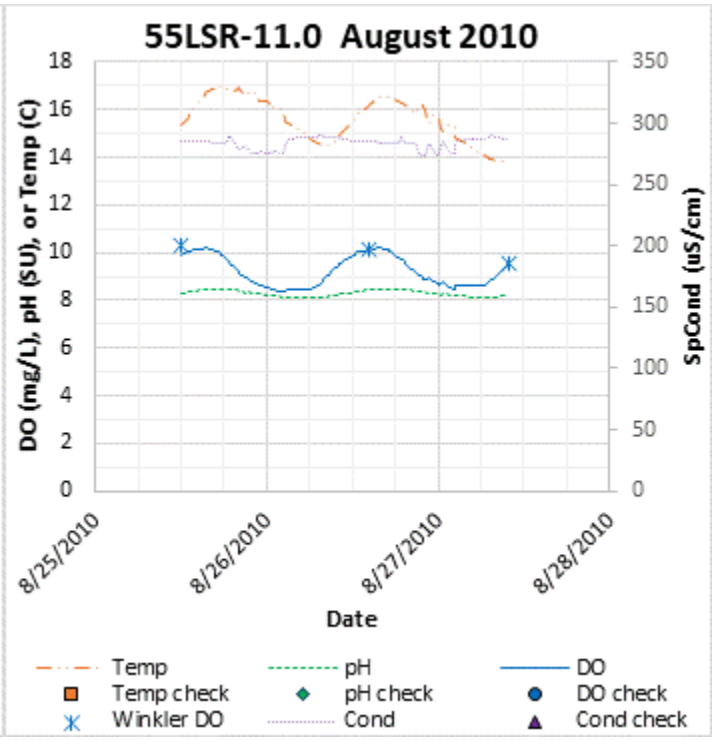



55LSR-13.5 July 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
Date
7/22/2015
7/23/2015
7/24/2015
7/25/2015
7/26/2015
7/27/2015
7/28/2015
7/29/2015
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

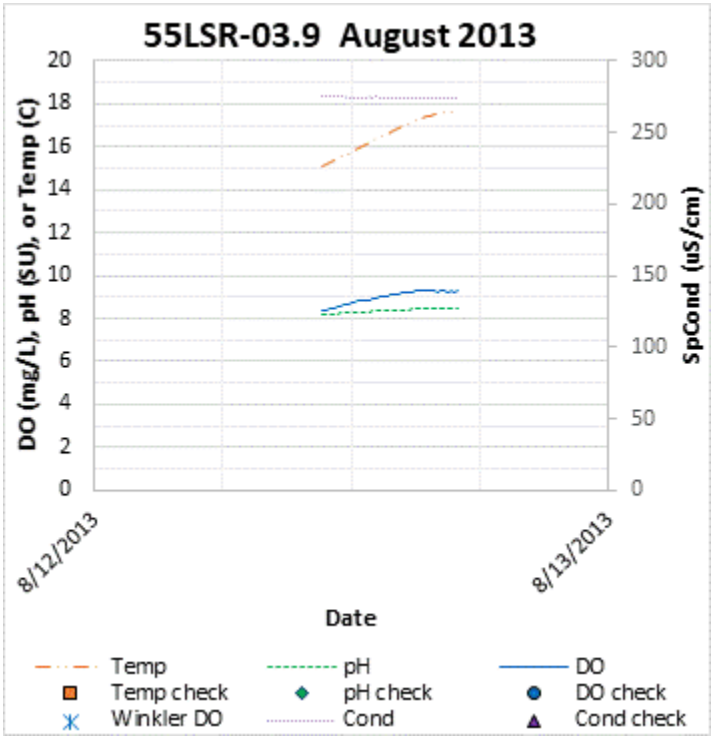

55LSR-13.5 August 2015
pH data are qualified.
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
Date
8/19/2015
8/20/2015
8/21/2015
8/22/2015
8/23/2015
8/24/2015
8/25/2015
8/26/2015
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

55LSR-11.0 (Little Spokane River @ Dartford USGS gage)

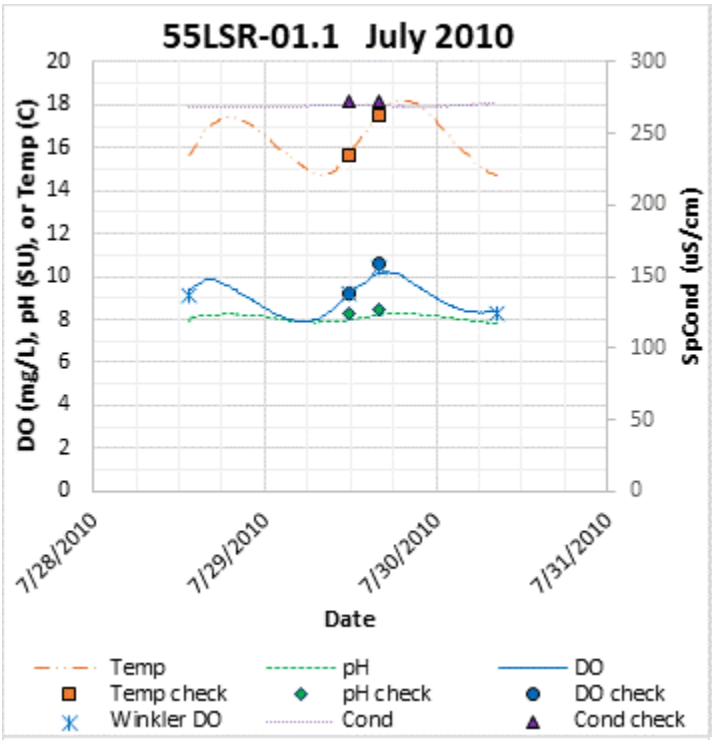


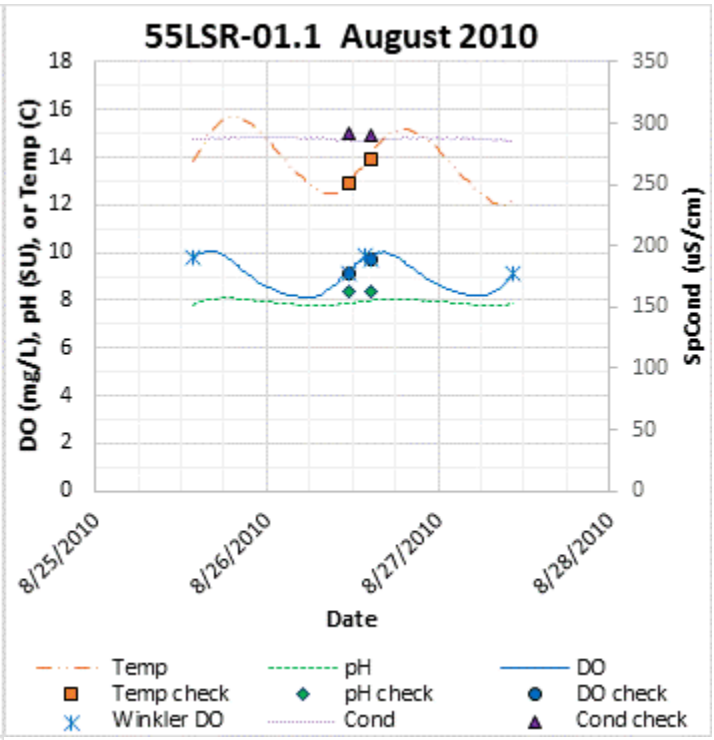


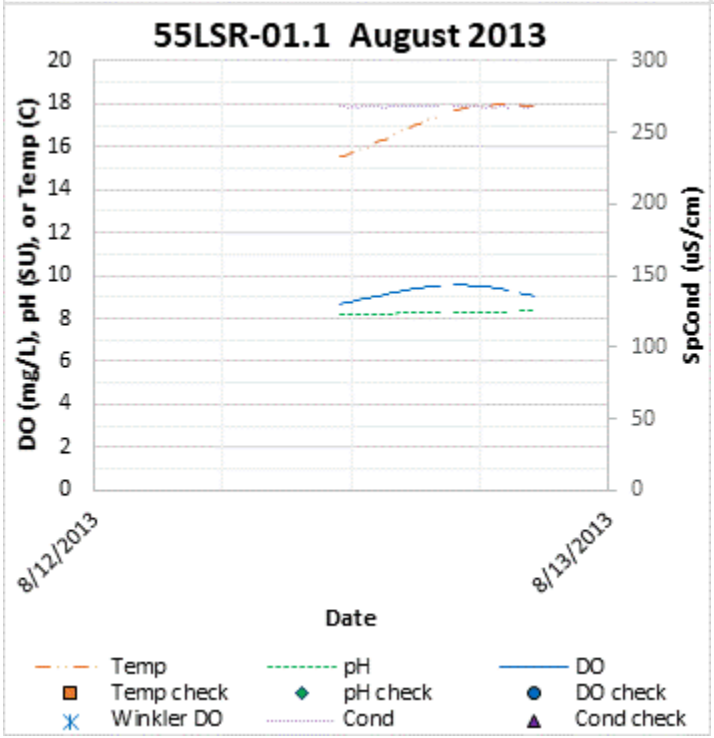
55LSR-03.9 (Little Spokane River @ Rutter Parkway / Painted Rocks)

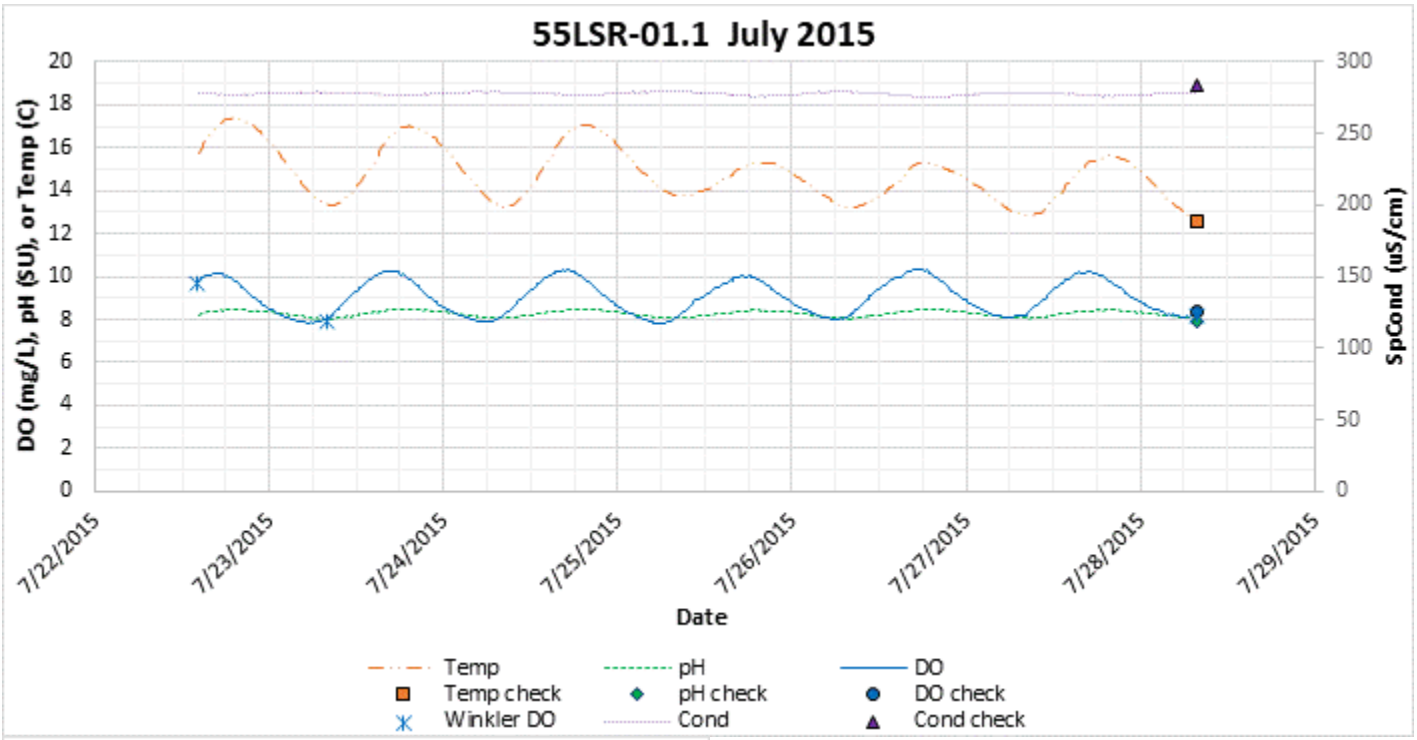


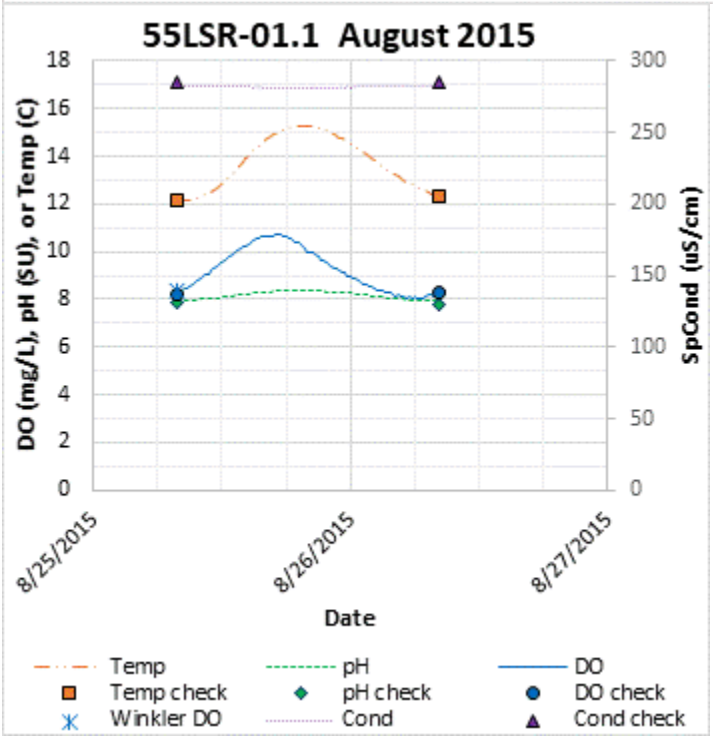
55LSR-01.1 (Little Spokane River @ Mouth)



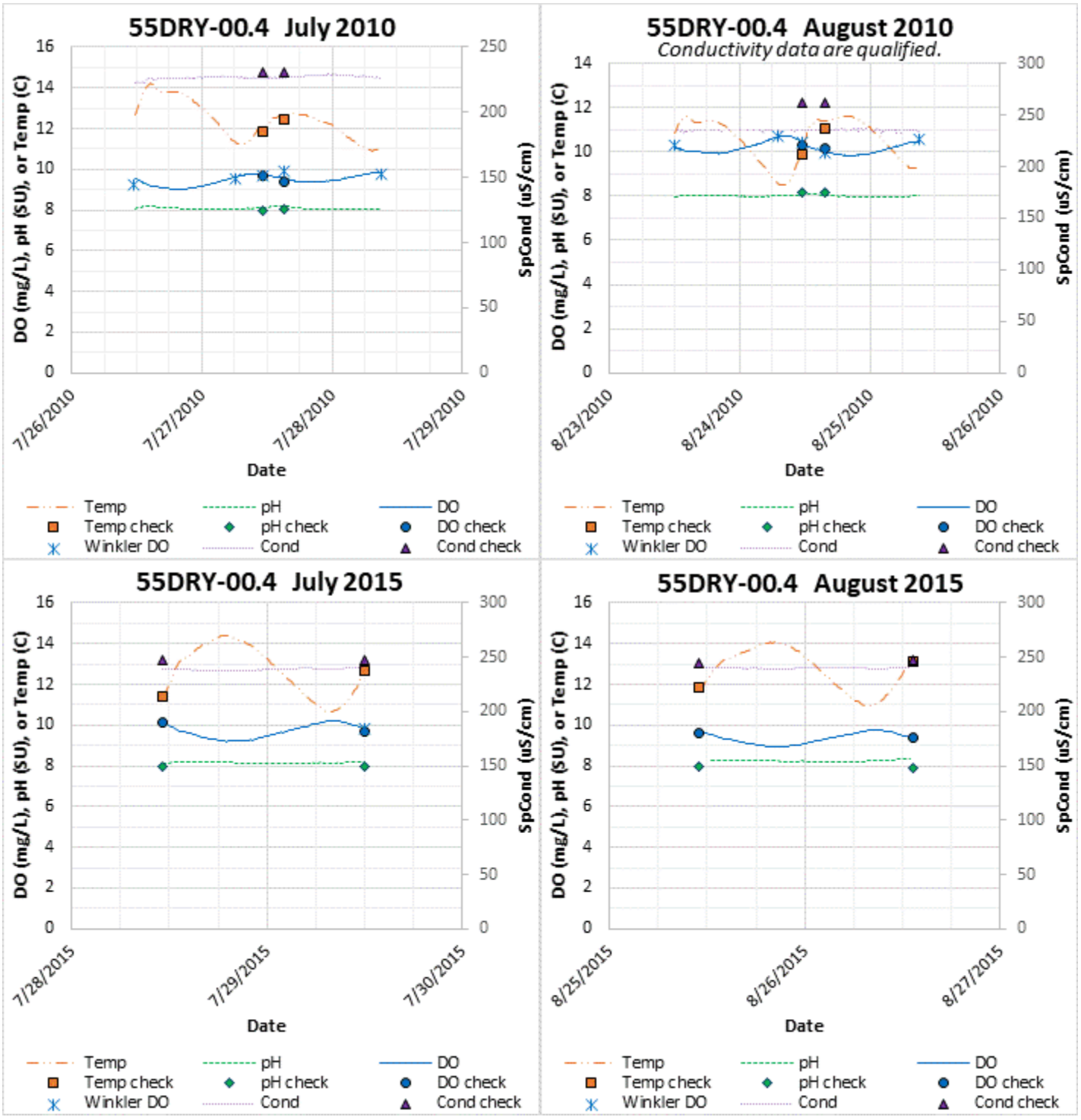




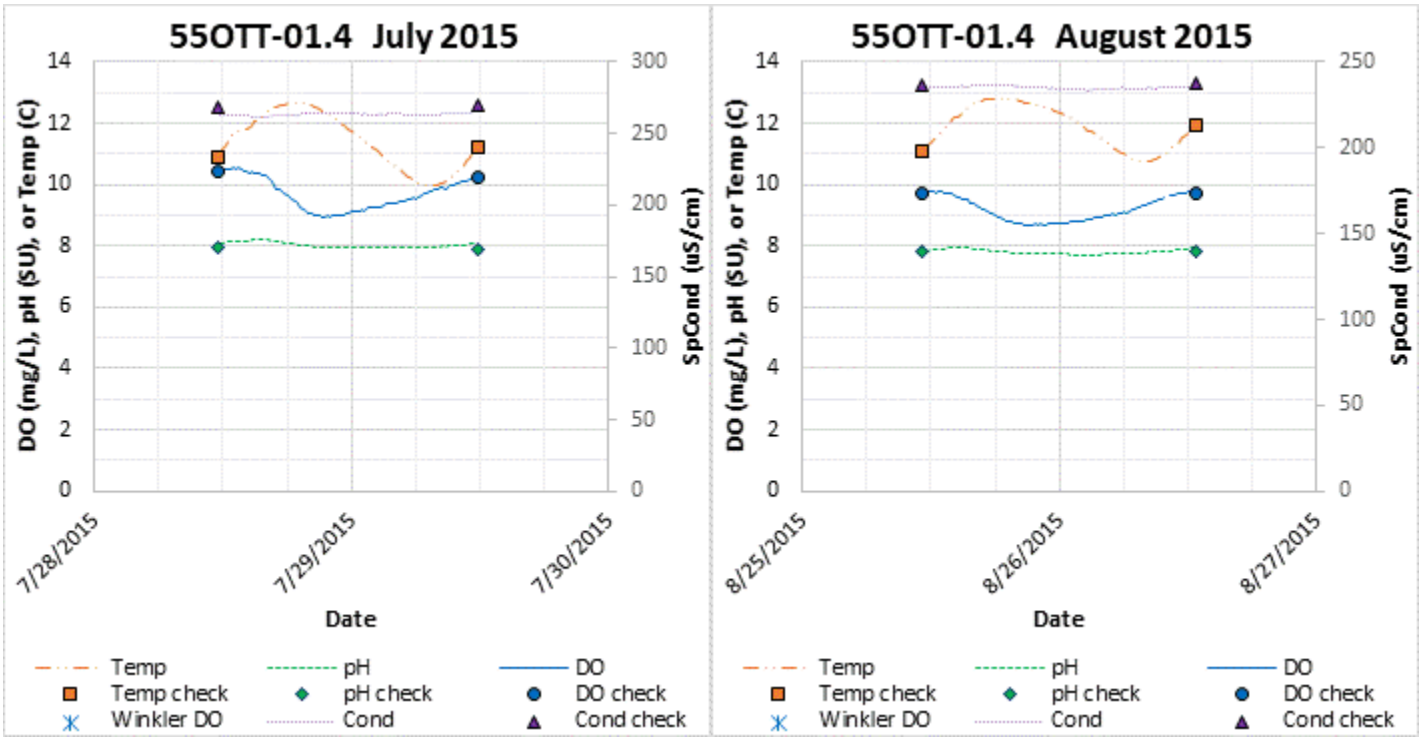

55LSR-01.1 July 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
Date
7/22/2015
7/23/2015
7/24/2015
7/25/2015
7/26/2015
7/27/2015
7/28/2015
7/29/2015
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check


55LSR-01.1 August 2015
DO (mg/L), pH (SU), or Temp (C)
SpCond (uS/cm)
Date
8/25/2015
8/26/2015
8/27/2015
Temp
Temp check
Winkler DO
pH
pH check
Cond
DO
DO check
Cond check

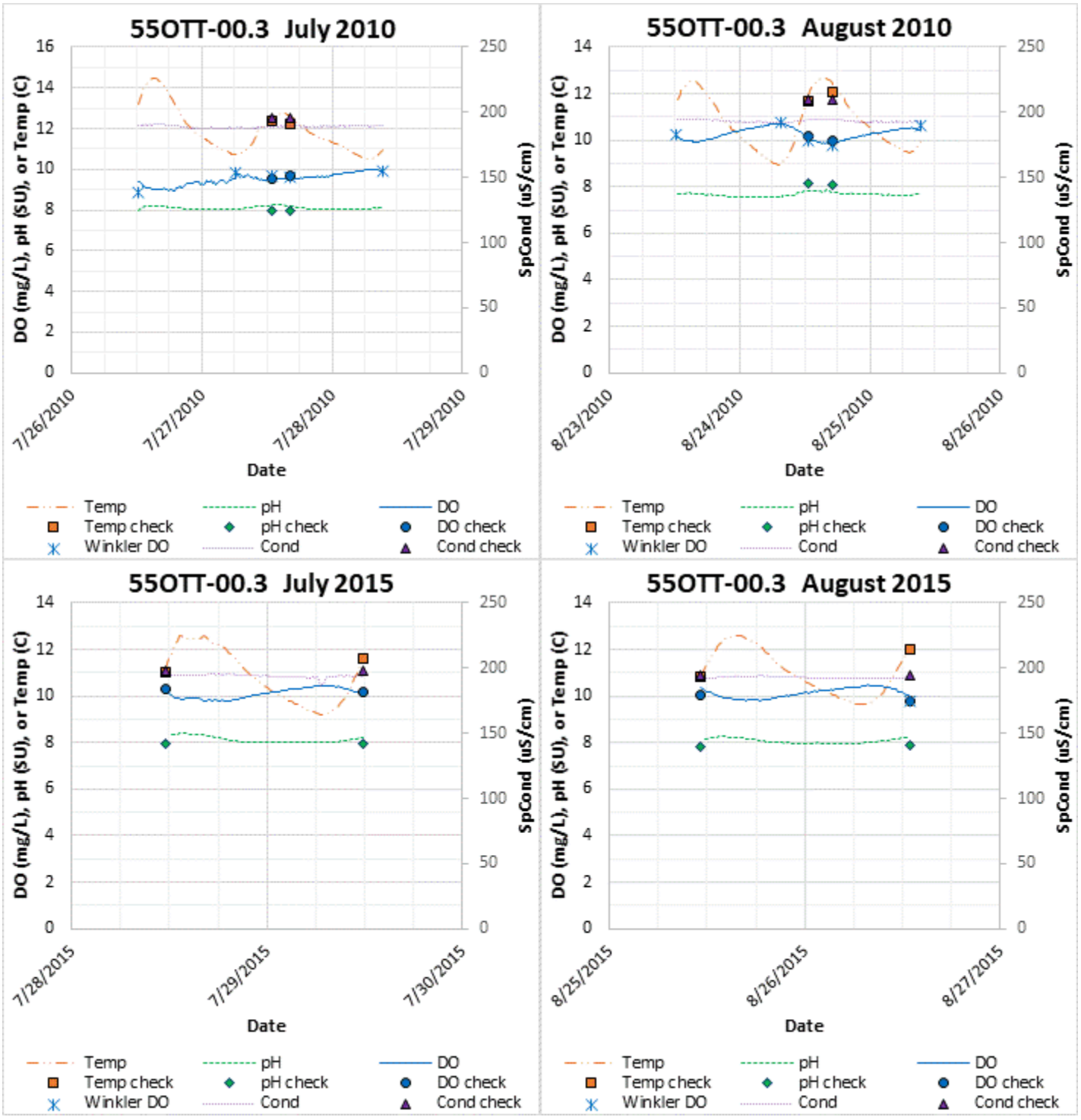
55DRY-00.4 (Dry Ck @ Mouth)



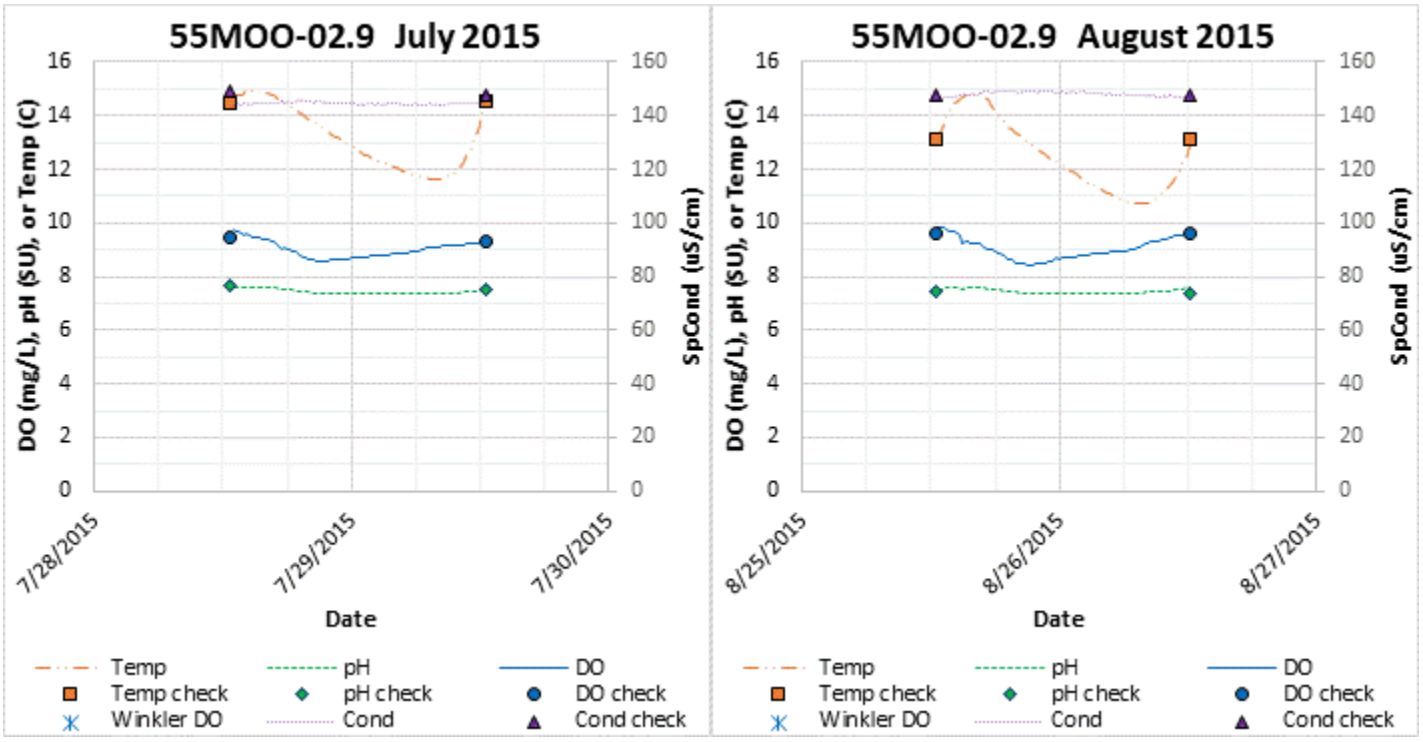
55OTT-01.4 (Otter Ck @ 2nd Valley Rd xing)



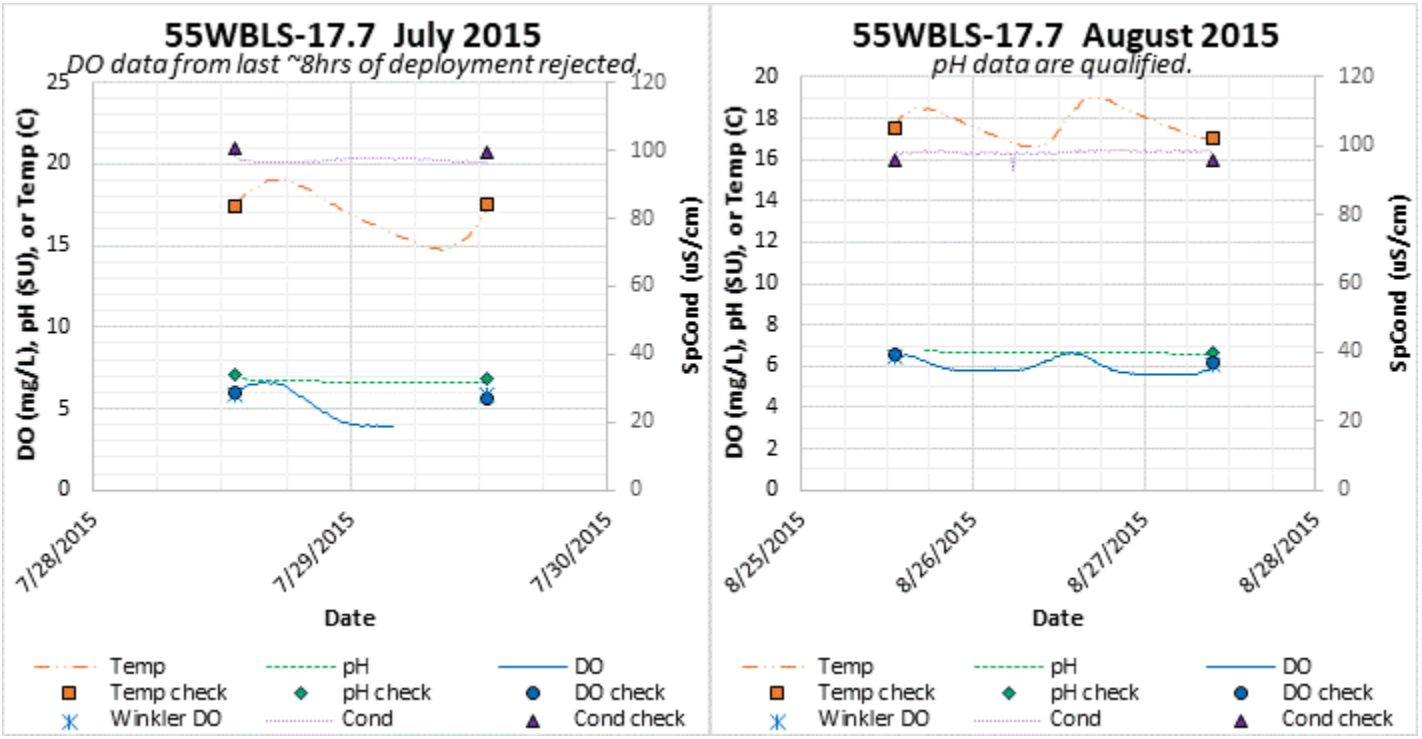
55OTT-00.3 (Otter Ck @ mouth)



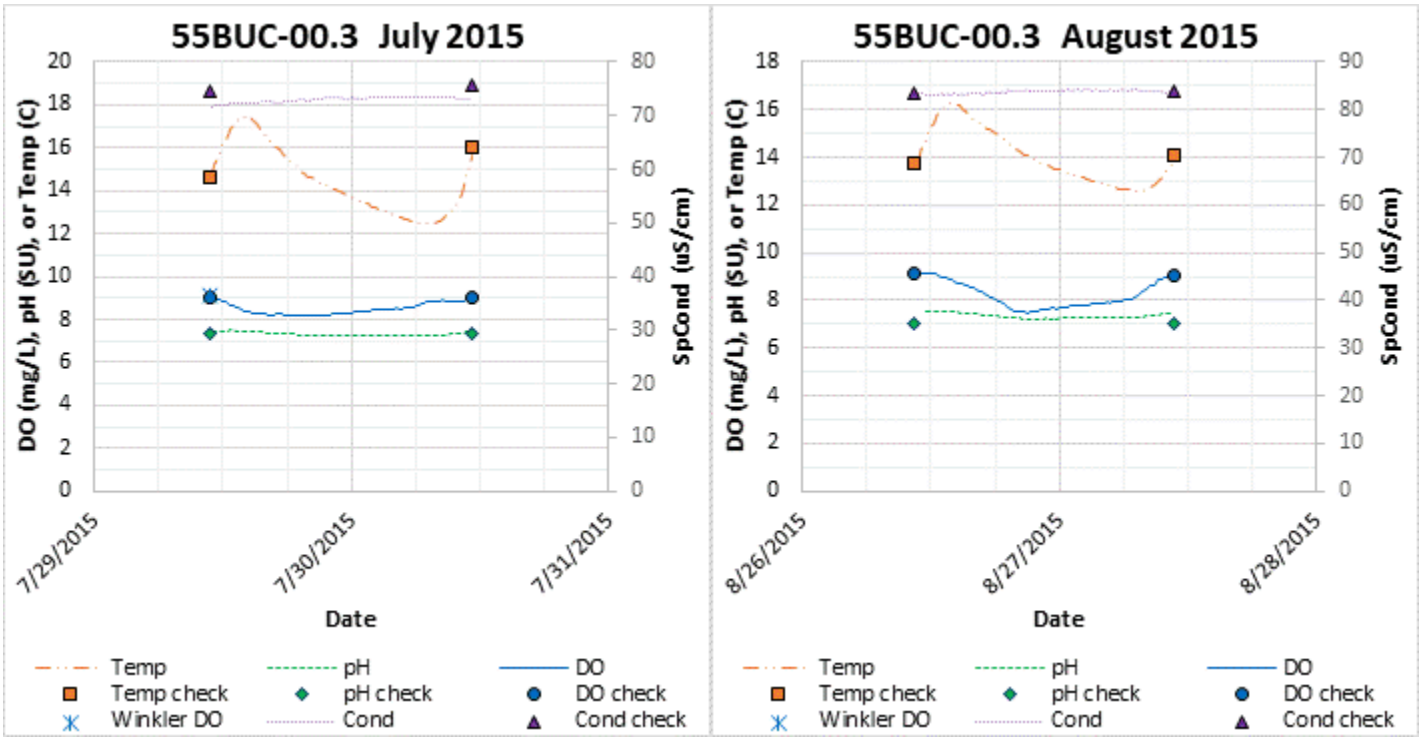
55MOO-02.9 (Moon Ck @ Hwy 211)



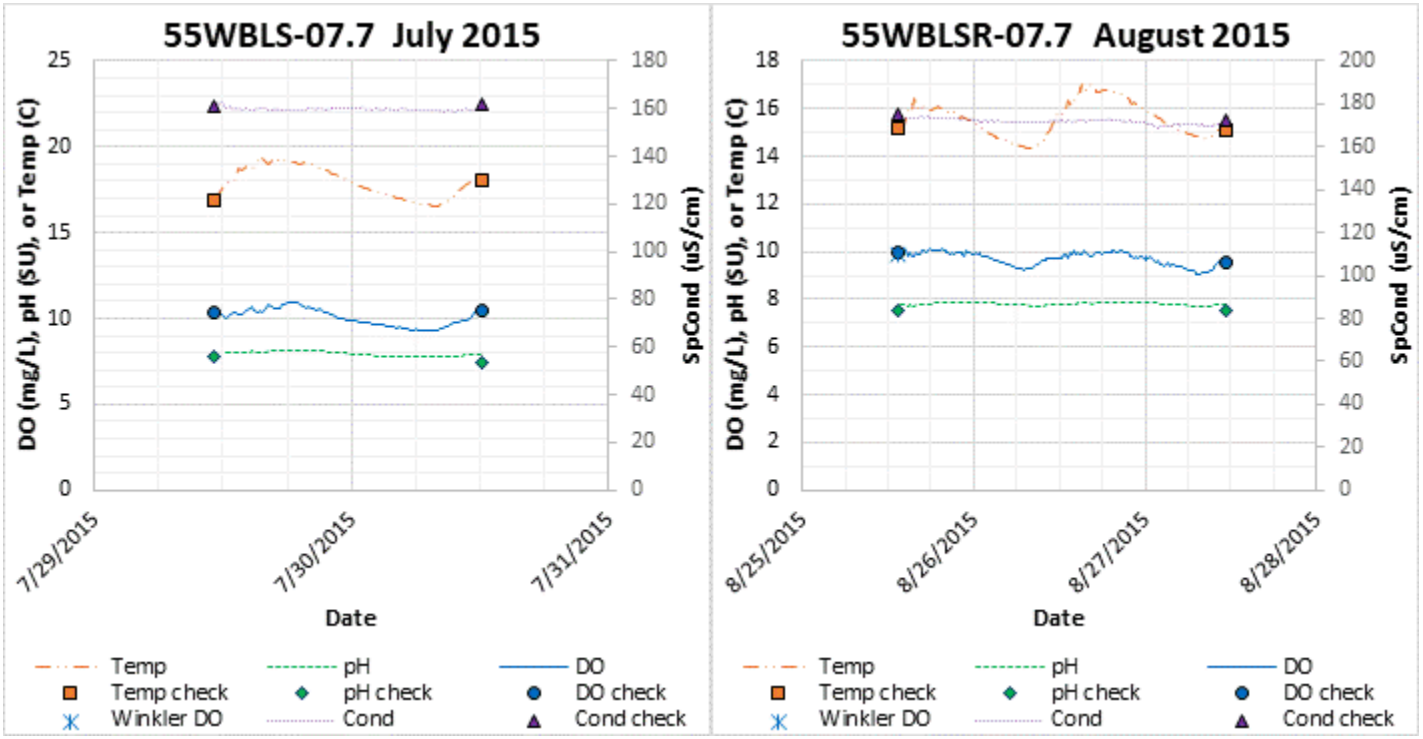
55WBLS-17.7 (W Branch Little Spokane River @ Harworth Rd)



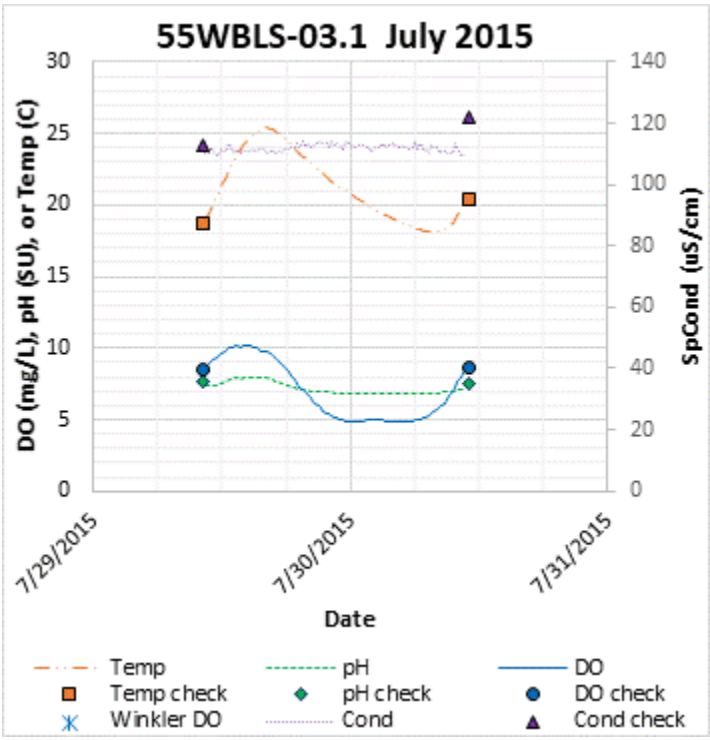
55BUC-00.3 (Buck Ck @ mouth)

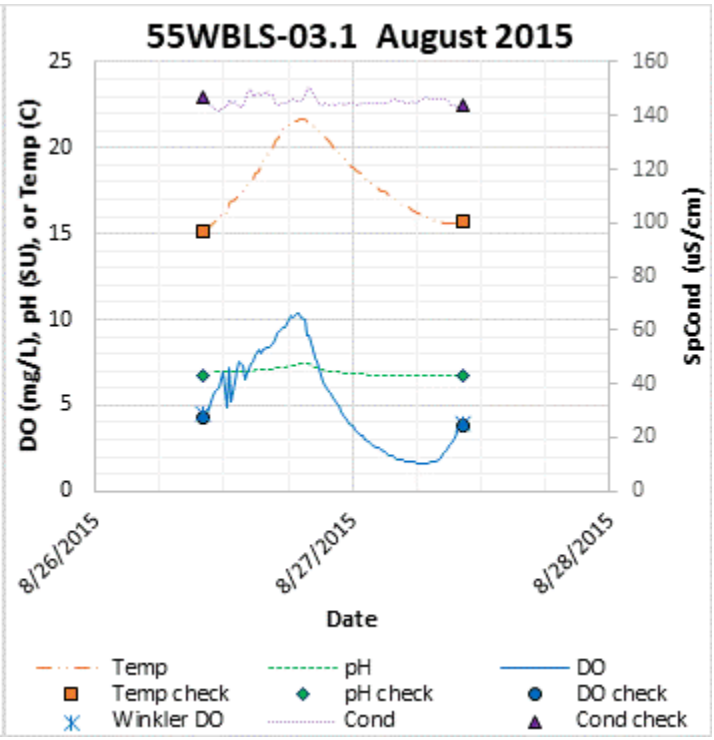


55WBLS-07.7 (W Branch Little Spokane River @ Fan Lk Rd)

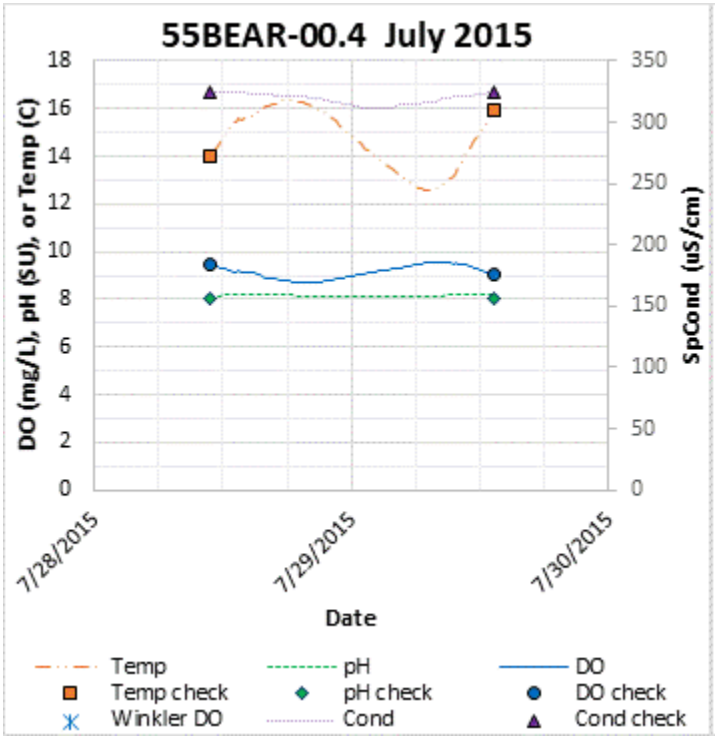


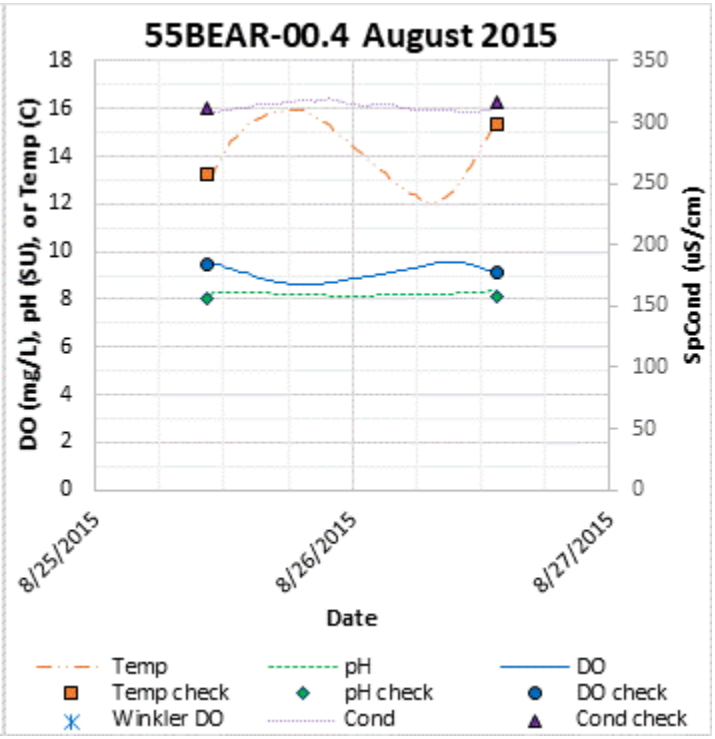
55WBLS-03.1 (W Branch Little Spokane River @ Eloika Lk Rd)



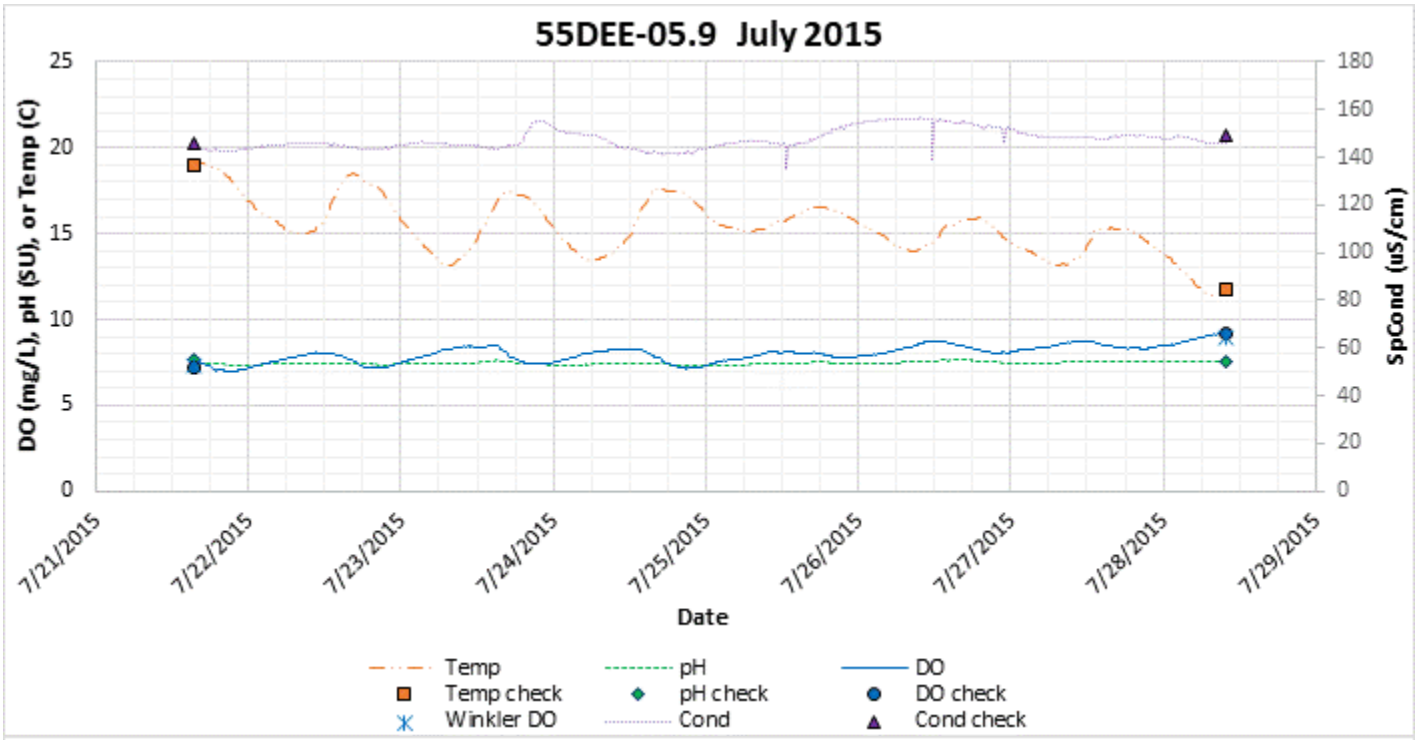


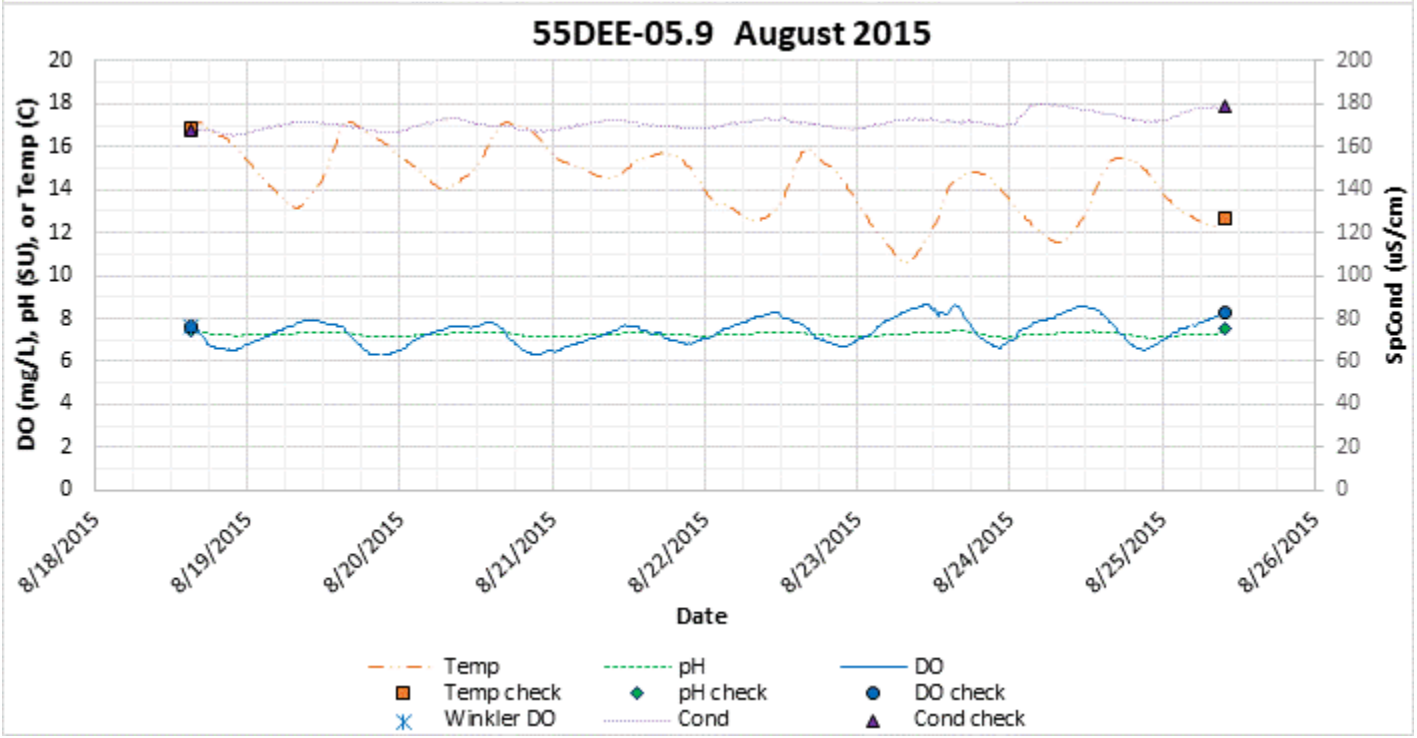
55BEAR-00.4 (Bear Ck @ Mouth)



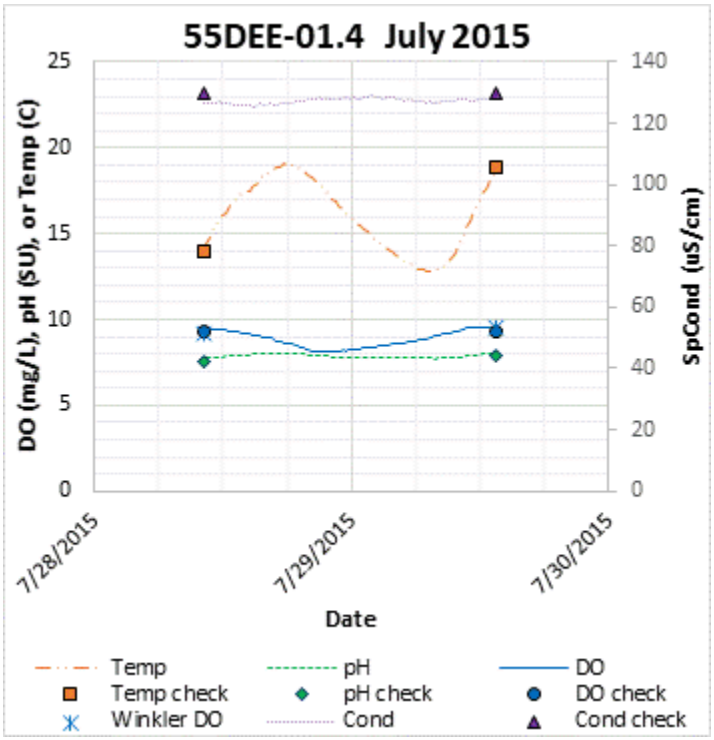


55DEE-05.9 (Deer Ck abv Little Deer Ck)

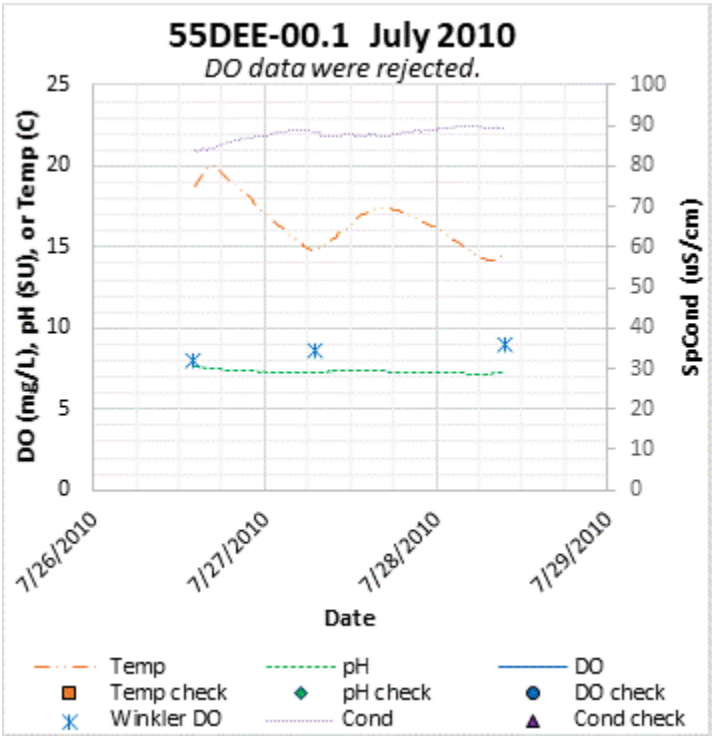


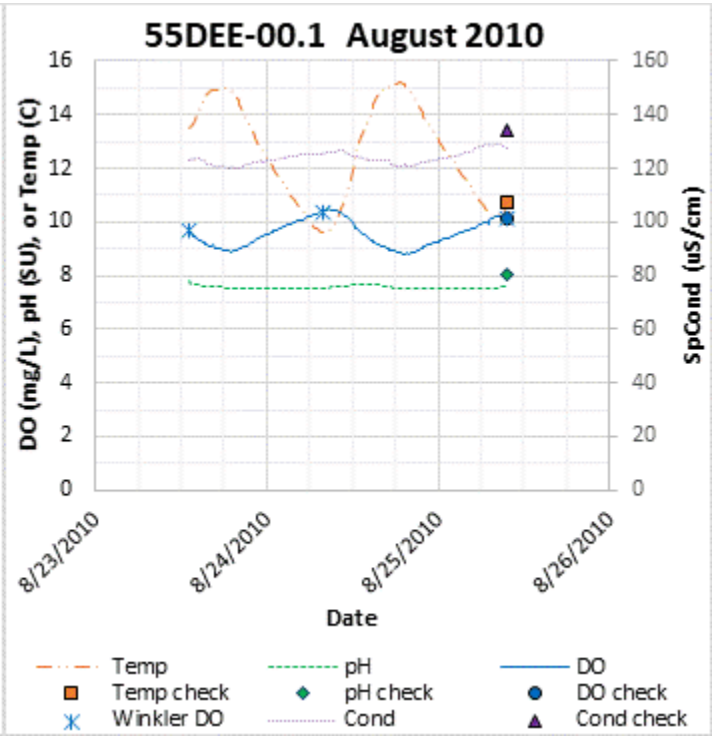


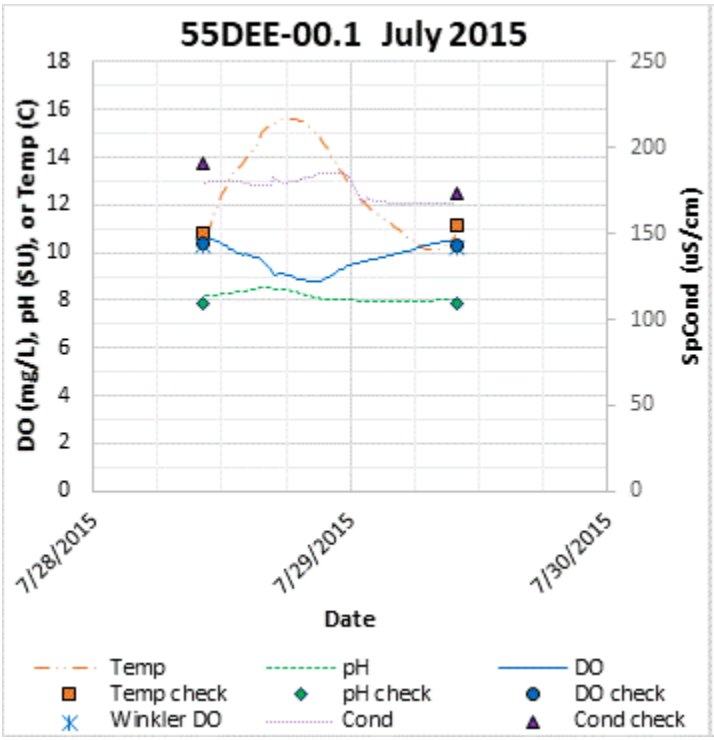
55DEE-01.4 (Deer Ck @ Elk-Chattaroy Rd)

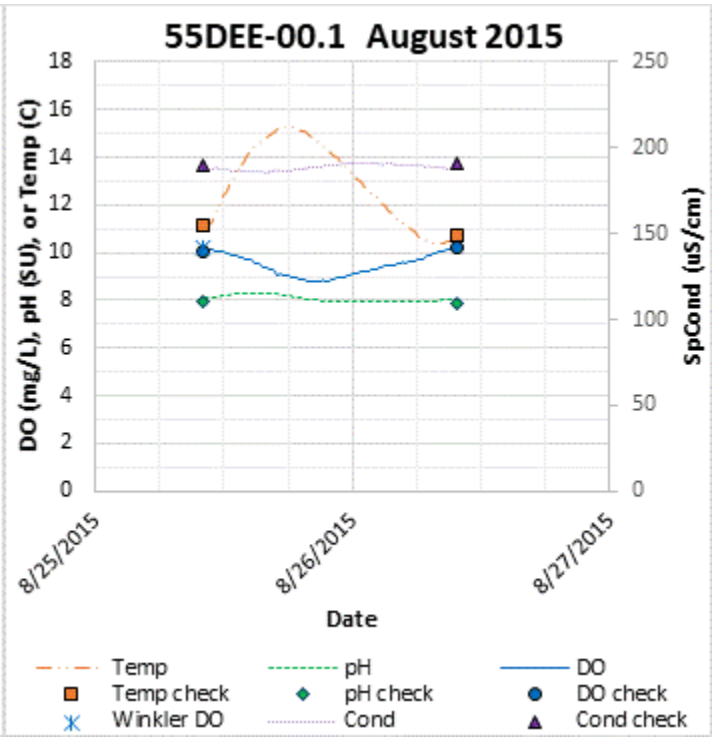


55DEE-00.1 (Deer Ck @ Mouth)

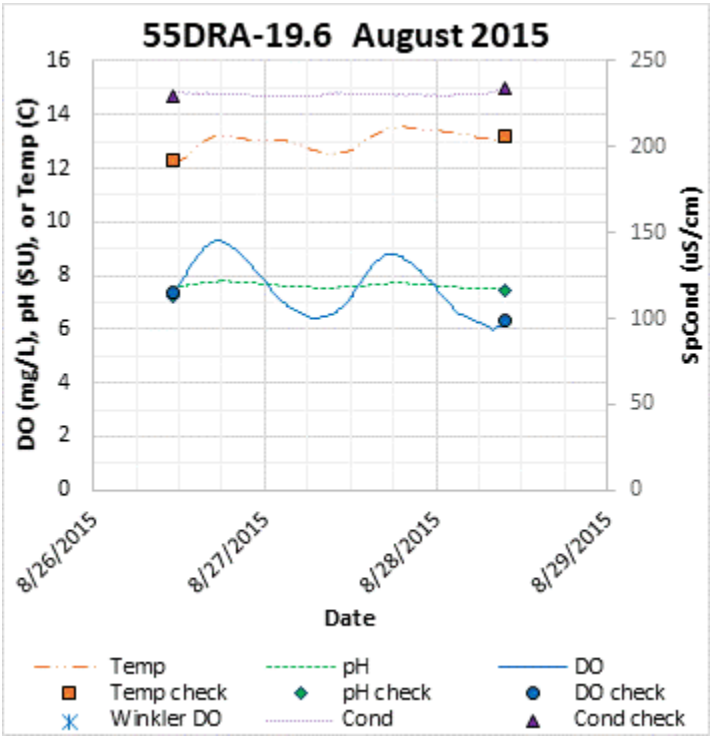




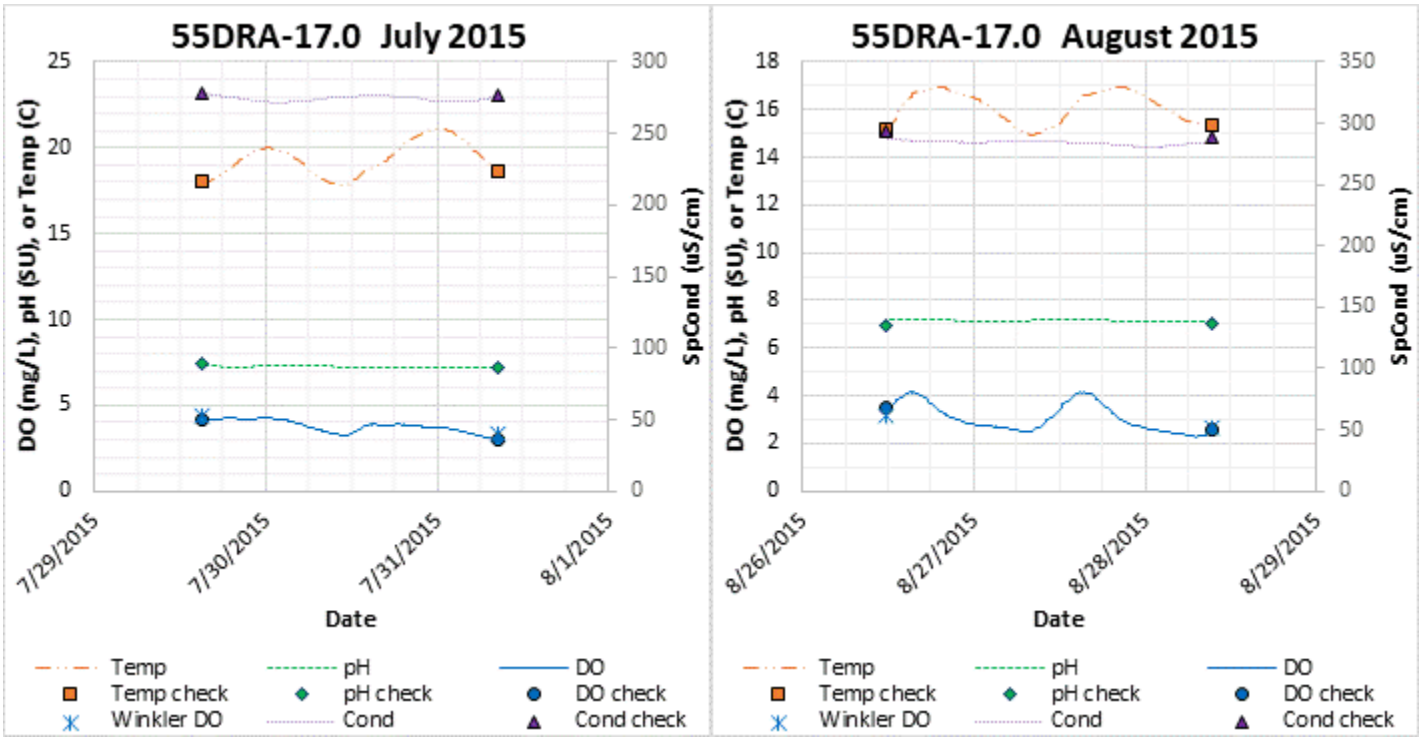




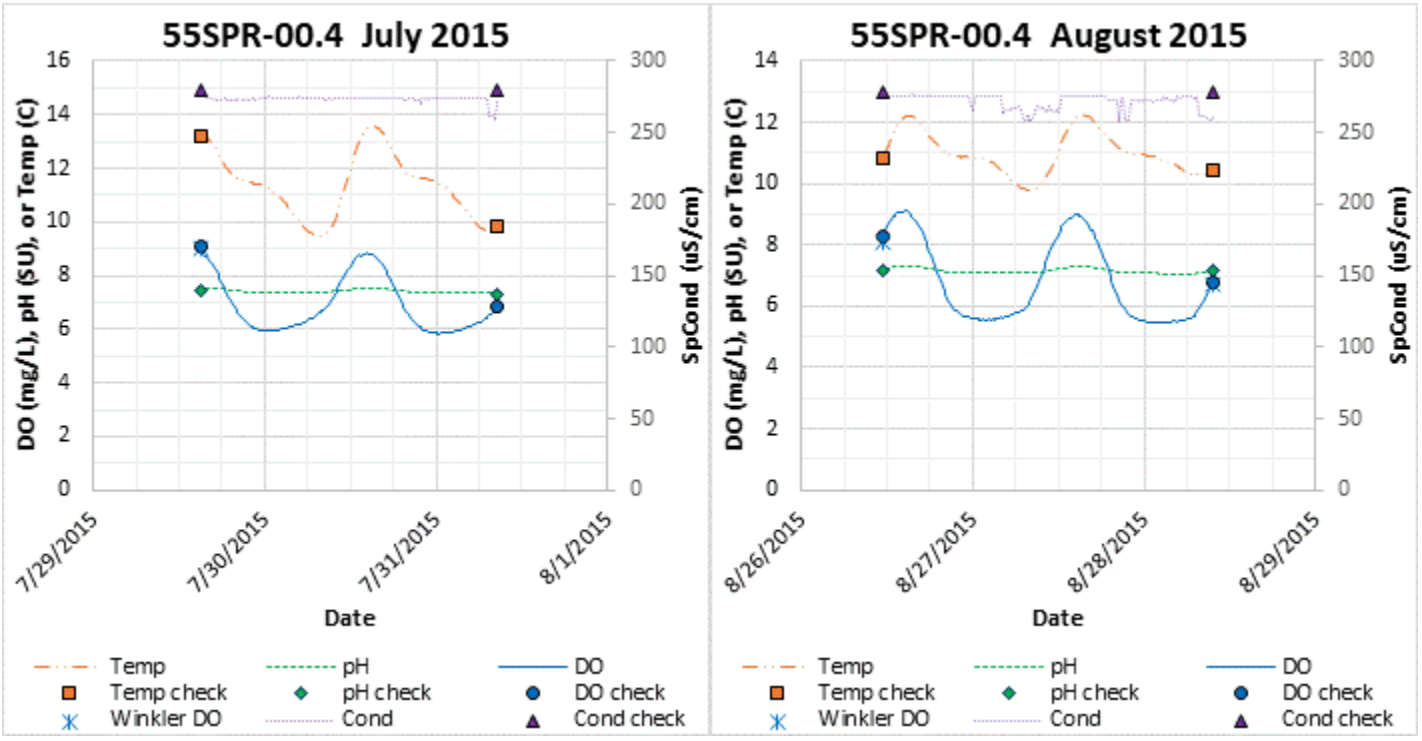
55DRA-19.6 (Dragoon Ck @ Montgomery Rd)



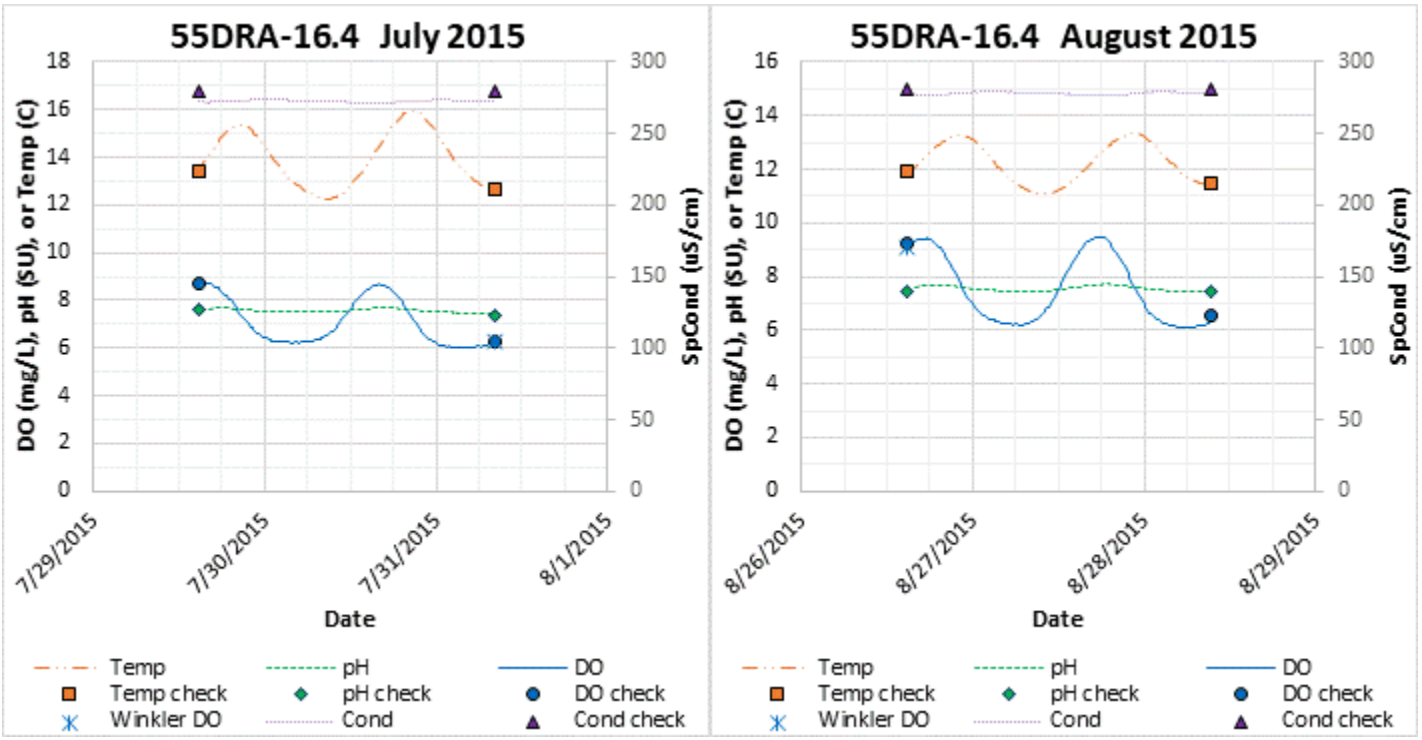
55DRA-17.0 (Dragoon Ck @ Dahl Rd)



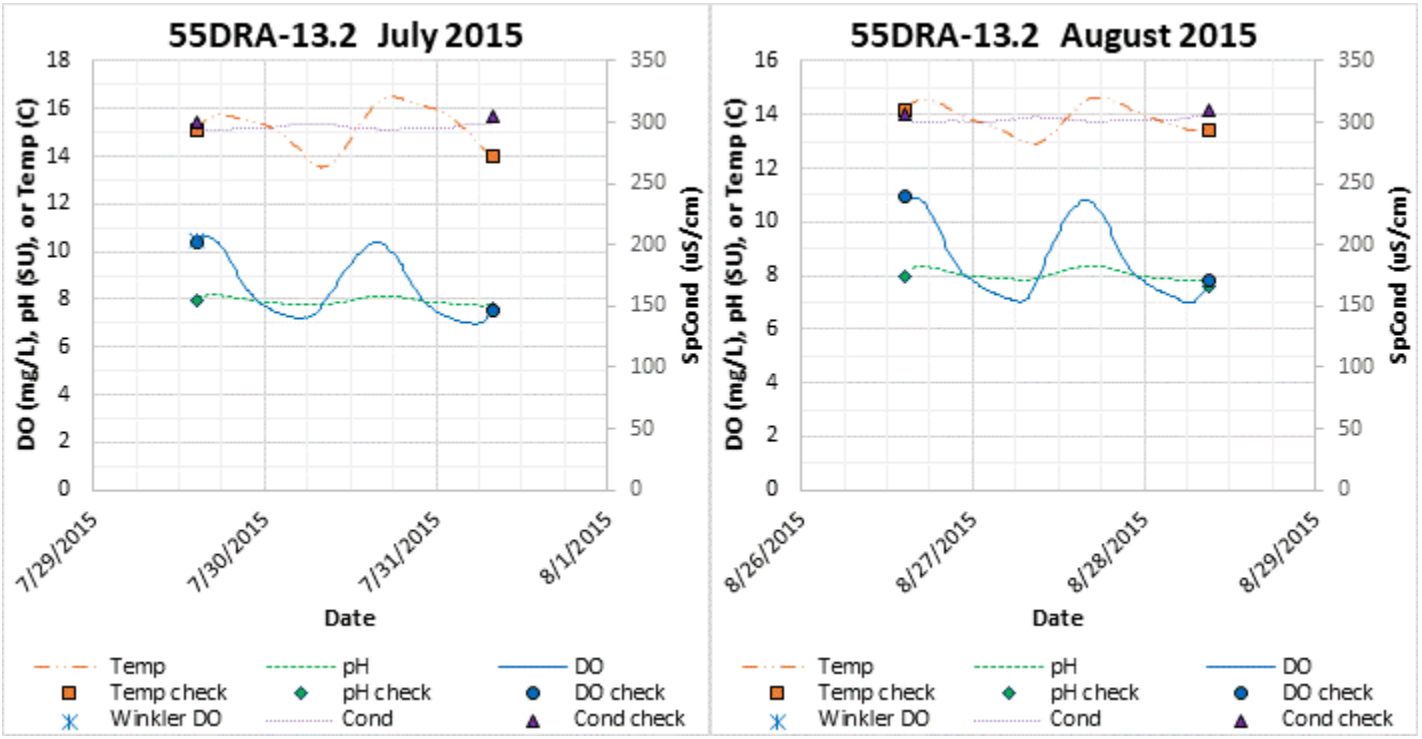
55SPR-00.4 (Spring Ck @ Spring Ck Rd)



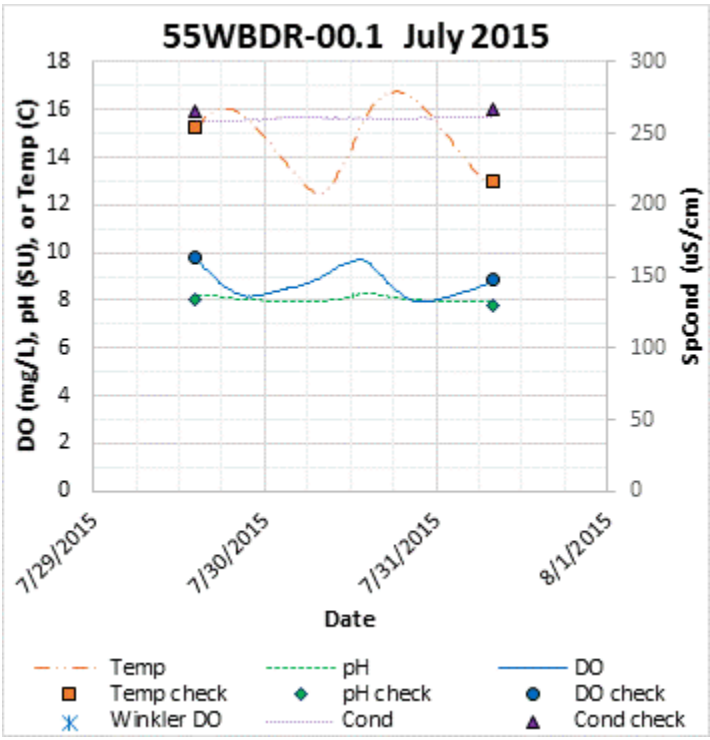
55DRA-16.4 (Dragoon Ck @ Hwy 395 nr Deer Park)

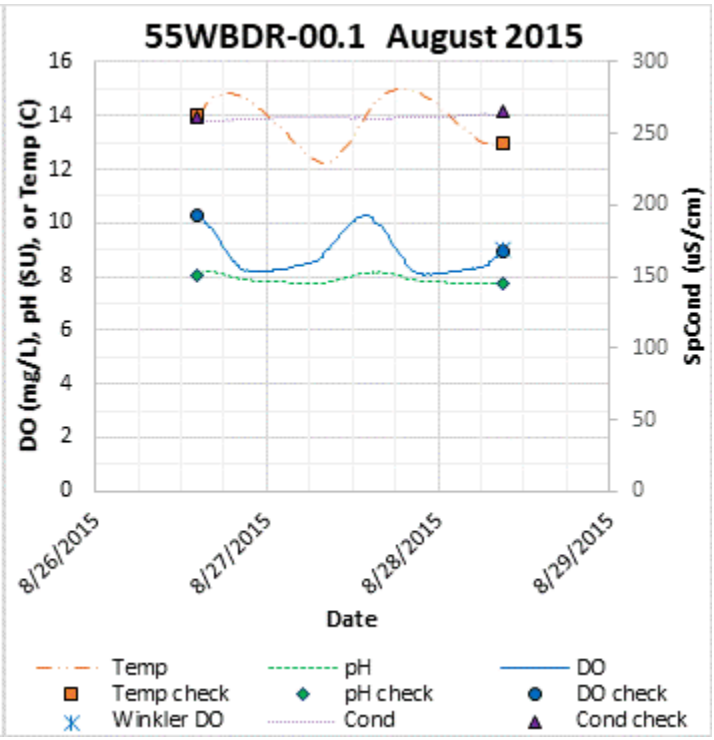


55DRA-13.2 (Dragoon Ck abv W Branch Dragoon Ck)

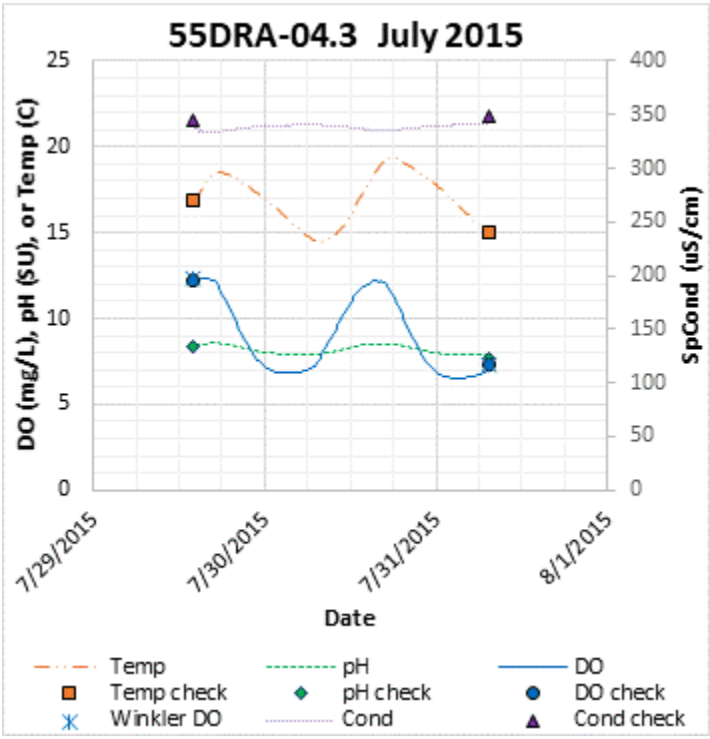


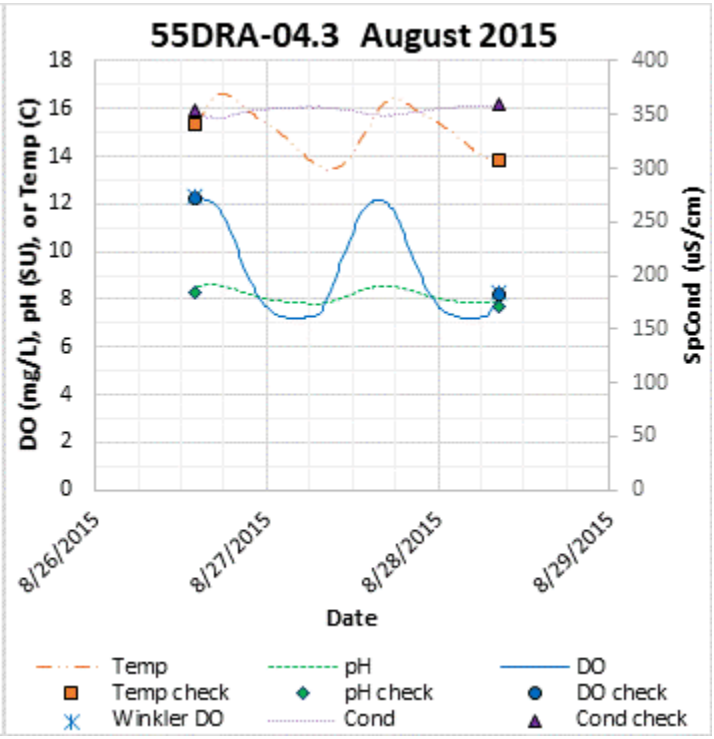
55WBDR-00.1 (W Branch Dragoon Ck @ Mouth)



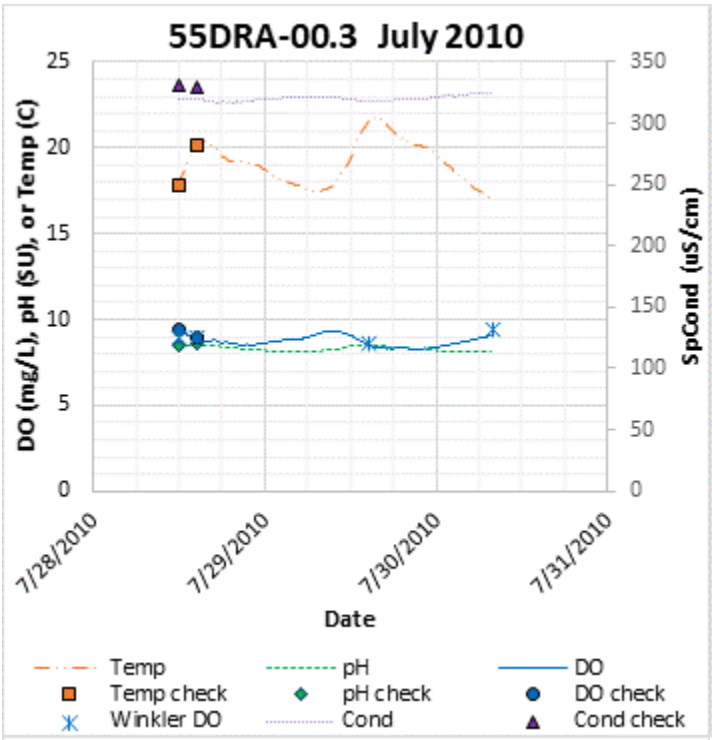


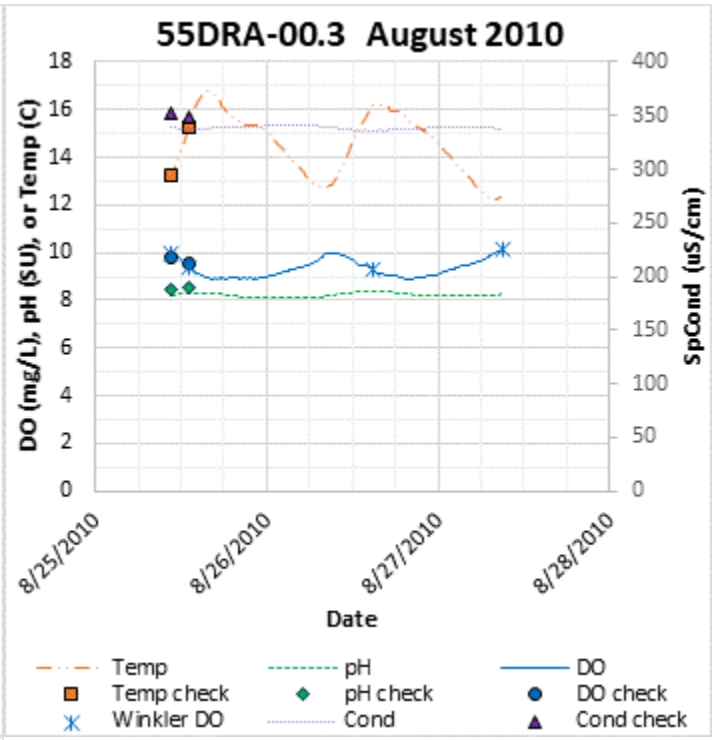
55DRA-04.3 (Dragoon Ck @ North Rd)

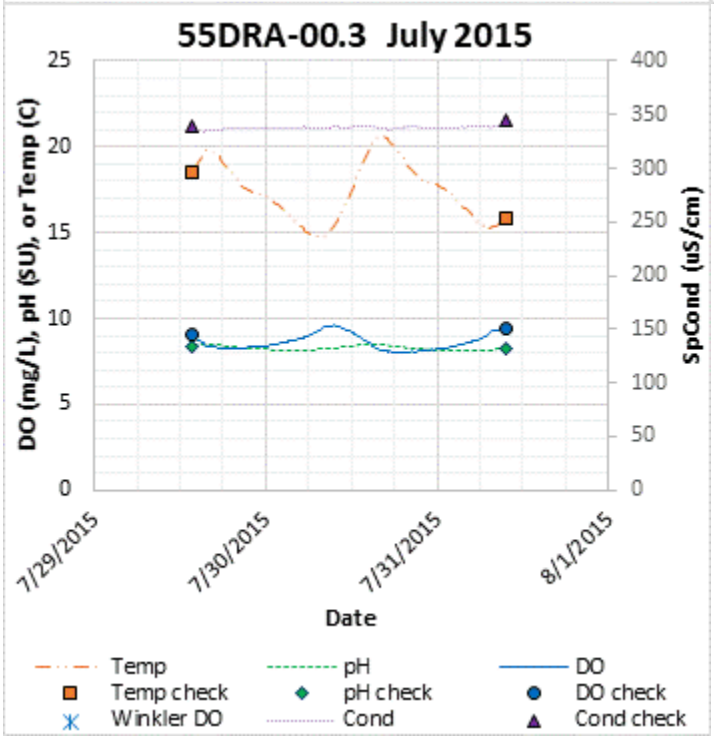




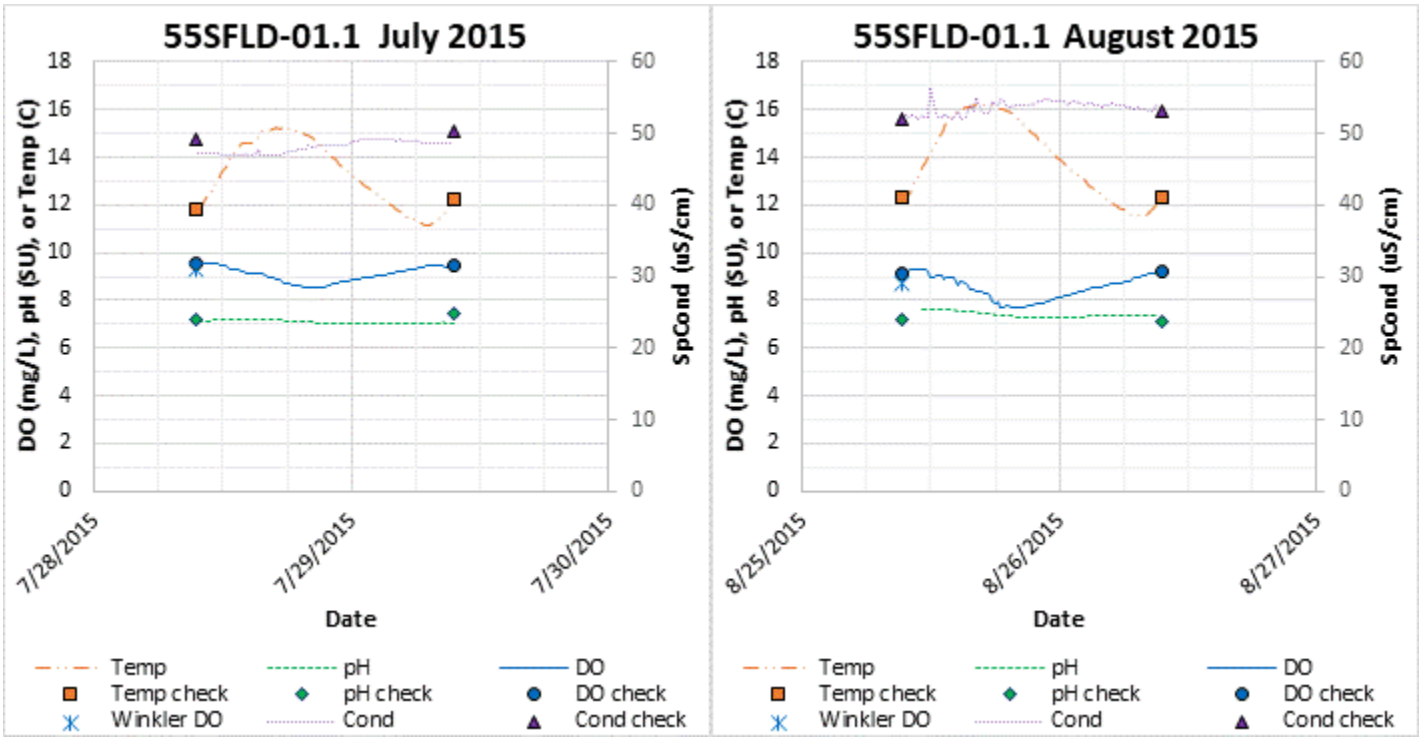
55DRA-00.3 (Dragoon Ck @ Mouth)



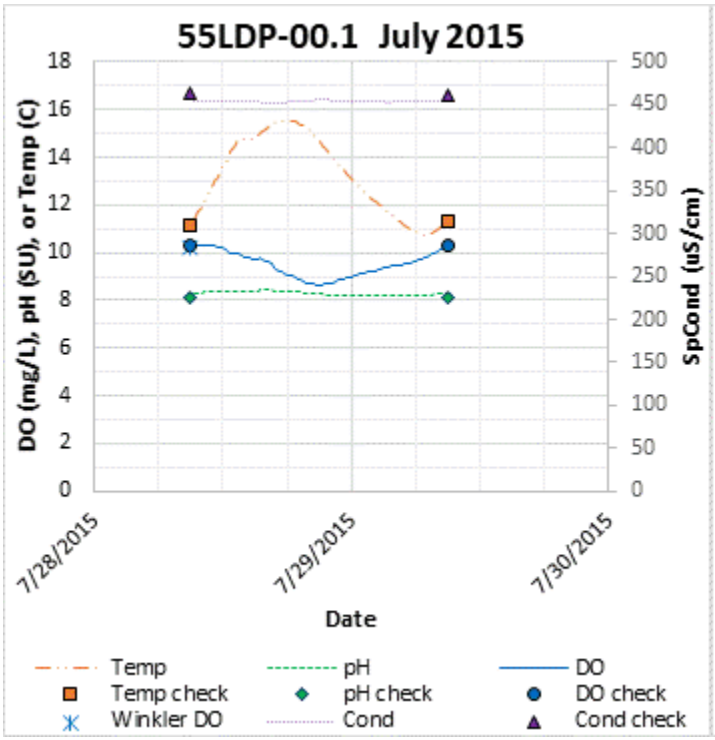


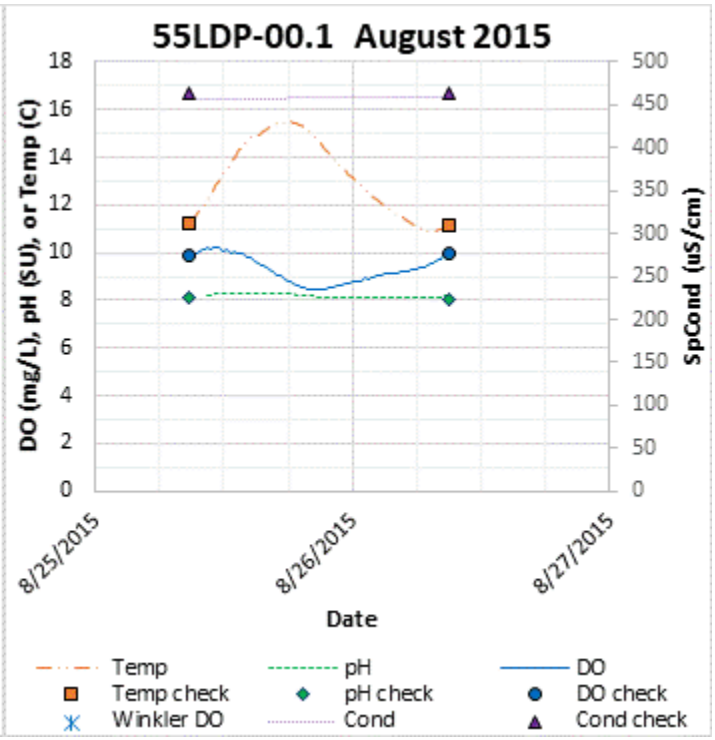


55SFLD-01.1 (South Fork Little Deep Ck @ Big Meadows Rd)

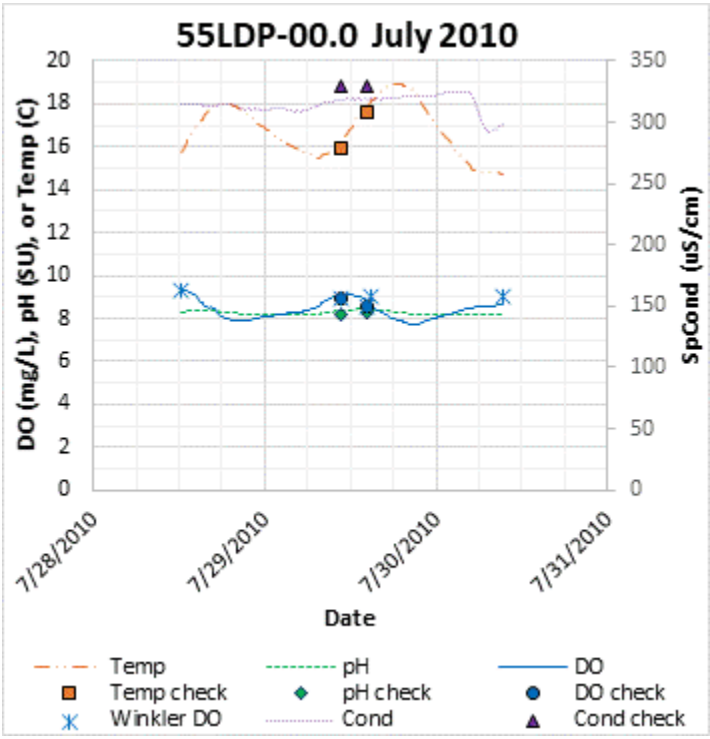


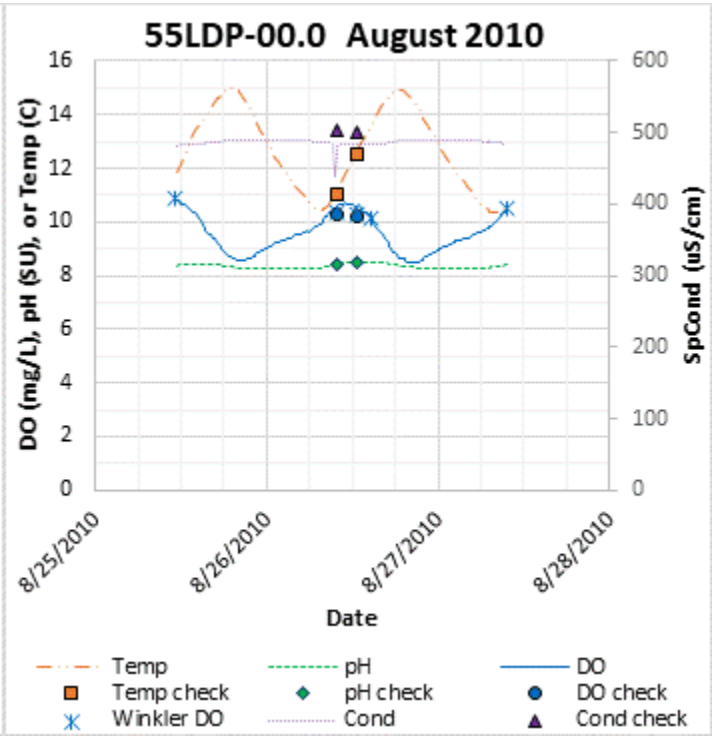
55LDP-00.1 (Little Deep Ck @ Shady Slope Rd)



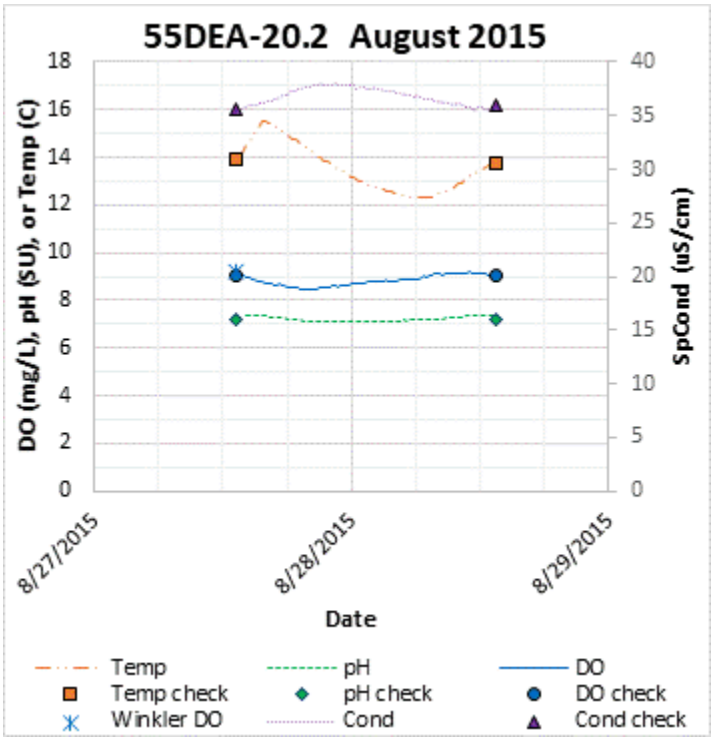


55LDP-00.0 (Little Deep Ck @ Mouth)

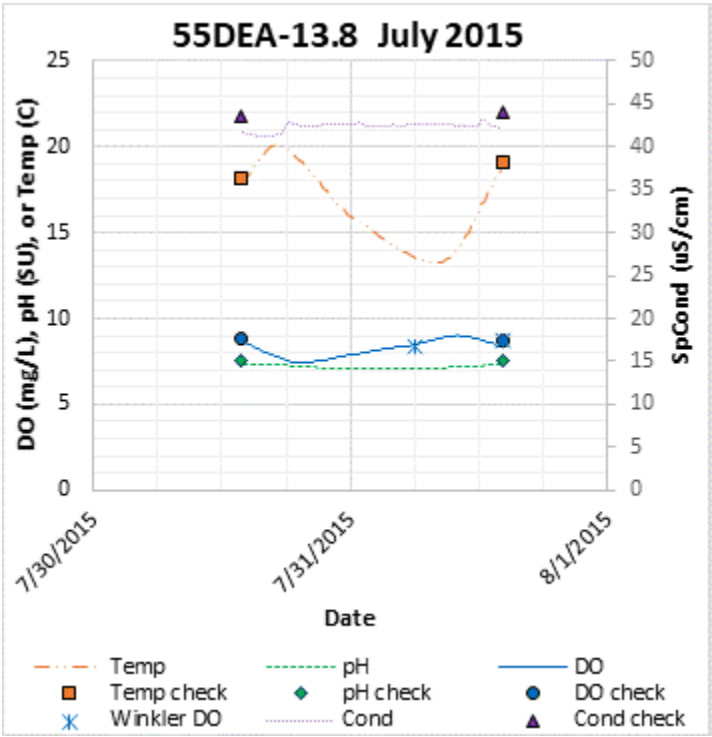


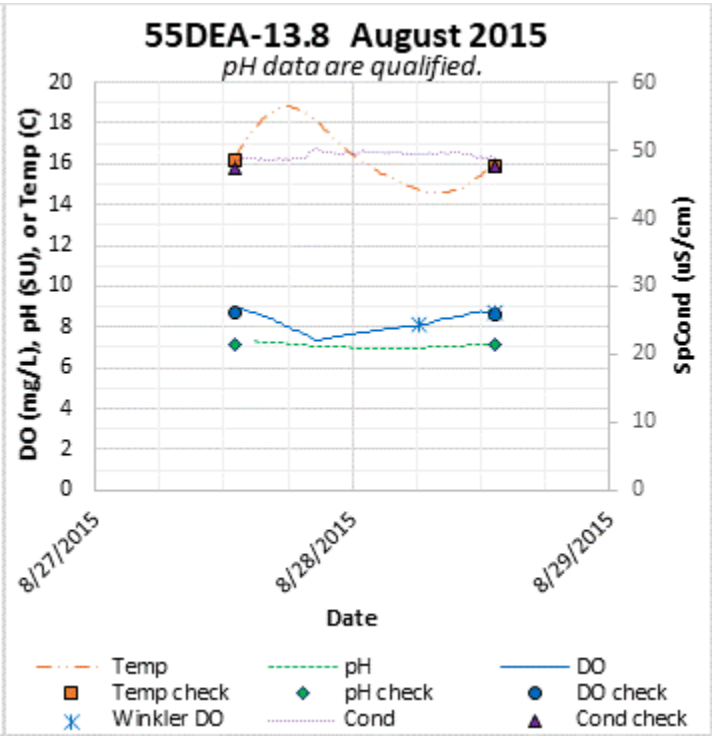


55DEA-20.2 (Deadman Ck @ Mt Spokane State Pk Bdy)

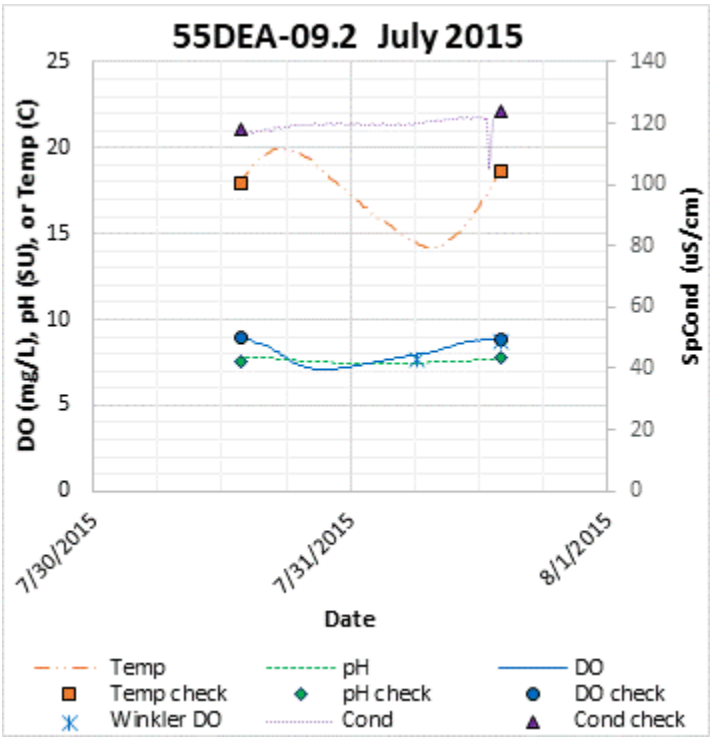


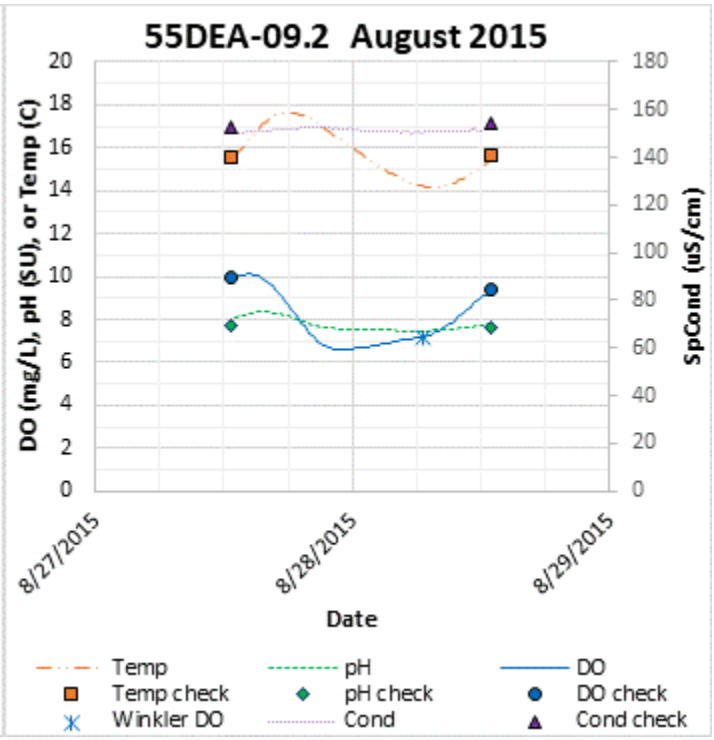
55DEA-13.8 (Deadman Ck @ Holcomb Rd)



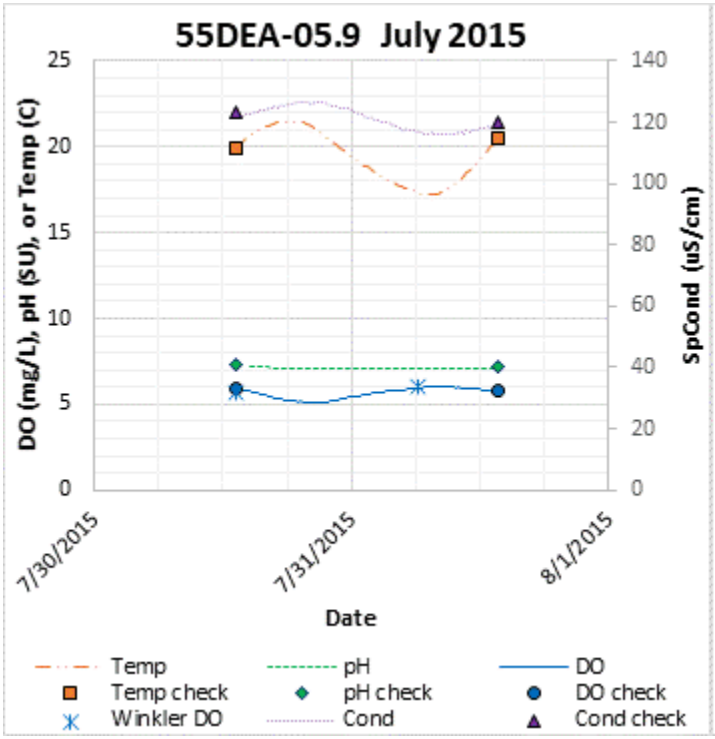


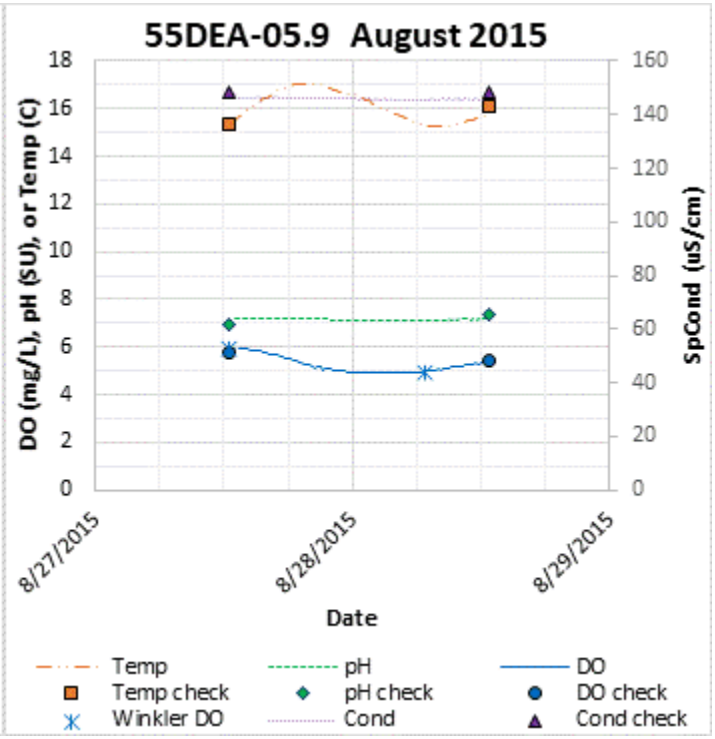
55DEA-09.2 (Deadman Ck @ Heglar Rd)



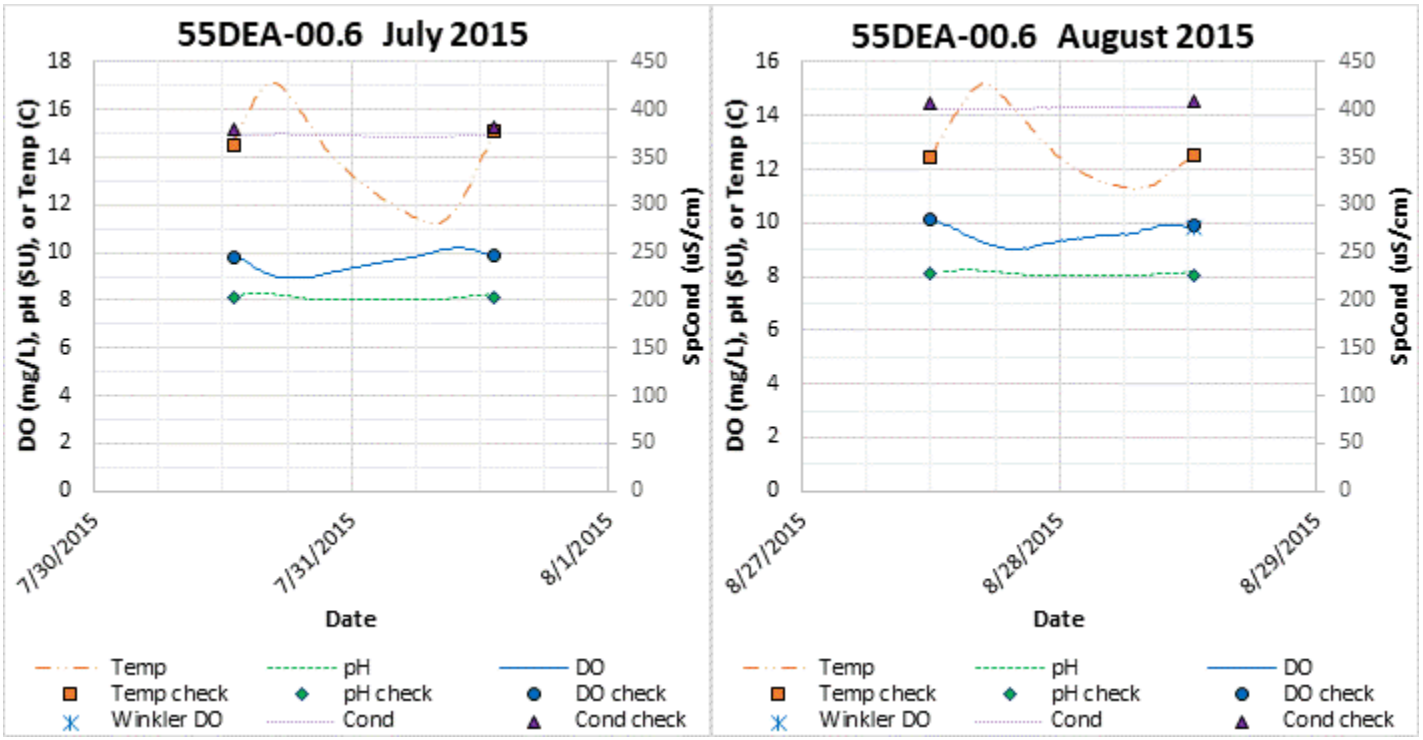


55DEA-05.9 (Deadman Ck @ Bruce Rd)

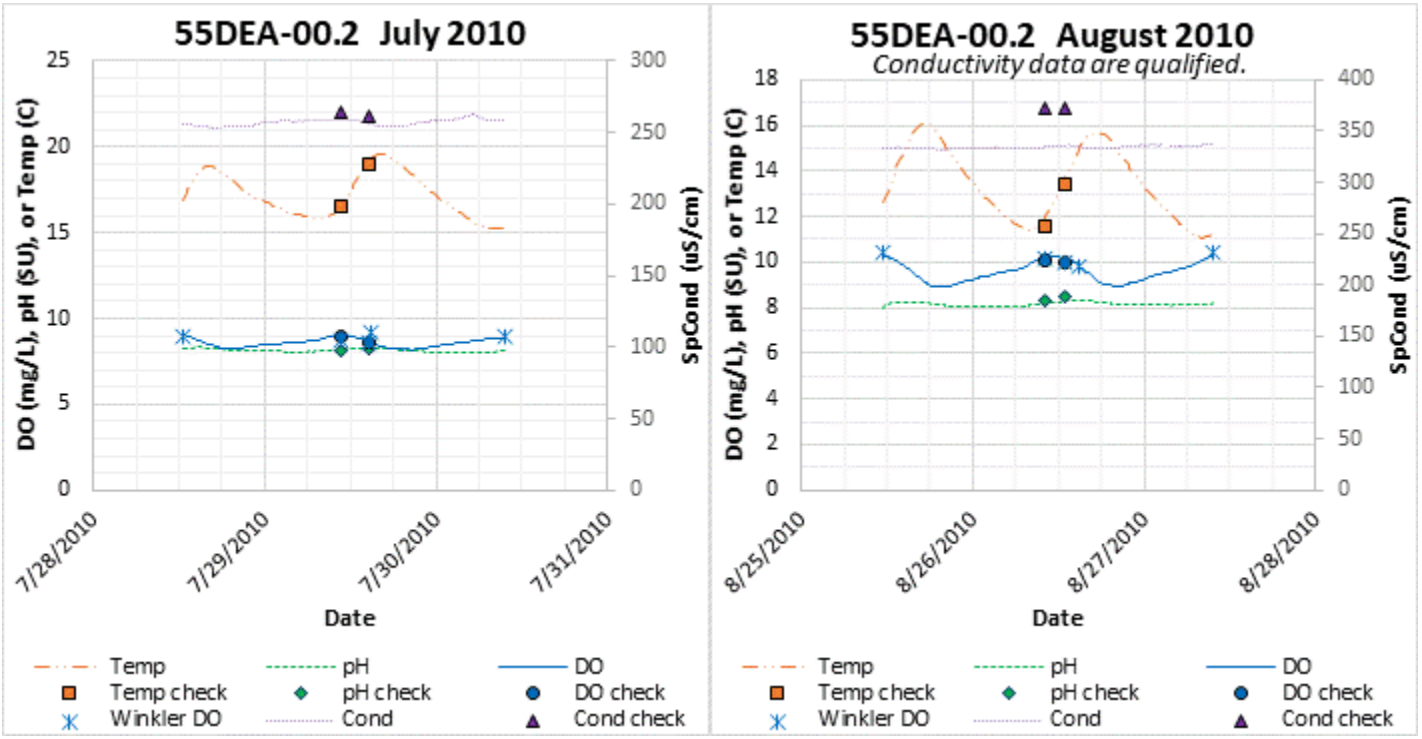




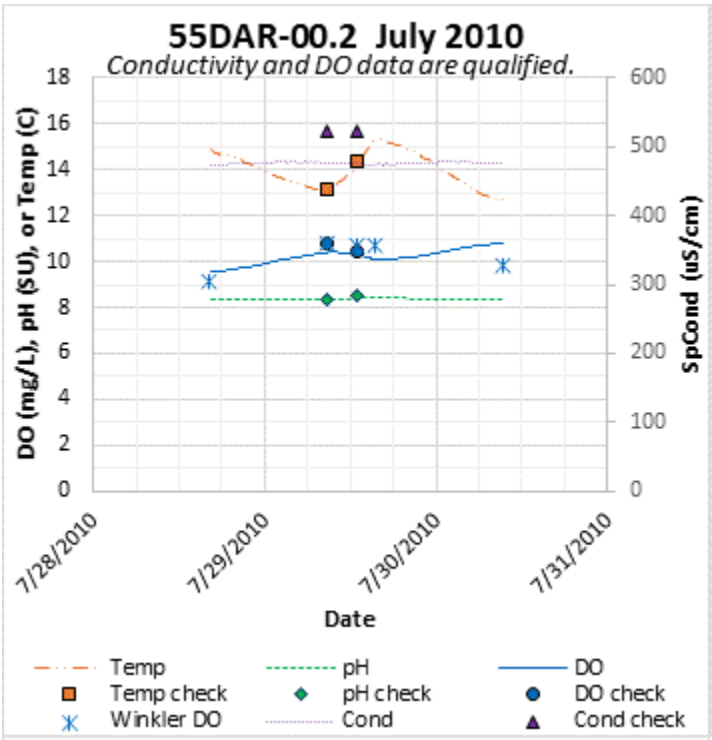
55DEA-00.6 (Deadman Ck @ Shady Slope Rd)

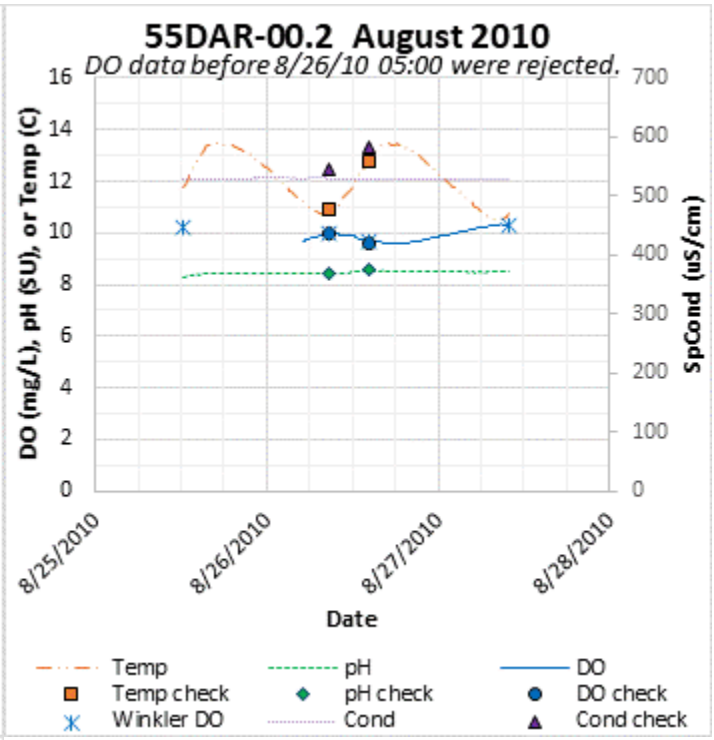


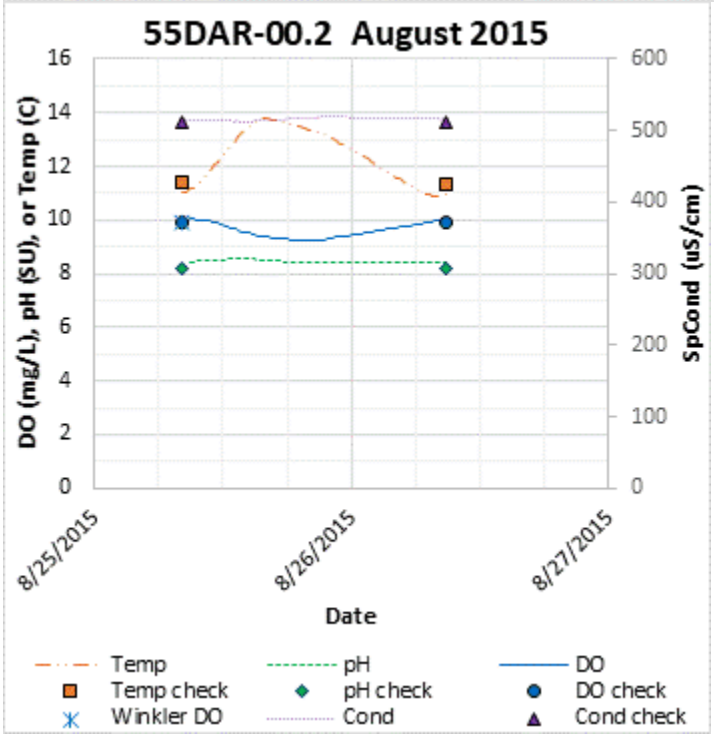
55DEA-00.2 (Deadman Ck blw Little Deep Ck)



55DAR-00.2 (Dartford Ck @ Mouth)

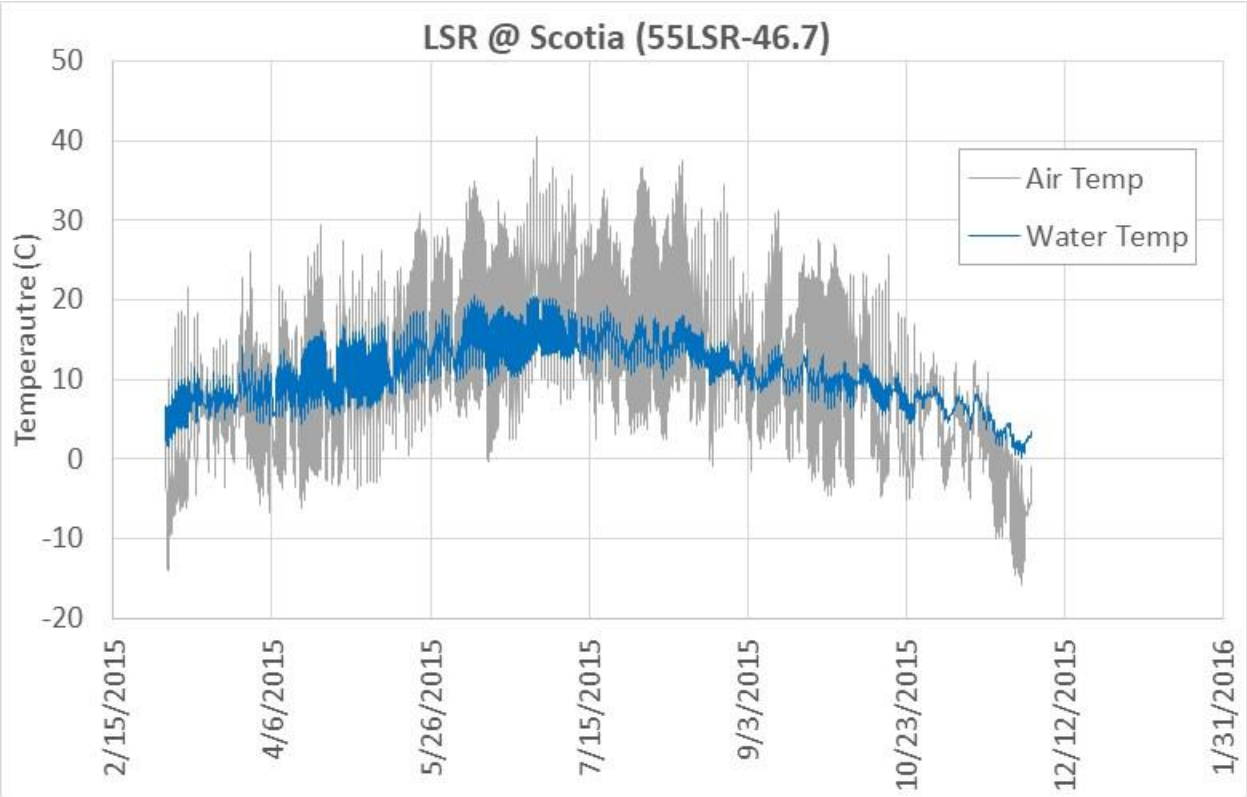


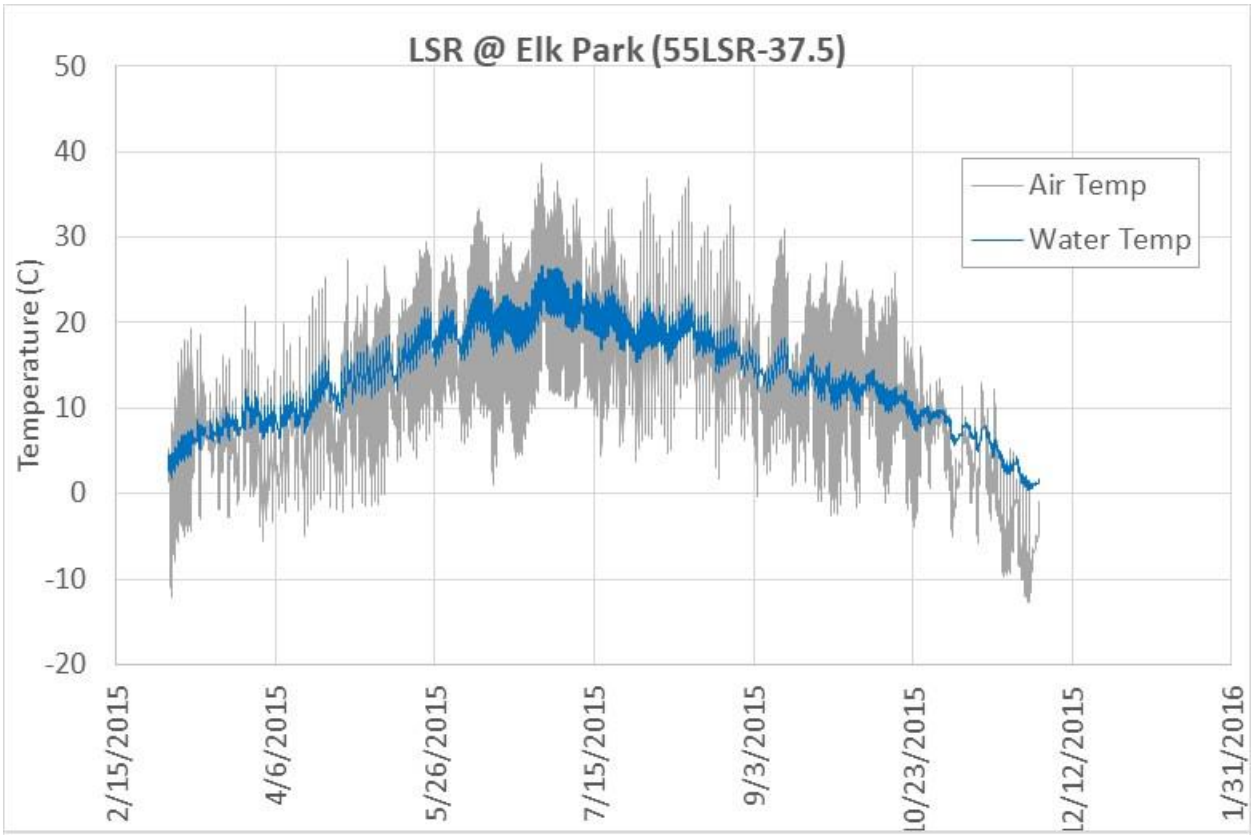


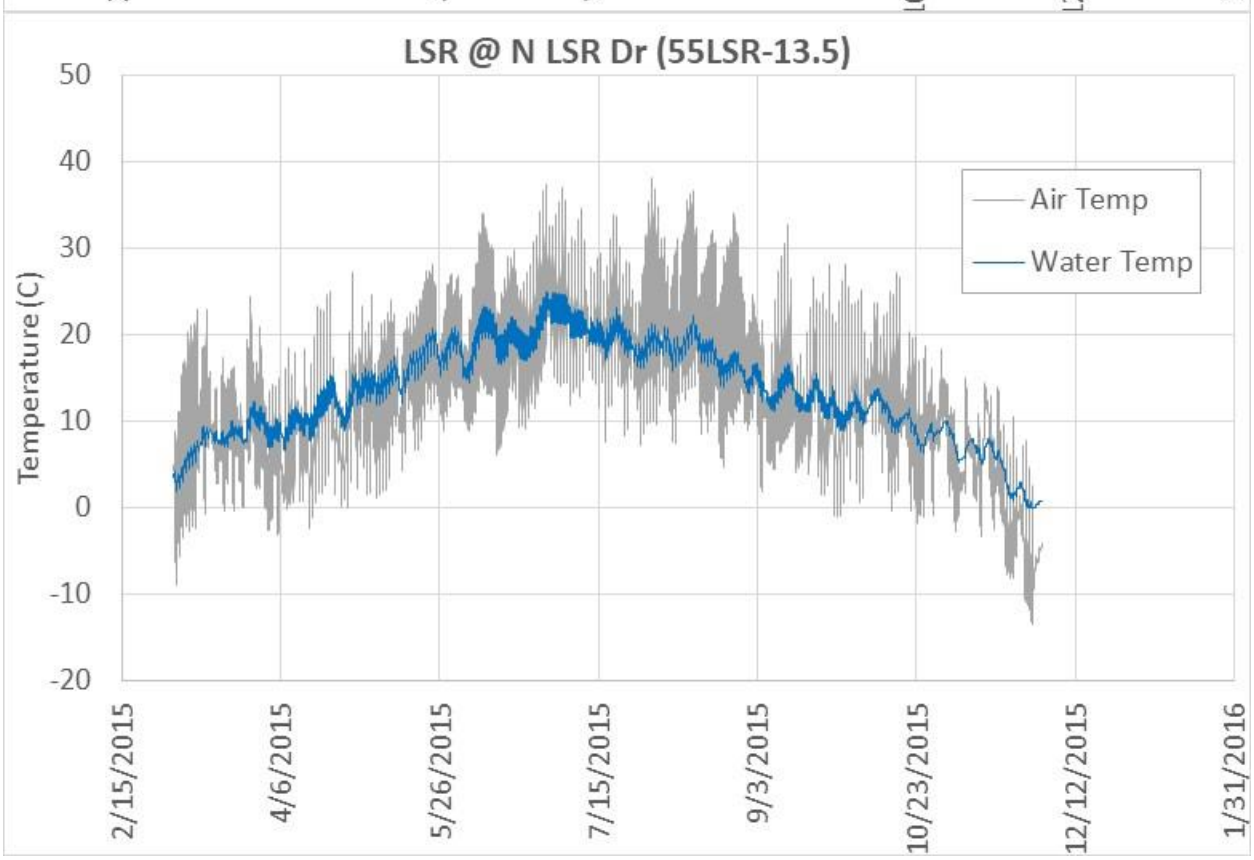


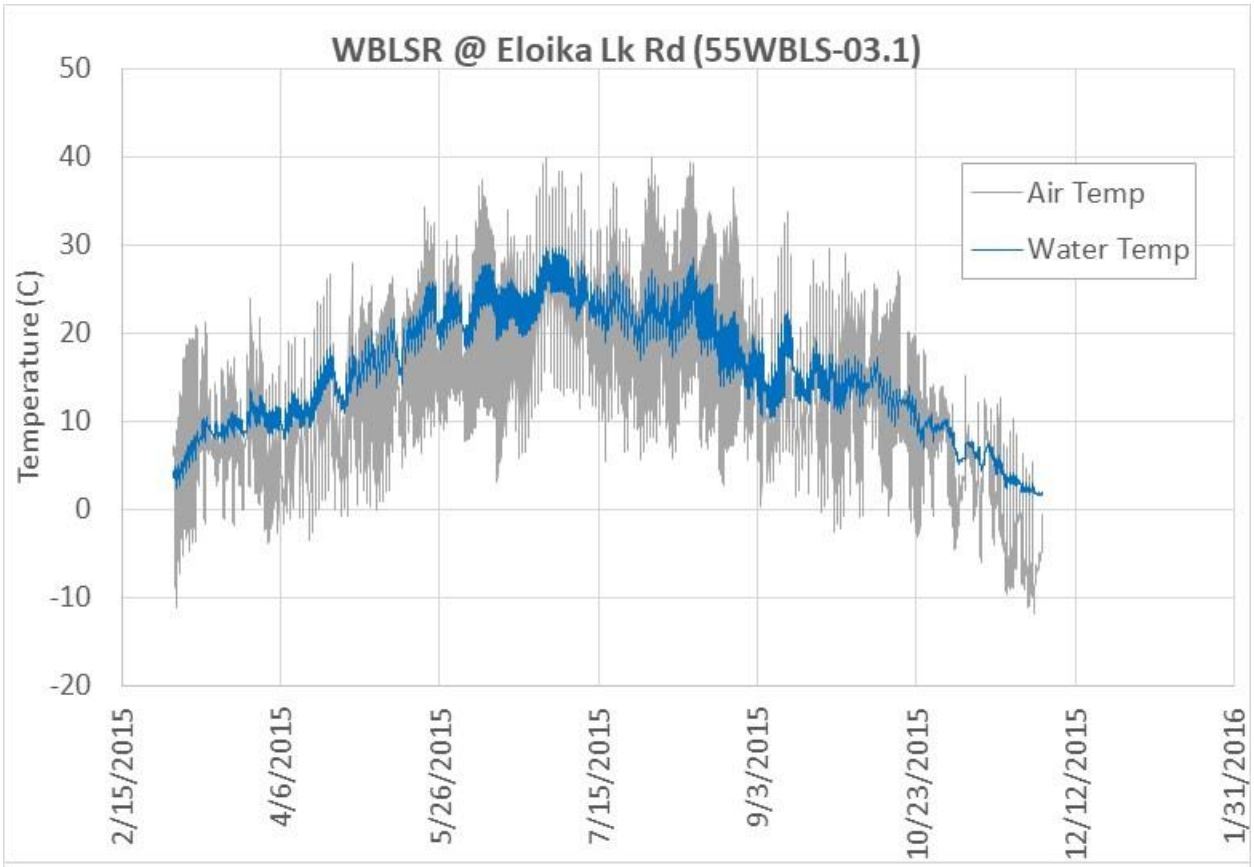
Continuous Temperature

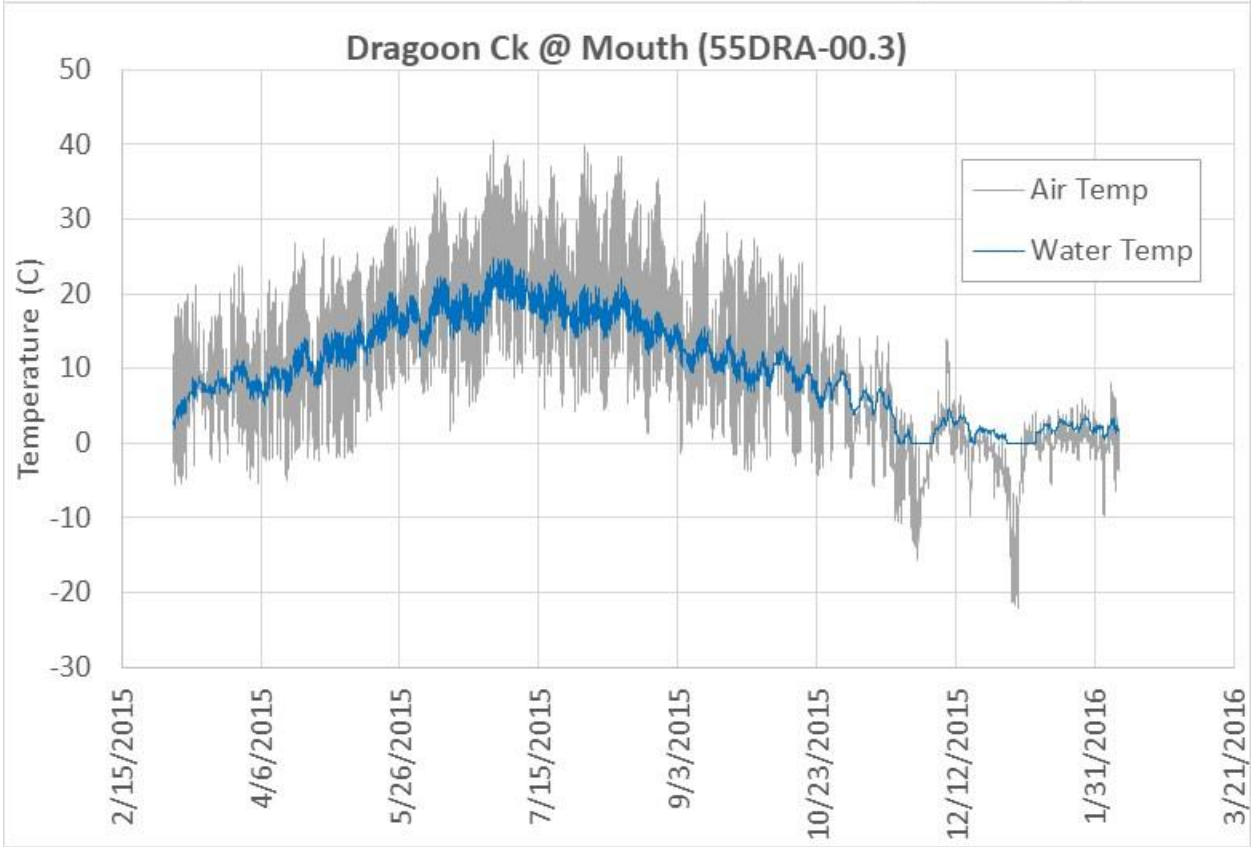
Figure D-5 (Following pages). Plots of continuous temperature collected in 2015.

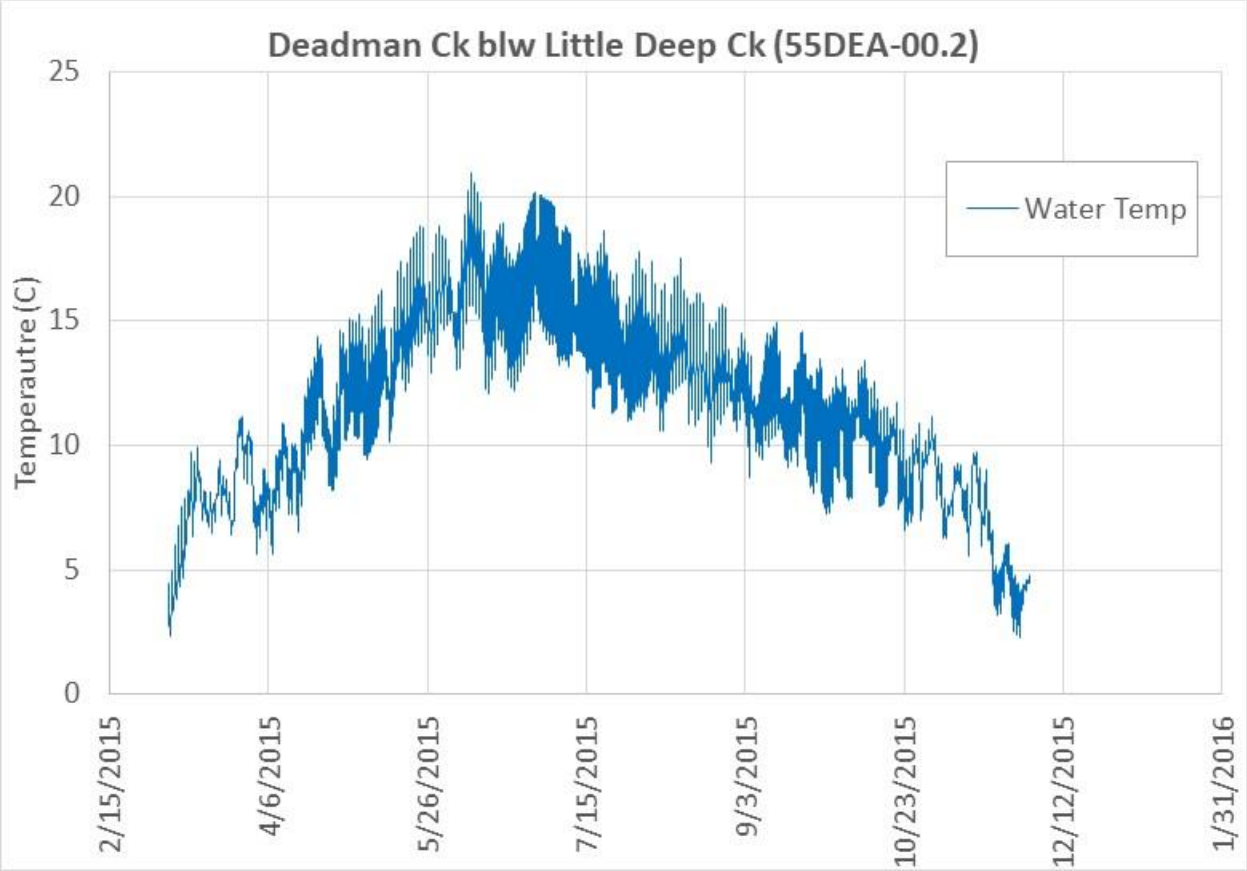



LSR @ Elk Park (55LSR-37.5)
Temperature (C)
50
40
30
20
10
0
-10
-20
Air Temp
Water Temp
2/15/2015
4/6/2015
5/26/2015
7/15/2015
9/3/2015
10/23/2015
12/12/2015
1/31/2016


LSR @ N LSR Dr (55LSR-13.5)
Temperature (C)
50
40
30
20
10
0
-10
-20
Air Temp
Water Temp
2/15/2015
4/6/2015
5/26/2015
7/15/2015
9/3/2015
10/23/2015
12/12/2015
1/31/2016


WBLSR @ Eloika Lk Rd (55WBLS-03.1)
Temperature (C)
50
40
30
20
10
0
-10
-20
Air Temp
Water Temp
2/15/2015
4/6/2015
5/26/2015
7/15/2015
9/3/2015
10/23/2015
12/12/2015
1/31/2016


Dragoon Ck @ Mouth (55DRA-00.3)
Temperature (C)
50
40
30
20
10
0
-10
-20
-30
Air Temp
Water Temp
2/15/2015
4/6/2015
5/26/2015
7/15/2015
9/3/2015
10/23/2015
12/12/2015
1/31/2016
3/21/2016



Periphyton Data

Table D-14. Periphyton taxonomy data collected during 2015.

Taxon	Count	PRA [a]	Portion
Little Spokane River at Elk Park (55LSR-37.5) – 9/16/2015			
Achnanthidium minutissimum	233	37.95%	Diatoms
Achnanthidium pyrenaicum	216	35.18%	Diatoms
Cymbella affinis	42	6.84%	Diatoms
Achnanthidium deflexum	36	5.86%	Diatoms
Homoeothrix	21		Algae
Staurosira construens v. venter	20	3.26%	Diatoms
Leptolyngbya	9		Algae
Amphora pediculus	9	1.47%	Diatoms
Chamaesiphon	5		Algae
Cocconeis pediculus	5	0.81%	Diatoms
Cocconeis placentula sensu lato	5	0.81%	Diatoms
Fragilaria vaucheriae	4	0.65%	Diatoms
Gomphonema parvulum	4	0.65%	Diatoms
Navicula capitatoradiata	3	0.49%	Diatoms
Navicula submuralis	3	0.49%	Diatoms
Planothidium rostratum	3	0.49%	Diatoms
Platessa conspicua	3	0.49%	Diatoms
Ulnaria ulna	3	0.49%	Diatoms
Calothrix	2		Algae

Taxon	Count	PRA [a]	Portion
Achnanthidium exiguum	2	0.33%	Diatoms
Encyonopsis microcephala	2	0.33%	Diatoms
Gomphonema sphaerophorum	2	0.33%	Diatoms
Gomphonema subclavatum	2	0.33%	Diatoms
Nitzschia agnita	2	0.33%	Diatoms
Nitzschia amphibia	2	0.33%	Diatoms
Cladophora	1		Algae
Cosmarium	1		Algae
Monoraphidium	1		Algae
Stigeoclonium	1		Algae
Encyonema silesiacum	1	0.16%	Diatoms
Fragilaria capucina v. gracilis	1	0.16%	Diatoms
Geissleria acceptata	1	0.16%	Diatoms
Gomphonema pumilum v. rigidum	1	0.16%	Diatoms
Melosira varians	1	0.16%	Diatoms
Navicula cryptotenella	1	0.16%	Diatoms
Nitzschia	1	0.16%	Diatoms
Nitzschia inconspicua	1	0.16%	Diatoms
Pseudostaurosira brevistriata	1	0.16%	Diatoms
Reimeria sinuata	1	0.16%	Diatoms
Rhoicosphenia abbreviata	1	0.16%	Diatoms
Staurosirella pinnata	1	0.16%	Diatoms
Synedra rumpens	1	0.16%	Diatoms
Little Spokane River at Chattaroy (55LSR-23.4) – 9/18/2015			
Achnanthidium druartii	180	28.71%	Diatoms
Achnanthidium minutissimum	136	21.69%	Diatoms
Achnanthidium pyrenaicum	77	12.28%	Diatoms
Achnanthidium deflexum	63	10.05%	Diatoms
Cymbella affinis	51	8.13%	Diatoms
Cocconeis placentula sensu lato	13	2.07%	Diatoms
Staurosira construens v. venter	11	1.75%	Diatoms
Encyonema silesiacum	8	1.28%	Diatoms
Cymbella subturgidula	7	1.12%	Diatoms
Opephora olsenii	7	1.12%	Diatoms
Karayevia clevei	6	0.96%	Diatoms
Staurosira construens v. binodis	6	0.96%	Diatoms
Diatoma vulgaris	5	0.80%	Diatoms
Melosira varians	5	0.80%	Diatoms
Eolimna minima	4	0.64%	Diatoms
Fragilaria mesolepta	4	0.64%	Diatoms
Staurosirella pinnata	4	0.64%	Diatoms
Geissleria acceptata	3	0.48%	Diatoms
Navicula capitatoradiata	3	0.48%	Diatoms
Planothidium frequentissimum	3	0.48%	Diatoms
Planothidium granum	3	0.48%	Diatoms
Homoeothrix	2		Algae
Scenedesmus	2		Algae
Caloneis bacillum	2	0.32%	Diatoms
Encyonopsis microcephala	2	0.32%	Diatoms
Fragilaria vaucheriae	2	0.32%	Diatoms
Gomphonema rhombicum	2	0.32%	Diatoms
Navicula antonii	2	0.32%	Diatoms

Taxon	Count	PRA [a]	Portion
Navicula submuralis	2	0.32%	Diatoms
Nitzschia acicularis	2	0.32%	Diatoms
Nitzschia fonticola	2	0.32%	Diatoms
Nitzschia gracilis	2	0.32%	Diatoms
Nitzschia supralitorea	2	0.32%	Diatoms
Rhoicosphenia abbreviata	2	0.32%	Diatoms
Monoraphidium	1		Algae
Mougeotia	1		Algae
Oedogonium	1		Algae
Pediastrum	1		Algae
Stigeoclonium	1		Algae
Cocconeis pediculus	1	0.16%	Diatoms
Gomphonema kobayasii	1	0.16%	Diatoms
Gomphonema parvulum	1	0.16%	Diatoms
Planothidium lanceolatum	1	0.16%	Diatoms
Planothidium rostratum	1	0.16%	Diatoms
Pseudostaurosira brevistriata	1	0.16%	Diatoms
Little Spokane River at Pine River Park (55LSR-11.7) – 9/24/2015			
Achnanthidium pyrenaicum	203	33.06%	Diatoms
Achnanthidium deflexum	64	10.42%	Diatoms
Nitzschia fonticola	61	9.93%	Diatoms
Cymbella turgidula	57	9.28%	Diatoms
Cymbella affinis	52	8.47%	Diatoms
Achnanthidium minutissimum	48	7.82%	Diatoms
Gomphonema parvulum	22	3.58%	Diatoms
Phormidium	16		Algae
Cocconeis placentula sensu lato	14	2.28%	Diatoms
Diatoma vulgaris	11	1.79%	Diatoms
Navicula capitatoradiata	11	1.79%	Diatoms
Leptolyngbya	9		Algae
Navicula tripunctata	7	1.14%	Diatoms
Staurosira construens v. venter	7	1.14%	Diatoms
Amphora pediculus	5	0.81%	Diatoms
Nitzschia archibaldii	5	0.81%	Diatoms
Scenedesmus	4		Algae
Ulnaria contracta	4	0.65%	Diatoms
Achnanthidium druartii	3	0.49%	Diatoms
Diatoma moniliformis	3	0.49%	Diatoms
Gomphonema pumilum v. rigidum	3	0.49%	Diatoms
Rhoicosphenia abbreviata	3	0.49%	Diatoms
Monoraphidium	2		Algae
Cocconeis pediculus	2	0.33%	Diatoms
Gomphonema	2	0.33%	Diatoms
Gomphonema kobayasii	2	0.33%	Diatoms
Karayevia clevei	2	0.33%	Diatoms
Navicula reichardtiana	2	0.33%	Diatoms
Nitzschia dissipata	2	0.33%	Diatoms
Nitzschia palea	2	0.33%	Diatoms
Coelastrum	1		Algae
Lyngbya	1		Algae
Stigeoclonium	1		Algae
Cymbella tumida	1	0.16%	Diatoms

Taxon	Count	PRA [a]	Portion
Encyonema silesiacum	1	0.16%	Diatoms
Geissleria acceptata	1	0.16%	Diatoms
Gomphoneis herculeana	1	0.16%	Diatoms
Gomphoneis olivaceum	1	0.16%	Diatoms
Navicula antonii	1	0.16%	Diatoms
Navicula cryptotenella	1	0.16%	Diatoms
Navicula gregaria	1	0.16%	Diatoms
Nitzschia columbiana	1	0.16%	Diatoms
Opephora olsenii	1	0.16%	Diatoms
Planothidium frequentissimum	1	0.16%	Diatoms
Planothidium granum	1	0.16%	Diatoms
Planothidium haynaldii	1	0.16%	Diatoms
Planothidium rostratum	1	0.16%	Diatoms
Sellaphora pupula	1	0.16%	Diatoms
Staurosira construens v. binodis	1	0.16%	Diatoms
Stephanocyclus meneghiniana	1	0.16%	Diatoms
West Br Little Spokane R at Fan Lk Rd (55WBLS-07.7) – 9/16/2015			
Achnanthidium minutissimum	166	27.57%	Diatoms
Staurosira construens v. venter	35	5.81%	Diatoms
Cocconeis placentula sensu lato	28	4.65%	Diatoms
Nitzschia acidoclinata	24	3.99%	Diatoms
Staurosira construens	22	3.65%	Diatoms
Eolimna minima	20	3.32%	Diatoms
Nitzschia archibaldii	20	3.32%	Diatoms
Adlafia minuscula	17	2.82%	Diatoms
Nitzschia supralitorea	17	2.82%	Diatoms
Leptolyngbya	15		Algae
Nitzschia dissipata	15	2.49%	Diatoms
Staurosirella pinnata	15	2.49%	Diatoms
Navicula cryptocephala	14	2.33%	Diatoms
Gomphonema subclavatum	13	2.16%	Diatoms
Planothidium daui	13	2.16%	Diatoms
Scenedesmus	12		Algae
Mayamaea atomus	12	1.99%	Diatoms
Navicula cryptotenella	12	1.99%	Diatoms
Nitzschia bacillum	12	1.99%	Diatoms
Opephora olsenii	11	1.83%	Diatoms
Pseudostaurosira brevistriata	11	1.83%	Diatoms
Fragilaria capucina v. gracilis	10	1.66%	Diatoms
Staurosira construens v. binodis	10	1.66%	Diatoms
Monoraphidium	9		Algae
Cocconeis pediculus	9	1.50%	Diatoms
Calothrix	8		Algae
Chamaepinnularia	8	1.33%	Diatoms
Fragilaria vaucheriae	8	1.33%	Diatoms
Aphanocapsa	7		Algae
Planothidium frequentissimum	7	1.16%	Diatoms
Fragilaria capucina	5	0.83%	Diatoms
Nitzschia gracilis	5	0.83%	Diatoms
Sellaphora seminulum	5	0.83%	Diatoms
Geissleria acceptata	4	0.66%	Diatoms
Navicula antonii	4	0.66%	Diatoms

Taxon	Count	PRA [a]	Portion
Nitzschia inconspicua	4	0.66%	Diatoms
Planothidium rostratum	4	0.66%	Diatoms
Rhoicosphenia abbreviata	4	0.66%	Diatoms
Oedogonium	3		Algae
Stigeoclonium	3		Algae
Navicula germainii	3	0.50%	Diatoms
Navicula submuralis	3	0.50%	Diatoms
Nitzschia acicularis	3	0.50%	Diatoms
Stauroneis kriegeri	3	0.50%	Diatoms
Chroococcus	2		Algae
Pediastrum	2		Algae
Tetraedron	2		Algae
Achnanthidium exiguum	2	0.33%	Diatoms
Achnanthidium rivulare	2	0.33%	Diatoms
Fragilaria crotonensis	2	0.33%	Diatoms
Gomphonema rhombicum	2	0.33%	Diatoms
Navicula concentrica	2	0.33%	Diatoms
Nitzschia palea	2	0.33%	Diatoms
Nitzschia subtilis	2	0.33%	Diatoms
Cladophora	1		Algae
Merismopedia	1		Algae
Mougeotia	1		Algae
Achnanthidium deflexum	1	0.17%	Diatoms
Amphora pediculus	1	0.17%	Diatoms
Aulacoseira	1	0.17%	Diatoms
Eolimna subminuscula	1	0.17%	Diatoms
Fallacia omissa	1	0.17%	Diatoms
Karayevia clevei	1	0.17%	Diatoms
Karayevia laterostrata	1	0.17%	Diatoms
Kobayasiella subtilissima	1	0.17%	Diatoms
Navicula capitatoradiata	1	0.17%	Diatoms
Navicula veneta	1	0.17%	Diatoms
Psammothidium marginulatum	1	0.17%	Diatoms
Stephanocyclus meneghiniana	1	0.17%	Diatoms
Dragoon Ck at DNR Campground (55DRA-05.4) – 9/16/2015			
Achnanthidium pyrenaicum	435	71.31%	Diatoms
Achnanthidium deflexum	86	14.10%	Diatoms
Nitzschia amphibia	18	2.95%	Diatoms
Phormidium	13		Algae
Amphora pediculus	11	1.80%	Diatoms
Achnanthidium minutissimum	10	1.64%	Diatoms
Cocconeis placentula sensu lato	9	1.48%	Diatoms
Undetermined alga	7		Algae
Rhoicosphenia abbreviata	5	0.82%	Diatoms
Nitzschia fonticola	4	0.66%	Diatoms
Pseudostaurosira brevistriata	4	0.66%	Diatoms
Stephanocyclus meneghiniana	4	0.66%	Diatoms
Cymbella affinis	3	0.49%	Diatoms
Gomphonema minutum	3	0.49%	Diatoms
Hippodonta capitata	3	0.49%	Diatoms
Planothidium frequentissimum	3	0.49%	Diatoms
Scenedesmus	2		Algae

Taxon	Count	PRA [a]	Portion
Diatoma moniliformis	2	0.33%	Diatoms
Nitzschia archibaldii	2	0.33%	Diatoms
Cladophora	1		Algae
Closterium	1		Algae
Monoraphidium	1		Algae
Oedogonium	1		Algae
Cocconeis pediculus	1	0.16%	Diatoms
Diatoma vulgaris	1	0.16%	Diatoms
Eolimna subminuscula	1	0.16%	Diatoms
Gomphonema kobayasii	1	0.16%	Diatoms
Nitzschia inconspicua	1	0.16%	Diatoms
Placoneis clementioides	1	0.16%	Diatoms
Sellaphora seminulum	1	0.16%	Diatoms
Ulnaria ulna	1	0.16%	Diatoms
Deadman Ck at Holcomb Rd (55DEA-13.8) – 9/18/2015			
Rhoicosphenia abbreviata	204	33.28%	Diatoms
Eolimna minima	48	7.83%	Diatoms
Nitzschia dissipata	28	4.57%	Diatoms
Gomphonema minutum	27	4.40%	Diatoms
Planothidium frequentissimum	25	4.08%	Diatoms
Planothidium lanceolatum	25	4.08%	Diatoms
Nitzschia bacillum	21	3.43%	Diatoms
Cocconeis placentula sensu lato	20	3.26%	Diatoms
Nostoc	19		Algae
Achnanthidium minutissimum	18	2.94%	Diatoms
Reimeria sinuata	17	2.77%	Diatoms
Nitzschia archibaldii	15	2.45%	Diatoms
Gomphosphenia sp. 1 Idaho DW ANSP	13	2.12%	Diatoms
Navicula cryptotenella	11	1.79%	Diatoms
Leptolyngbya	10		Algae
Fragilaria capucina v. gracilis	8	1.31%	Diatoms
Mayamaea atomus	8	1.31%	Diatoms
Nitzschia acidoclinata	8	1.31%	Diatoms
Adlafia suchlandtii	7	1.14%	Diatoms
Navicula gregaria	7	1.14%	Diatoms
Homoeothrix	6		Algae
Hippodonta capitata	6	0.98%	Diatoms
Melosira varians	6	0.98%	Diatoms
Nitzschia columbiana	6	0.98%	Diatoms
Stephanocyclus meneghiniana	6	0.98%	Diatoms
Geissleria acceptata	5	0.82%	Diatoms
Navicula reichardtiana	5	0.82%	Diatoms
Nitzschia palea	5	0.82%	Diatoms
Calothrix	4		Algae
Achnanthidium kriegeri	4	0.65%	Diatoms
Amphora pediculus	4	0.65%	Diatoms
Encyonema silesiacum	4	0.65%	Diatoms
Fragilaria vaucheriae	4	0.65%	Diatoms
Gomphonema rhombicum	4	0.65%	Diatoms
Karayevia suchlandtii	4	0.65%	Diatoms
Navicula cryptotenelloides	4	0.65%	Diatoms
Sellaphora seminulum	4	0.65%	Diatoms

Taxon	Count	PRA [a]	Portion
Closterium	3		Algae
Geissleria decussis	3	0.49%	Diatoms
Nitzschia gracilis	3	0.49%	Diatoms
Nitzschia linearis	3	0.49%	Diatoms
Stauroneis kriegeri	3	0.49%	Diatoms
Synedra rumpens	3	0.49%	Diatoms
Komvophoron	2		Algae
Oedogonium	2		Algae
Achnanthidium deflexum	2	0.33%	Diatoms
Chamaepinnularia soehrensis v. muscicola	2	0.33%	Diatoms
Navicula submuralis	2	0.33%	Diatoms
Merismopedia	1		Algae
Monoraphidium	1		Algae
Achnanthidium exiguum	1	0.16%	Diatoms
Adlafia minuscula	1	0.16%	Diatoms
Chamaepinnularia	1	0.16%	Diatoms
Gomphonema drutelingense	1	0.16%	Diatoms
Navicula cari	1	0.16%	Diatoms
Navicula cryptocephala	1	0.16%	Diatoms
Navicula difficillima	1	0.16%	Diatoms
Nitzschia acicularis	1	0.16%	Diatoms
Nitzschia intermedia	1	0.16%	Diatoms
Nitzschia subacicularis	1	0.16%	Diatoms
Rossithidium nodosum	1	0.16%	Diatoms

[a] Percent relative abundance. Equals [count for given species] / [total count for site]. Applies only to diatoms.

Time of Travel data

Table D-15. Time of travel dye study data from 2013. [a]

Upstream Location	Downstream Location	Reach length (mi) [b]	Upstream dye peak date/time [c]	Downstream dye peak date/time [d]	Time of Travel (hours)	Avg Velocity (ft/s)
55LSR-39.5	55LSR-37.1	3.35	8/14/2013 7:45 [e]	8/14/2013 12:30	4.75	1.03
55LSR-37.1	55LSR-33.2	4.65	8/14/2013 12:30	8/14/2013 19:00[f]	6.50[f]	1.05
55LSR-33.2	55LSR-31.8	1.60	8/14/2013 19:00	8/14/2013 21:35	2.58[f]	0.91
55LSR-31.8	55LSR-23.4	8.15	8/14/2013 21:35	8/15/2013 14:10	16.58	0.72
55LSR-23.4	55LSR-19.8	2.90	8/13/2013 7:05 [e]	8/13/2013 10:20	3.25	1.31
55LSR-19.8	55LSR-16.0	3.90	8/13/2013 10:20	8/13/2013 15:35	5.25	1.09
55LSR-16.0	55LSR-13.5	2.65	8/13/2013 15:35	8/13/2013 19:40	4.08	0.95
55LSR-13.5	55LSR-10.3	2.65	8/13/2013 19:40	8/13/2013 22:10	2.50	1.55
55LSR-10.3	55LSR-07.5	3.35	8/12/2013 8:38 [e]	8/12/2013 12:20	3.70	1.33
55LSR-07.5	55LSR-03.9	4.05	8/12/2013 12:20	8/12/2013 16:20	4.00	1.49
55LSR-03.9	55LSR-01.1	3.50	8/12/2013 16:20	8/12/2013 20:10	3.83	1.34

Total time of travel from Frideger Rd. (55LSR-39.5) to mouth (55LSR-01.1): **57 hours (2.4 days)**

[a] All times of travel from this dye study are average times of travel, calculated from dye peak to dye peak. We do not present leading edge times, and therefore this data is not appropriate for uses relating to transport of toxic substances and/or human health.

[b] Reach lengths calculated from high-resolution linework digitized by Ecology. Distances do not exactly correspond with river mile distances used in Site ID's, which are based on USGS river miles.

[c] This can be either: 1.) the time of dye injection at the upstream location; or 2.) the time when the peak dye concentration occurred at the upstream location.

[d] This is the time when the peak dye concentration occurred at the downstream location.

[e] Dye injection

[f] The dye concentration data logged at 55LSR-33.2 was very noisy. We estimated the time of peak dye concentration by taking the 1-hour rolling average of this noisy data signal. Estimate is probably accurate ±1 hour.

Channel Survey data

Table D-16. Locations of channel surveys conducted during 2015.

Location	Date of survey	# of x-sections surveyed [a]	Location of first transect		Location of last transect	
			Latitude	Longitude	Latitude	Longitude
LSR @ Scotia	10/15/2015	10	48.1060	-117.1528	48.1074	-117.1528
LSR in Scotia Gap	10/28/2015	10	48.0765	-117.1696	48.0785	-117.1685
Dry Ck at Dunn Rd	10/8/2015	10	47.9821	-117.2849	47.9824	-117.2872
Otter Ck at 3rd Valley Rd xing	10/6/2015	10	48.0090	-117.3112	48.0074	-117.3097
Otter Ck nr Mouth	10/6/2015	10	47.9890	-117.3212	47.9909	-117.3216
WBLSR between Horseshoe and Eloika Lakes	10/26-27/2015	28 [b]	48.0607	-117.4000	48.0925	-117.4119
Bear Ck @ Deer Park - Milan Rd.	10/18/2015	5	47.9642	-117.3714	47.9633	-117.3713
Deer Ck blw Conklin Rd	10/14/2015	10	47.9588	-117.2276	47.9608	-117.2253
Deer Ck at Bruce Rd	10/14/2015	10	47.8947	-117.3043	47.8944	-117.3021
Dragoon Ck abv Mason Rd	5/21/2015	10	48.0111	-117.5170	48.0094	-117.5168
Dragoon Ck abv WB Dragoon Ck	5/12/2015	10	47.9319	-117.4982	47.9300	-117.4972
WB Dragoon Ck nr Mouth	5/14/2015	10	47.9176	-117.5001	47.9191	-117.4990
Dragoon Ck at DNR Campground	5/14/2015	10	47.8862	-117.4406	47.8877	-117.4432
Dragoon Ck at Chattaroy Rd	5/14/2015	10	47.8874	-117.3844	47.8892	-117.3867
Dragoon Ck at Mouth	5/12/2015	10	47.8749	-117.3726	47.8746	-117.3694
SF Little Deep Ck abv Day-Mt Spokane Rd	10/5/2015	10	47.8874	-117.2071	47.8880	-117.2040
Deadman Ck at Park Bdy	5/26/2015	10	47.8821	-117.1345	47.8843	-117.1319
Deadman Ck nr Fire Station	10/5/2015	10	47.8342	-117.1767	47.8344	-117.1803
Deadman Ck at Heglar Rd	5/21/2015	10	47.7873	-117.2490	47.7856	-117.2510
Deadman Ck abv Shady Slope Rd	5/26/2015	10	47.7908	-117.3708	47.7899	-117.3686

[a]The distance between cross-section transects was typically 100 ft, for ~900 ft total reach length at locations with 10 cross-sections.

[b]West Branch LSR survey included a total of 166 points along the length of the channel; channel cross-sections were surveyed at 28 of those points. At the remainder, only thalweg depth was measured.

Table D-17. Summary of 2015 channel survey results.

Location		Date of survey	Flow during survey (cfs) [a]	Geometric mean [d] of channel characteristics measured during channel surveys		
				wetted width (ft)	average depth (ft)	average velocity (ft/s) [e]
LSR @ Scotia		10/15/2015	20 [b]	25.0	2.11	0.38
LSR in Scotia Gap		10/28/2015	27	20.8	1.59	0.82
Dry Ck at Dunn Rd		10/8/2015	1.3	11.6	0.70	0.16
Otter Ck at 3rd Valley Rd xing		10/6/2015	1.9	8.2	0.70	0.33
Otter Ck nr Mouth		10/6/2015	6.1	12.8	0.49	0.98
WBLSR between Horseshoe and Eloika Lakes	Trans 101 - 165	10/26-27/2015	7.1 [c]	29.0	0.85	0.29
	Trans 41 - 100			25.5	1.58	0.18
	Trans 0 - 40			29.6 [f]	4.2 [f]	0.057 [f]
Bear Ck @ Deer Park - Milan Rd.		10/18/2015	2.2	8.3	0.72	0.37
Deer Ck blw Conklin Rd		10/14/2015	0.24	5.6	0.16	0.28
Deer Ck at Bruce Rd		10/14/2015	0.52	8.2	0.47	0.14
Dragoon Ck abv Mason Rd		5/21/2015	1.9	7.7	0.53	0.47
Dragoon Ck abv WB Dragoon Ck		5/12/2015	11	16.2	1.00	0.68
WB Dragoon Ck nr Mouth		5/14/2015	8.2	15.5	1.01	0.52
Dragoon Ck at DNR Campground		5/14/2015	27	23.8	1.49	0.76
Dragoon Ck at Chattaroy Rd		5/14/2015	27	23.1	1.14	1.03
Dragoon Ck at Mouth		5/12/2015	24	24.6	1.07	0.91
SF Little Deep Ck abv Day-Mt Spokane Rd		10/5/2015	0.10	4.8	0.16	0.13
Deadman Ck at Park Bdy		5/26/2015	4.2	9.4	0.54	0.82
Deadman Ck nr Fire Station		10/5/2015	1.0	11.5	0.35	0.25
Deadman Ck at Heglar Rd		5/21/2015	9.6	14.1	0.81	0.84
Deadman Ck abv Shady Slope Rd		5/26/2015	17	17.5	0.97	1.00

[a] We were not able to perform all channel surveys during similar flow conditions. In particular, flow conditions during May were much higher than flow conditions during October. It is not possible to meaningfully compare channel characteristics measured under one set of flow conditions to those measured under another, without accounting for this. See Appendix J, and particularly Figure J-2 for an explanation of how we handled this during analysis.

[b] Flow measured five days after survey during sampling run on 10/20/2015.

[c] Average flow measured at gage station at 55WBLS-03.1 during two days of survey.

[d] We used the geometric, rather than arithmetic, mean for averaging together results from multiple cross-sections. This is because of a mathematical property of these calculations: for each individual cross section, flow = wetted width * average depth * average velocity. But, if you take the arithmetic mean for all 10 cross-sections each of wetted width, average depth, and average velocity, and then multiply these together, their product will not equal the flow. Rather, their product will equal a number somewhat higher than the flow. However, when using the geometric mean, the product will equal the flow exactly.

[e] We did not directly measure velocity during channel surveys. (Except for during the flow measurement, which we typically took once at the beginning of the survey near transect #1.) For each individual cross-section, we calculated average velocity as [Flow / (Wetted width * Average depth)].

[f] This reach was too deep to wade in most locations. We estimated values based on: 1.) widths measured for this reach using GIS; and 2.) Estimated average depth of 4.2 ft, based on an assumed maximum (thalweg) depth of 5.6 ft and a mean/max depth ratio of 0.745 derived from the three locations where we were able to survey cross-sections. We estimated the assumed thalweg depth of 5.6 ft using a statistical analysis based on the relative frequency of wadeble transects and the amount of depth variation typically seen in other parts of the stream.

We present channel survey cross-section plots on the following pages in the following format. For the sake of simplicity and space, we show the axis titles and legend here, and omit them from cross-section plots thereafter.

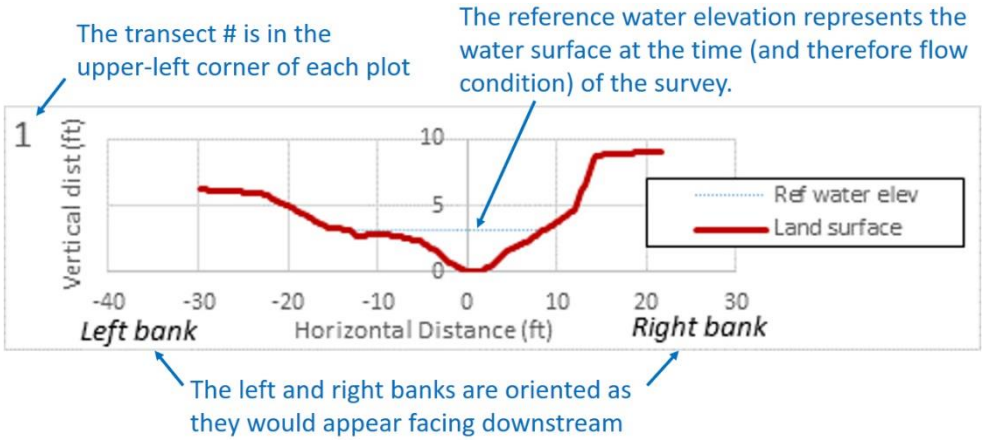
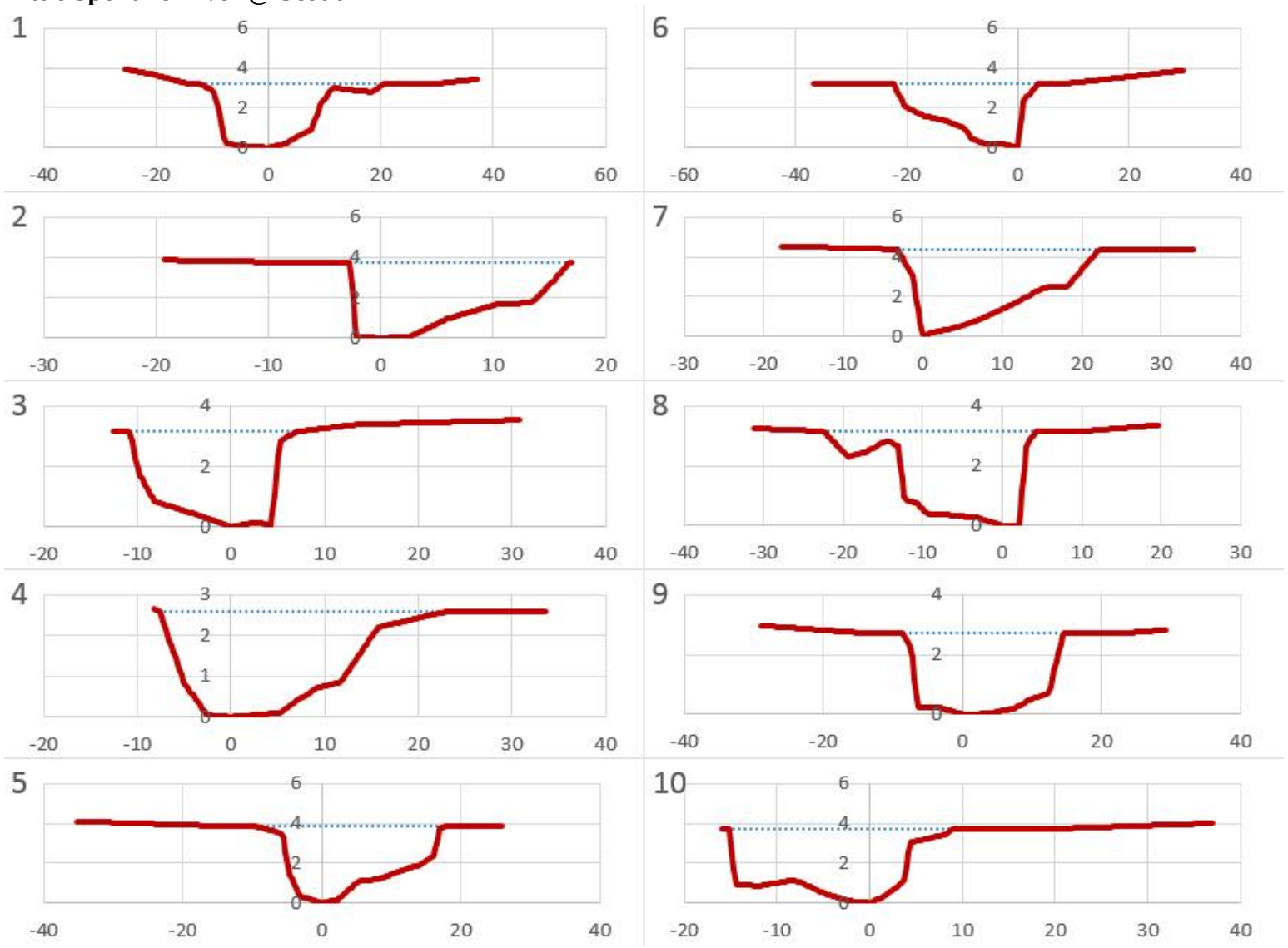
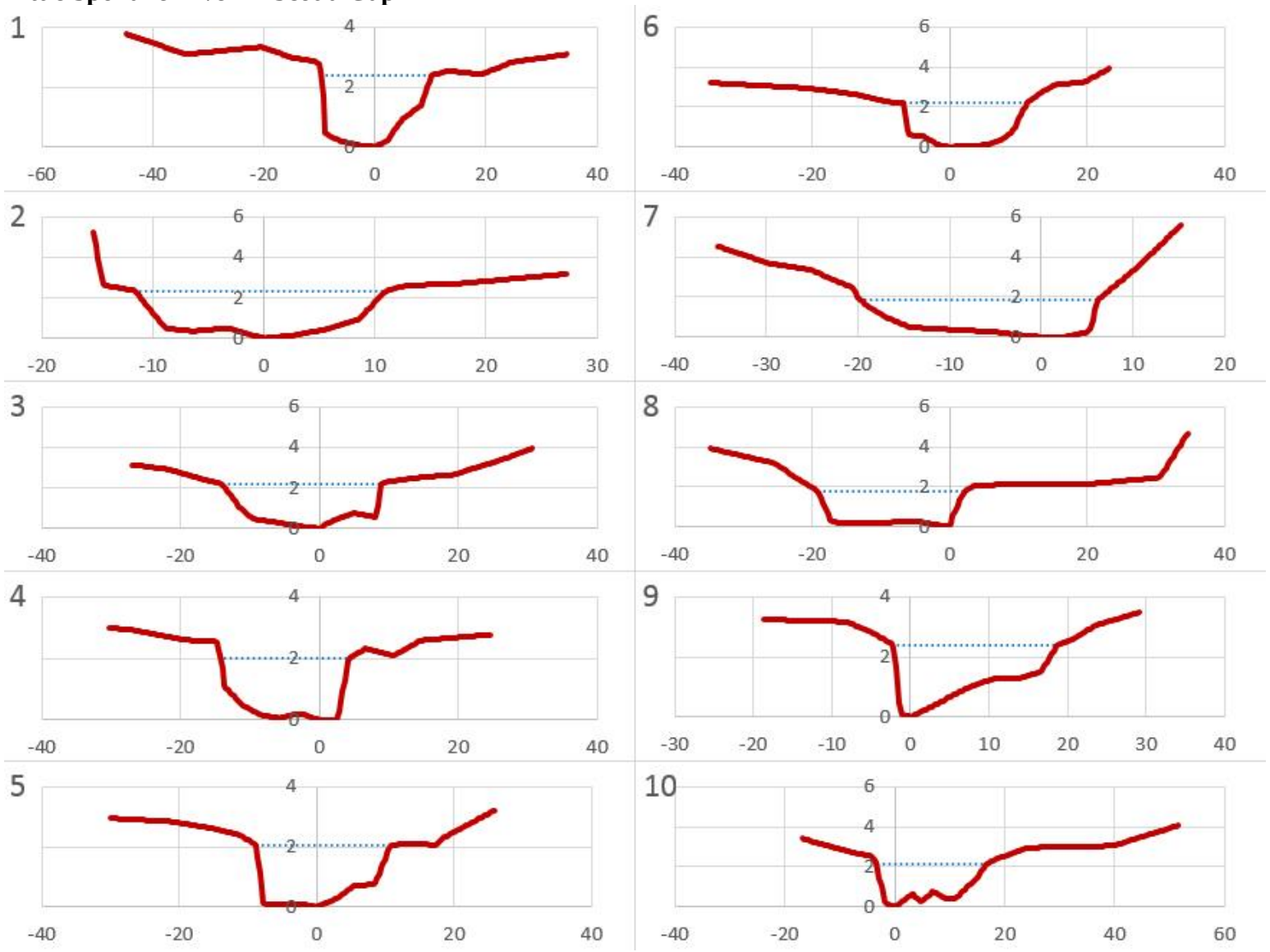


Figure D-6 (Following pages). Channel survey cross-section plots.

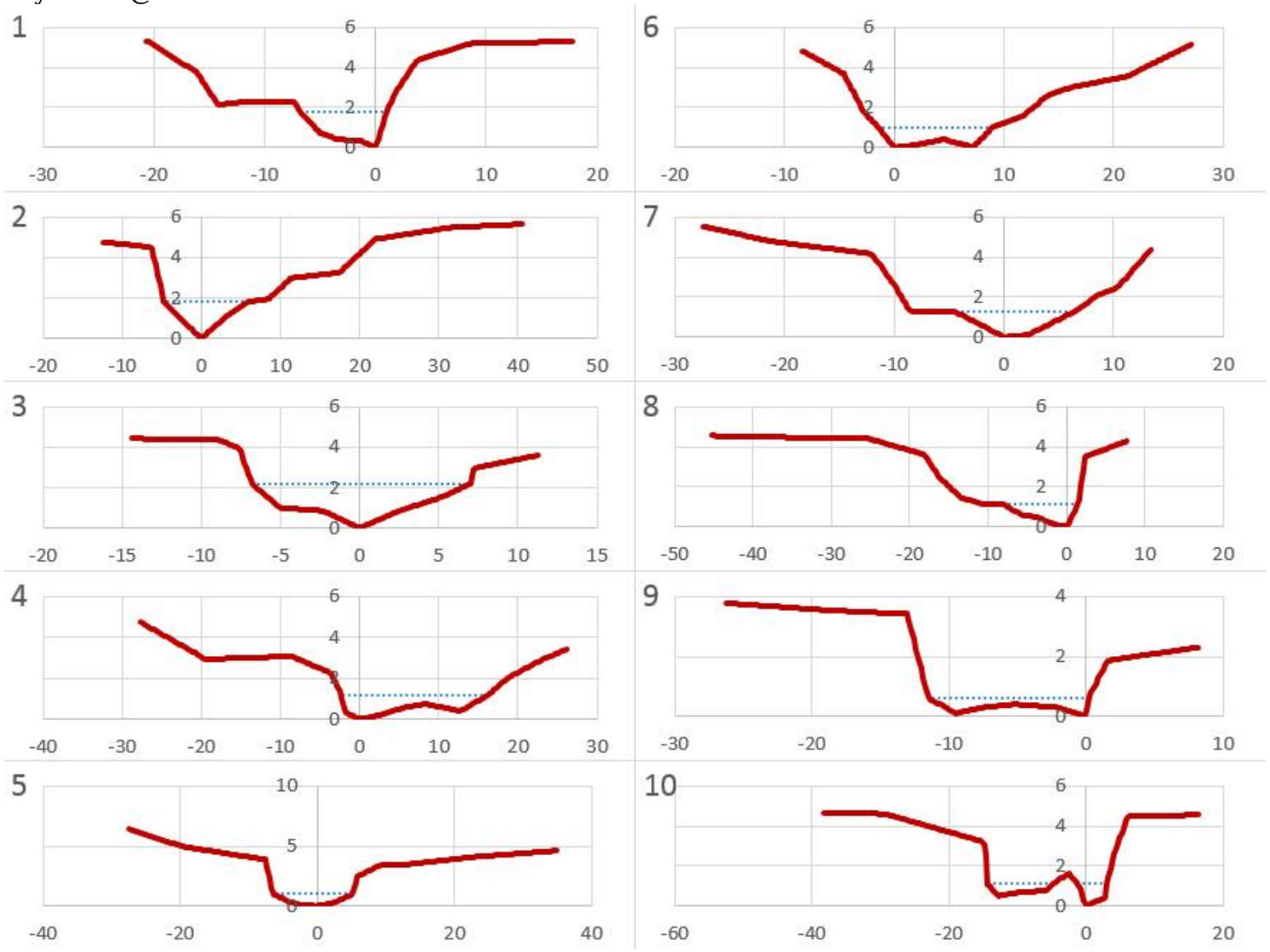
Little Spokane River @ Scotia



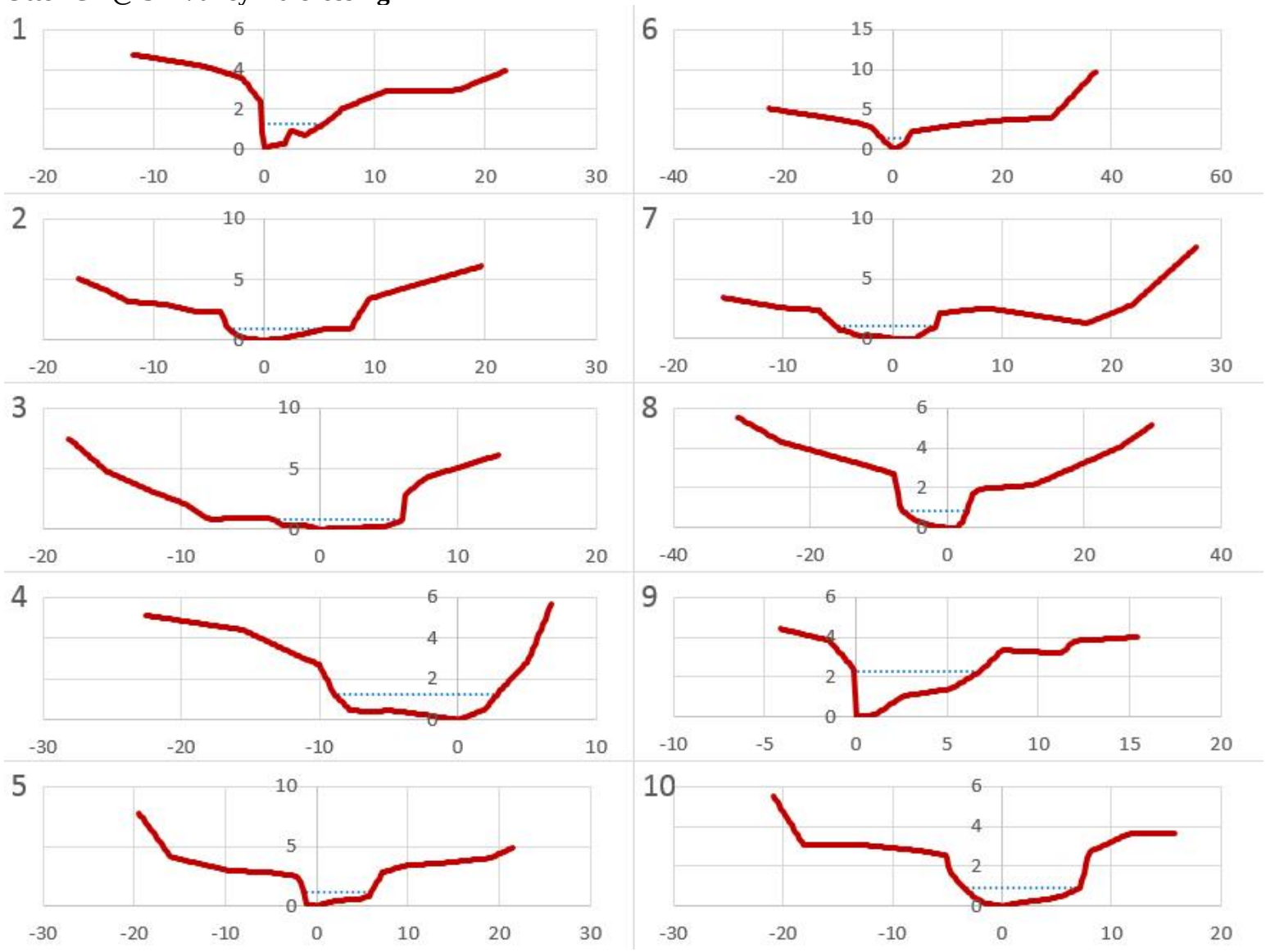
Little Spokane River in Scotia Gap



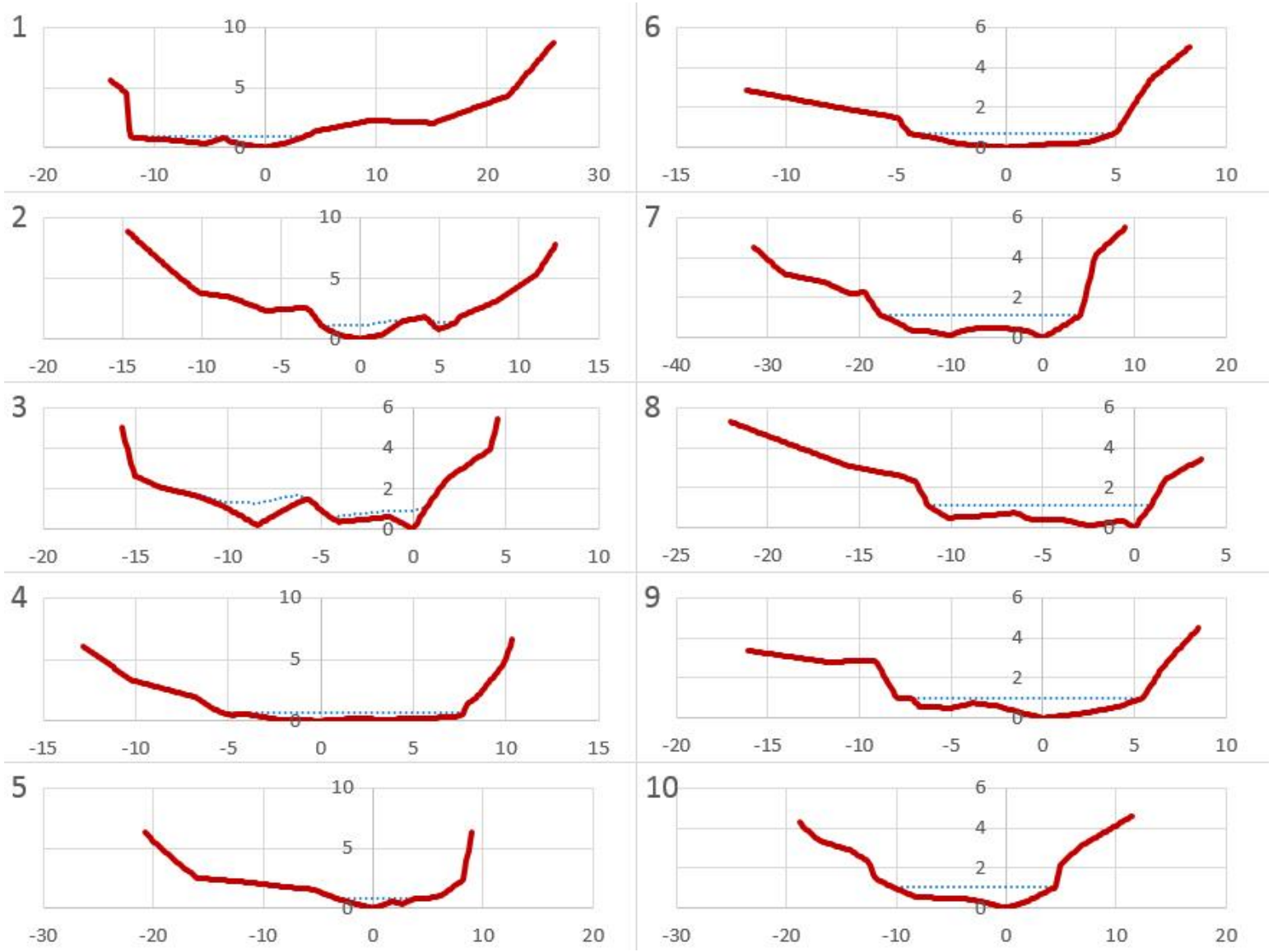
Dry Creek @ Dunn Rd



Otter Ck @ 3rd Valley Rd crossing



Otter Ck near mouth



West Branch Little Spokane River between Horseshoe and Eloika Lakes

At this location, we numbered the transects 0-165, counting upstream from Fan Lk Rd. Transects were located every 100 ft. We measured the maximum cross-section depth (thalweg depth) at each transect. We surveyed a full cross-section at selected transects, typically every 5th transect where wadeable.

#	Thalweg Depth (ft)
0	>> 4.5
1	>> 4.5
2	> 4.5
3	~ 4.5
4	> 4.5
5	> 5
6	> 5
7	> 4.5
8	> 4.5
9	> 3.5
10	> 3.5
11	> 4
12	> 4.5
13	> 5
14	> 4.8
15	> 4.1
16	4
17	> 4.8
18	> 4.3
19	4.3
20	>> 4
21	> 4.5
22	4.6
23	> 4.2
24	3.4
25	> 5
26	> 4.2
27	> 4.8
28	> 4.7
29	3.9
30	> 5.2
31	> 4.2

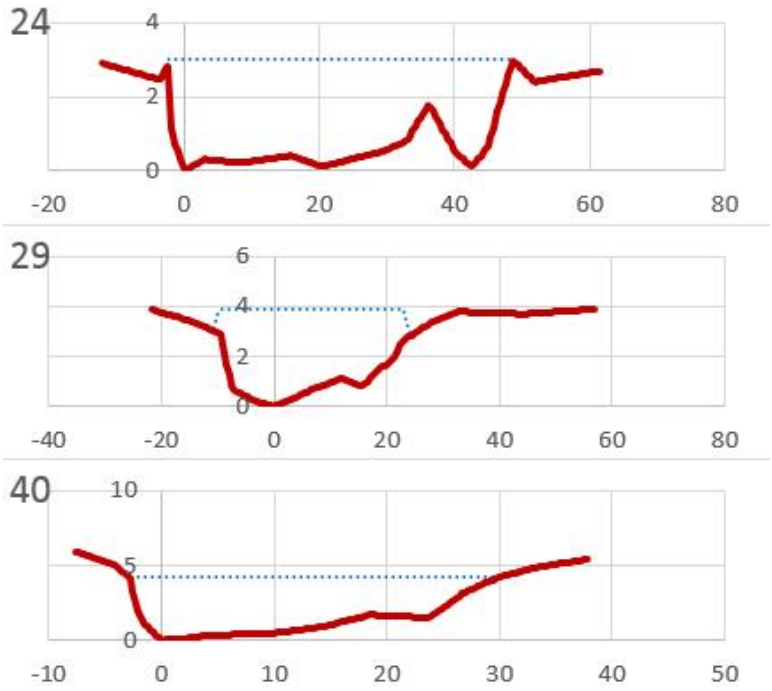
#	Thalweg Depth (ft)
32	4.5
33	> 4
34	> 4.9
35	> 4.4
36	> 5.1
37	~ 5
38	> 5
39	~ 5.2
40	4.2
41	3.5
42	2.3
43	1.1
44	0.9
45	4.1
46	>> 4.3
47	4.2
48	4.4
49	2.3
50	1.9
51	4.2
52	3.3
53	4.2
54	2.9
55	2.8
56	4.5
57	3.5
58	~ 4
59	3.1
60	3.3
61	2.8
62	1.8
63	2.7

#	Thalweg Depth (ft)
64	0.75
65	3.6
66	3.1
67	3
68	2.1
69	4.2
70	1.65
71	> 5
72	3.2
73	2.9
74	2.8
75	3.3
76	1.1
77	4.3
78	3
79	2
80	2
81	2.9
82	1.6
83	0.6
84	1
85	1
86	2.8
87	1.5
88	2.6
89	1
90	4.4
91	3
92	2.1
93	3.4
94	2.7
95	2.8

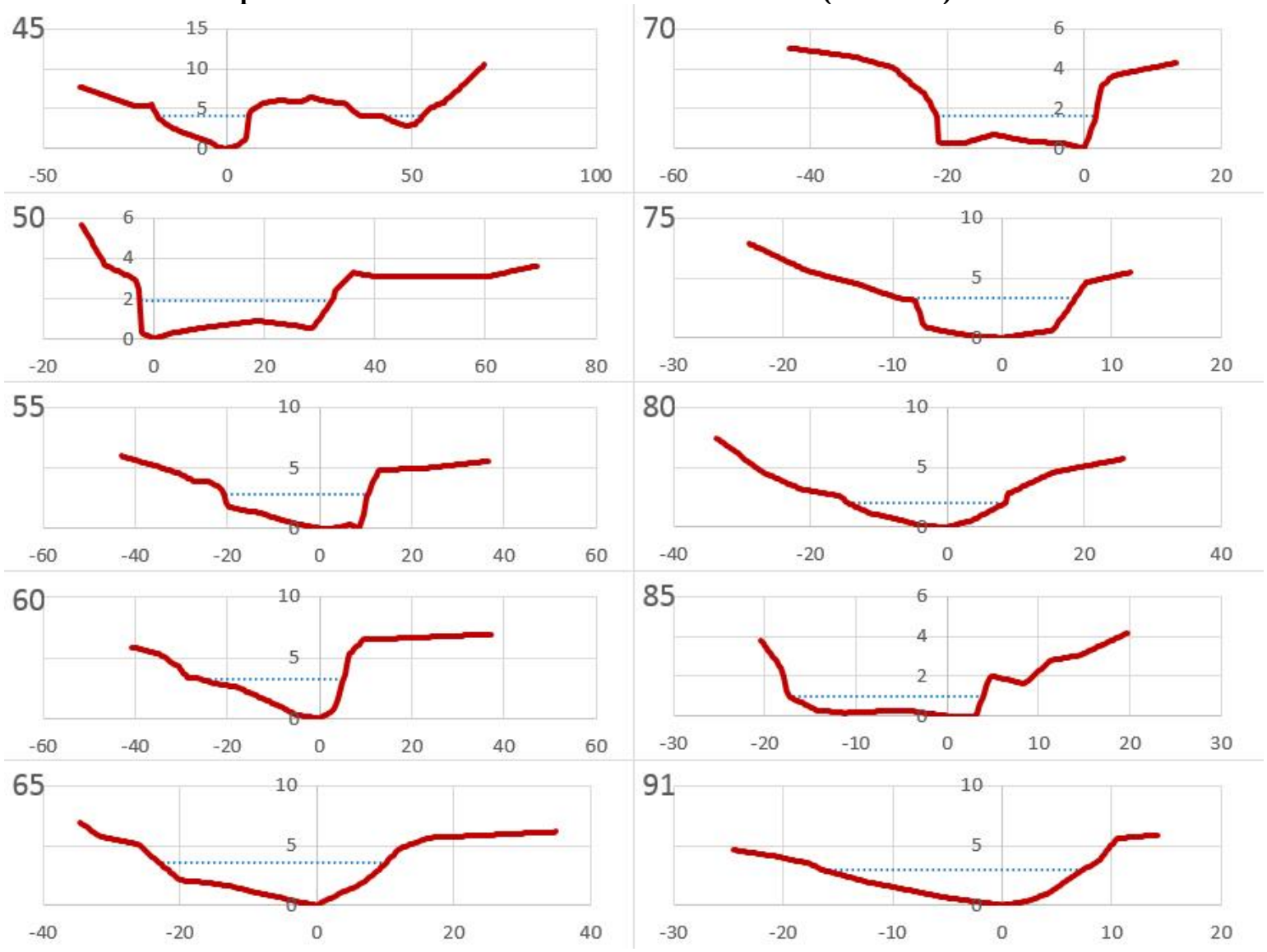
#	Thalweg Depth (ft)
96	3.25
97	1.8
98	1.4
99	4.1
100	2.15
101	0.5
102	2.75
103	3.2
104	3.1
105	1.1
106	2.6
107	2
108	1.35
109	1.4
110	3
111	0.9
112	0.9
113	1.5
114	1.2
115	1.7
116	0.65
117	1.4
118	1
119	1.3
120	1.3
121	1.8
122	1.5
123	1.3
124	3.8
125	2.1
126	> 4.3
127	1.7

#	Thalweg Depth (ft)
128	3.25
129	4.15
130	2.45
131	0.85
132	0.5
133	2.3
134	0.7
135	0.5
136	0.65
137	0.9
138	0.95
139	1.1
140	3.2
141	3.1
142	2.6
143	2.7
144	1.95
145	1
146	0.75
147	0.7
148	2.55
149	1.9
150	0.85
151	0.65
152	2
153	1.6
154	0.5
155	1
156	1.05
157	0.8
158	0.9
159	3.7

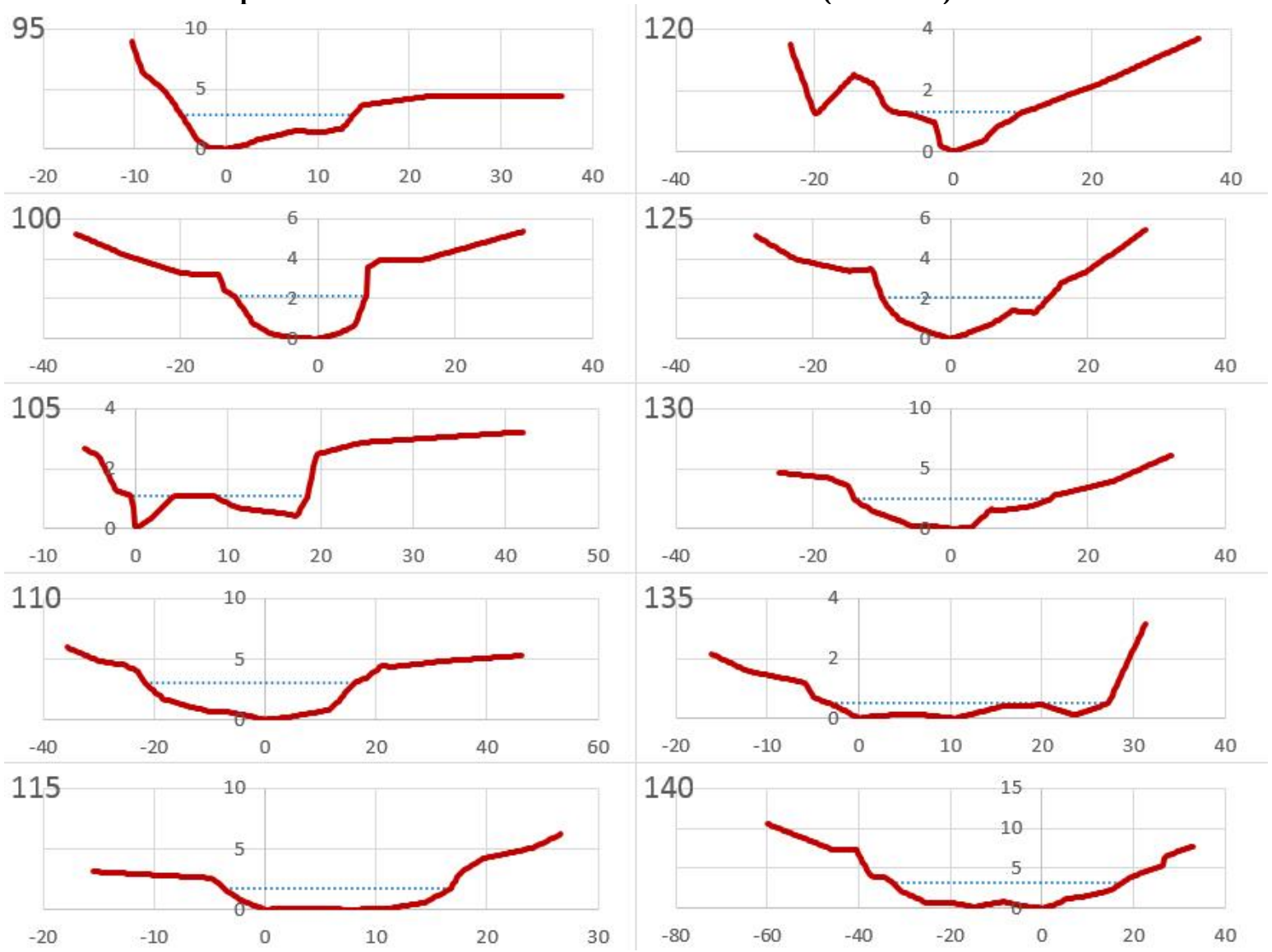
#	Thalweg Depth (ft)
160	2
161	1.1
162	3.2
163	4.3
164	2.1
165	1.5



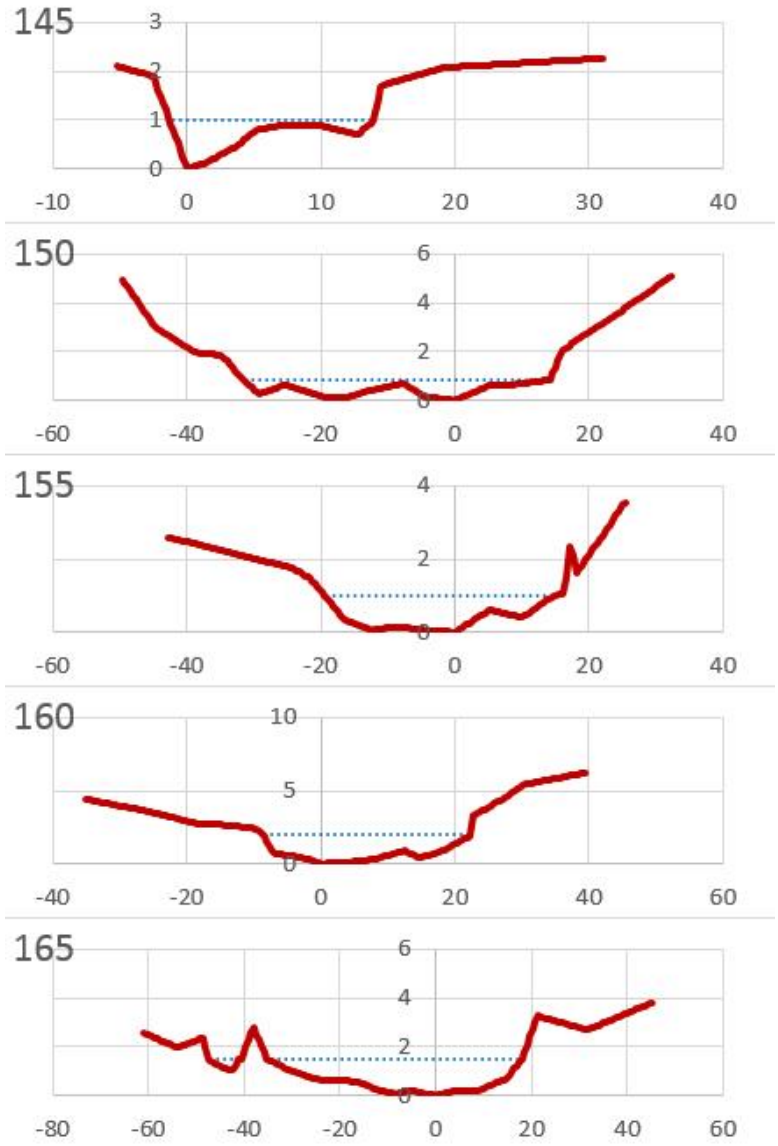
West Branch Little Spokane River between Horseshoe and Eloika Lakes (continued)



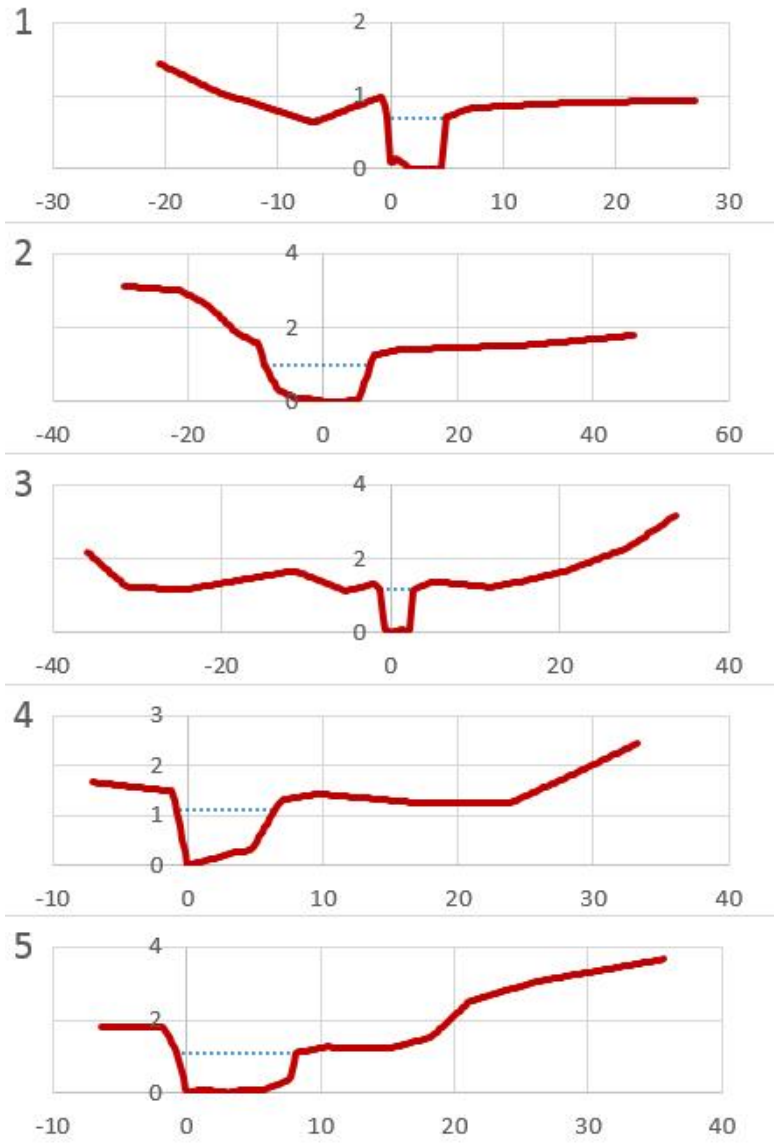
West Branch Little Spokane River between Horseshoe and Eloika Lakes (continued)



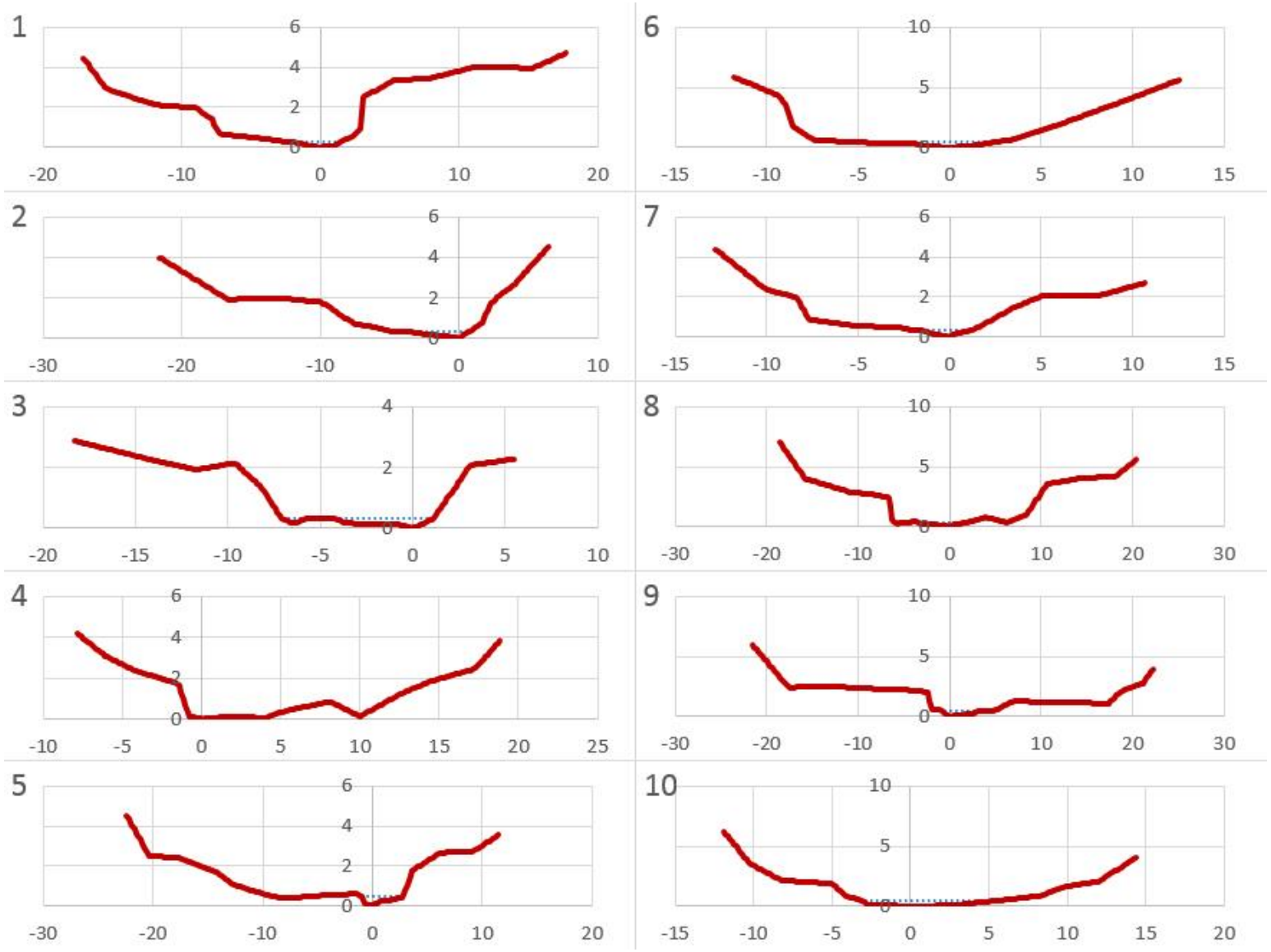
WB LSR between Horseshoe and Eloika Lakes (cont.)



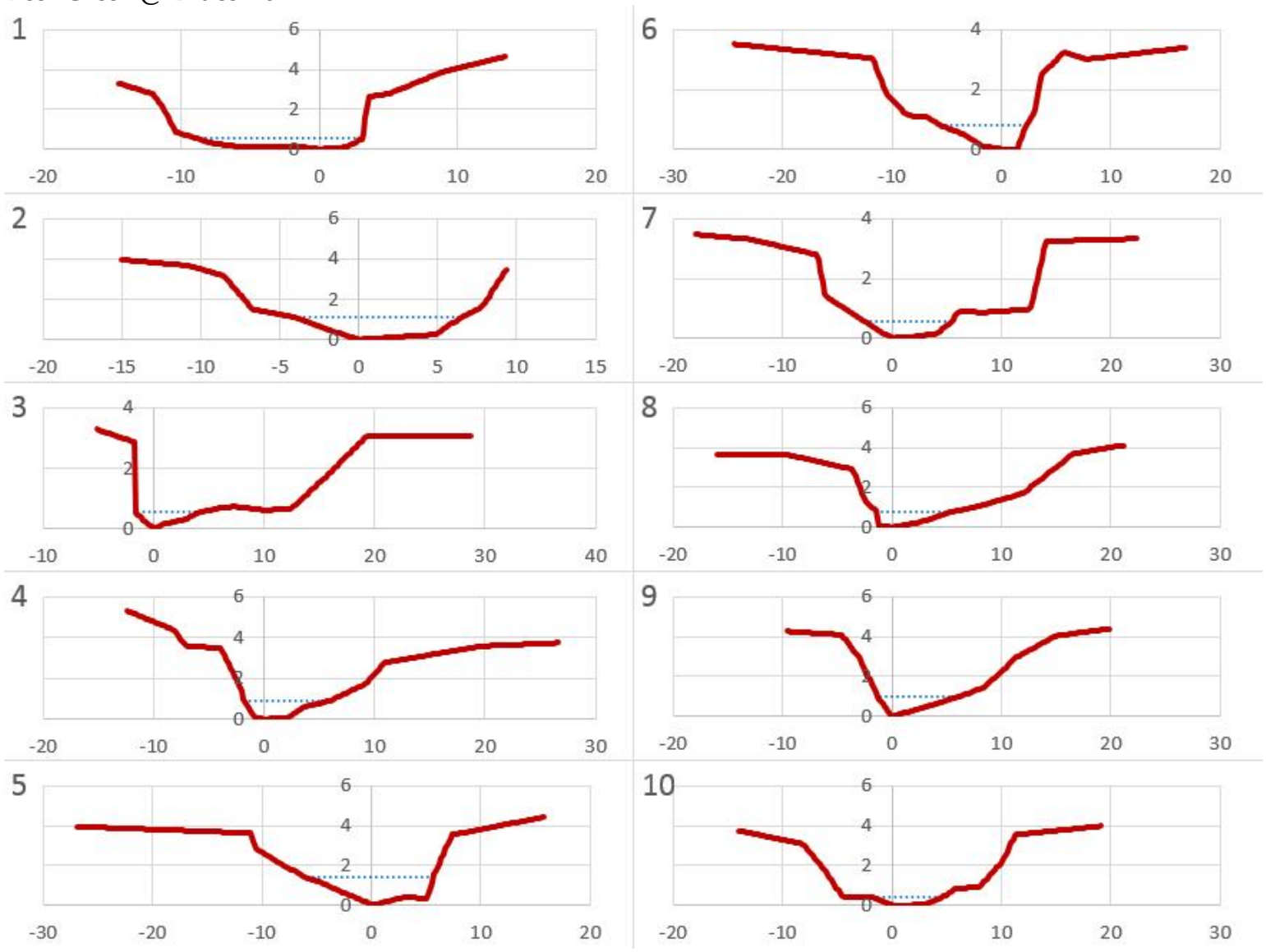
Bear Creek @ Deer Park – Milan Rd.



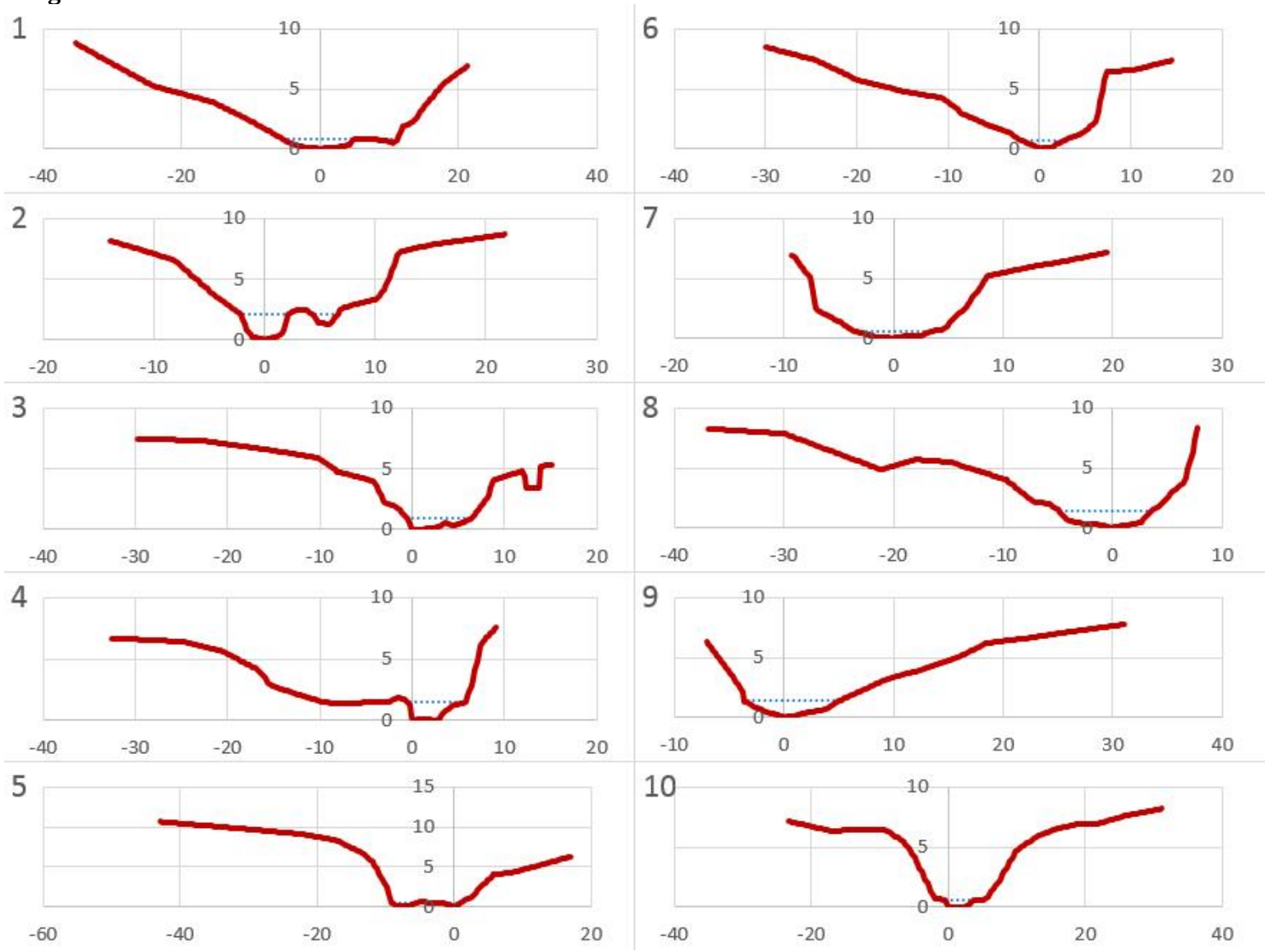
Deer Creek below Conklin Rd



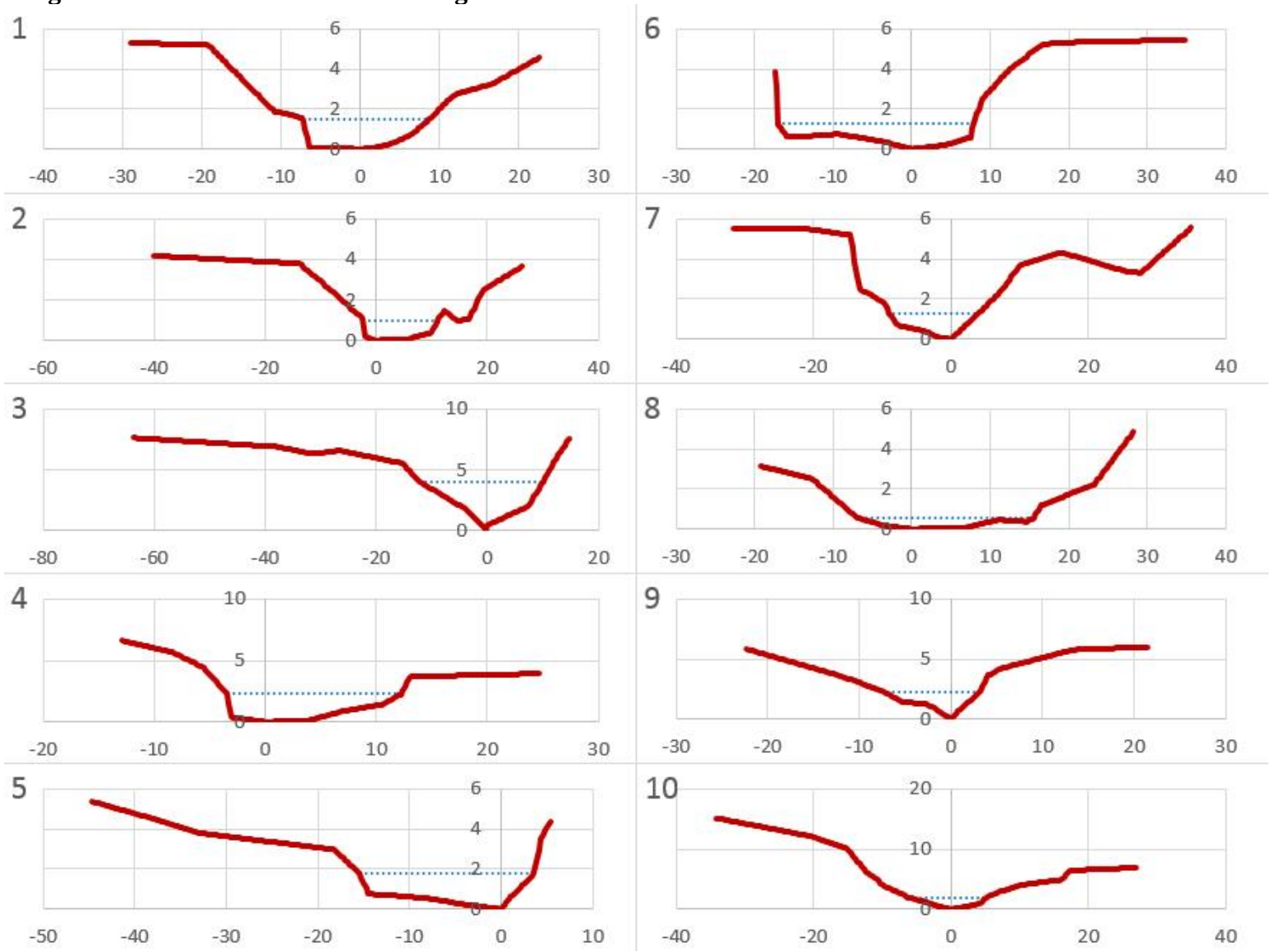
Deer Creek @ Bruce Rd



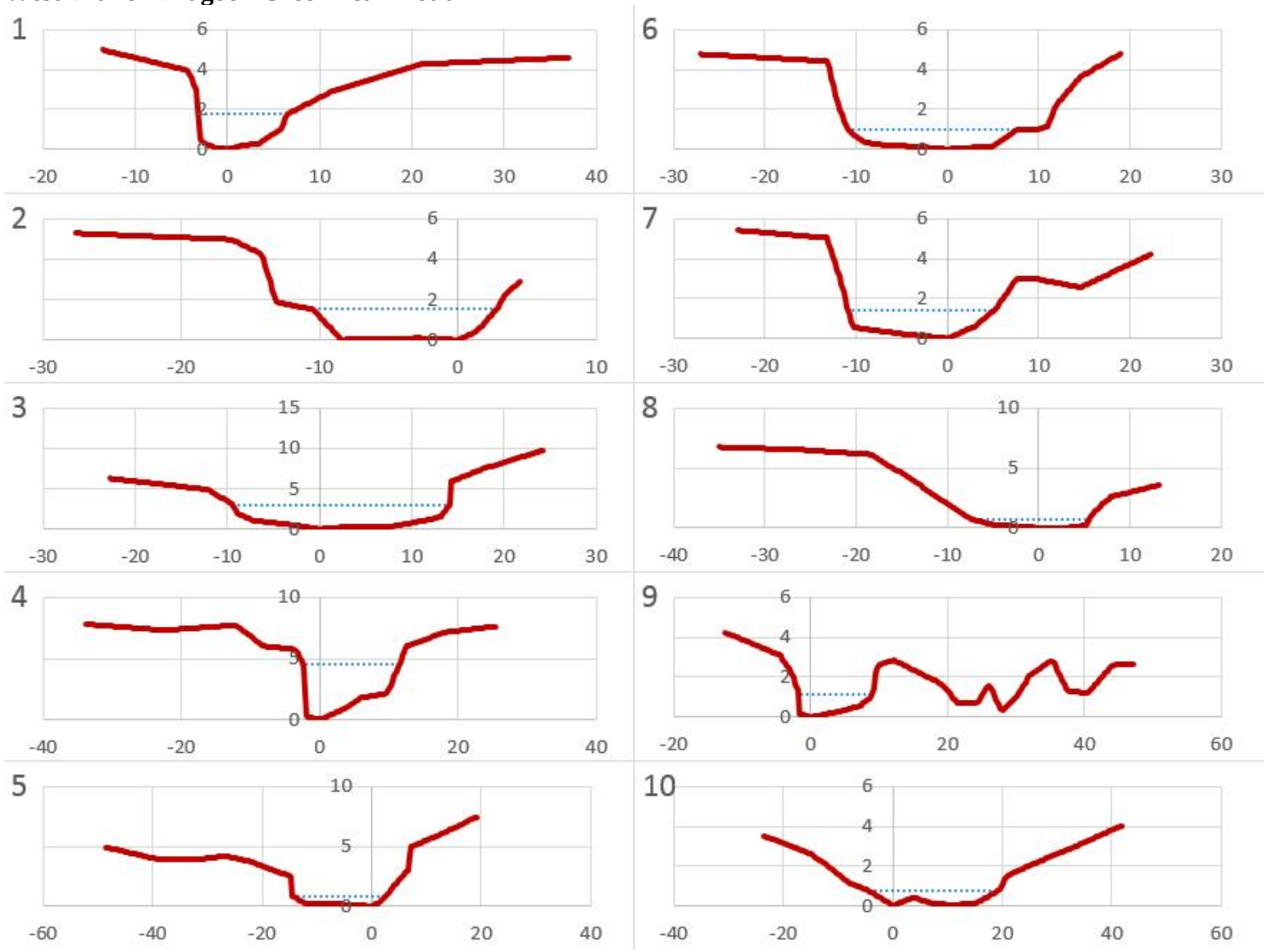
Dragoon Creek above Mason Rd



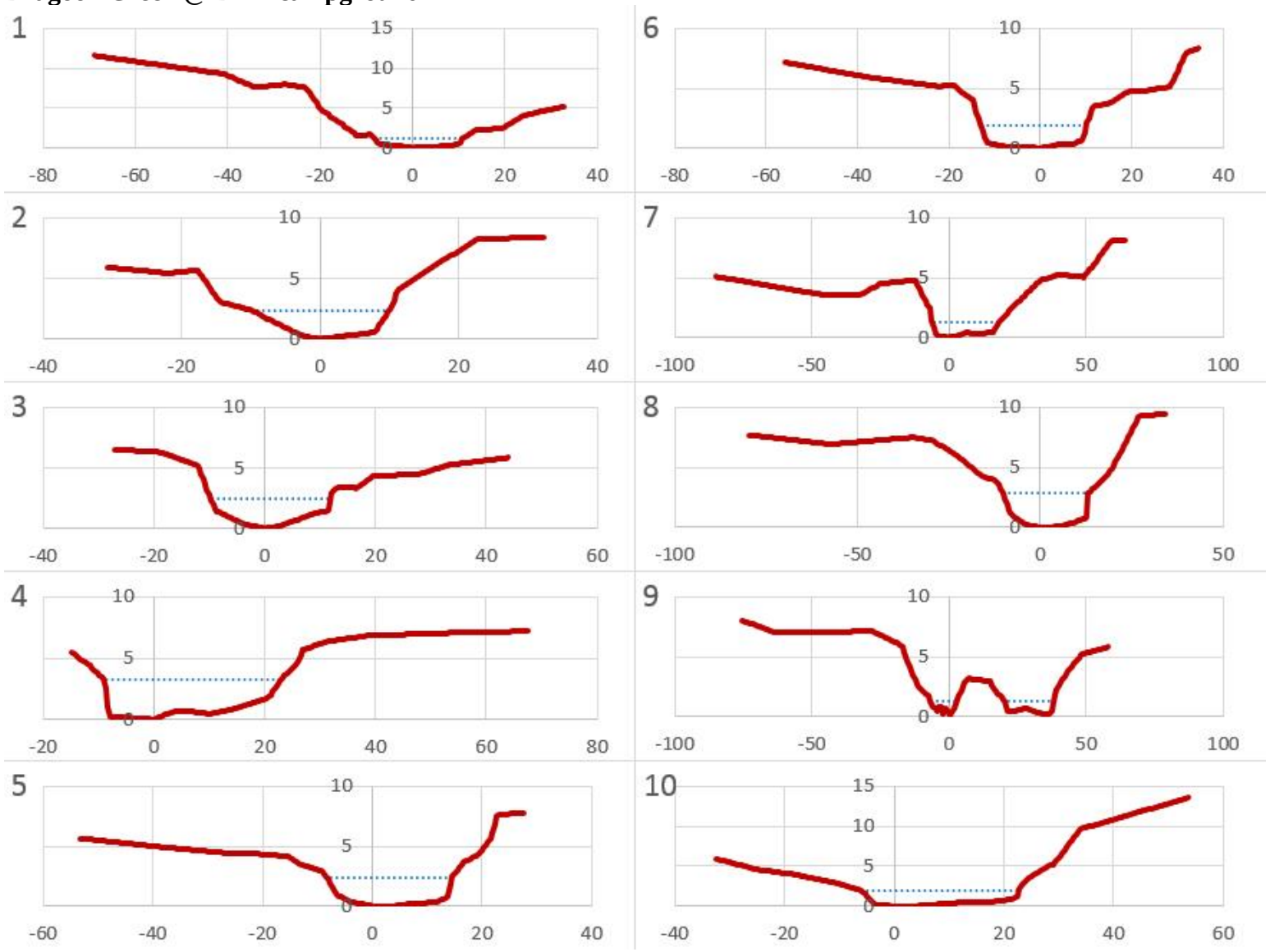
Dragoon Creek above West Branch Dragoon Creek



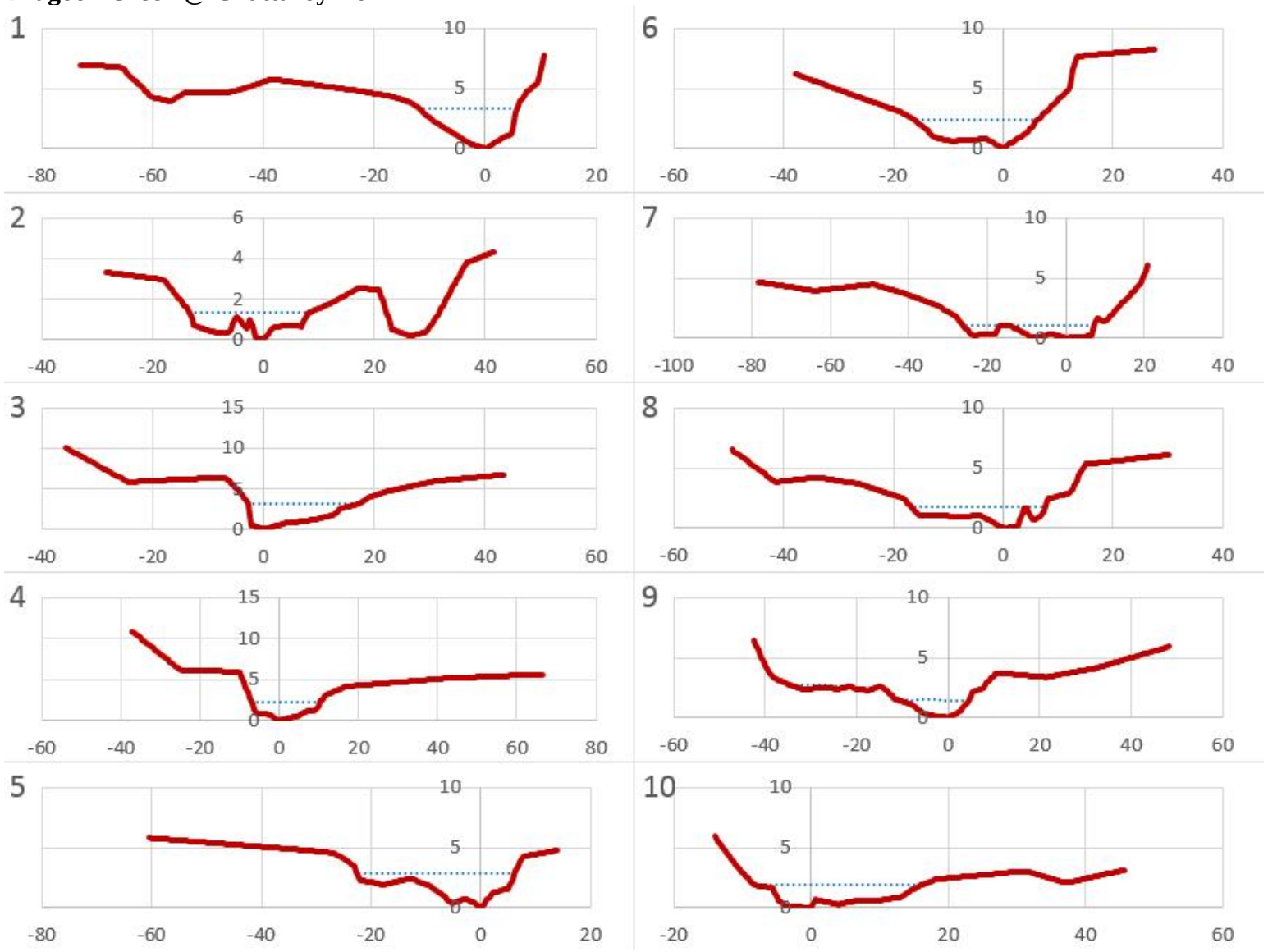
West Branch Dragoon Creek near mouth



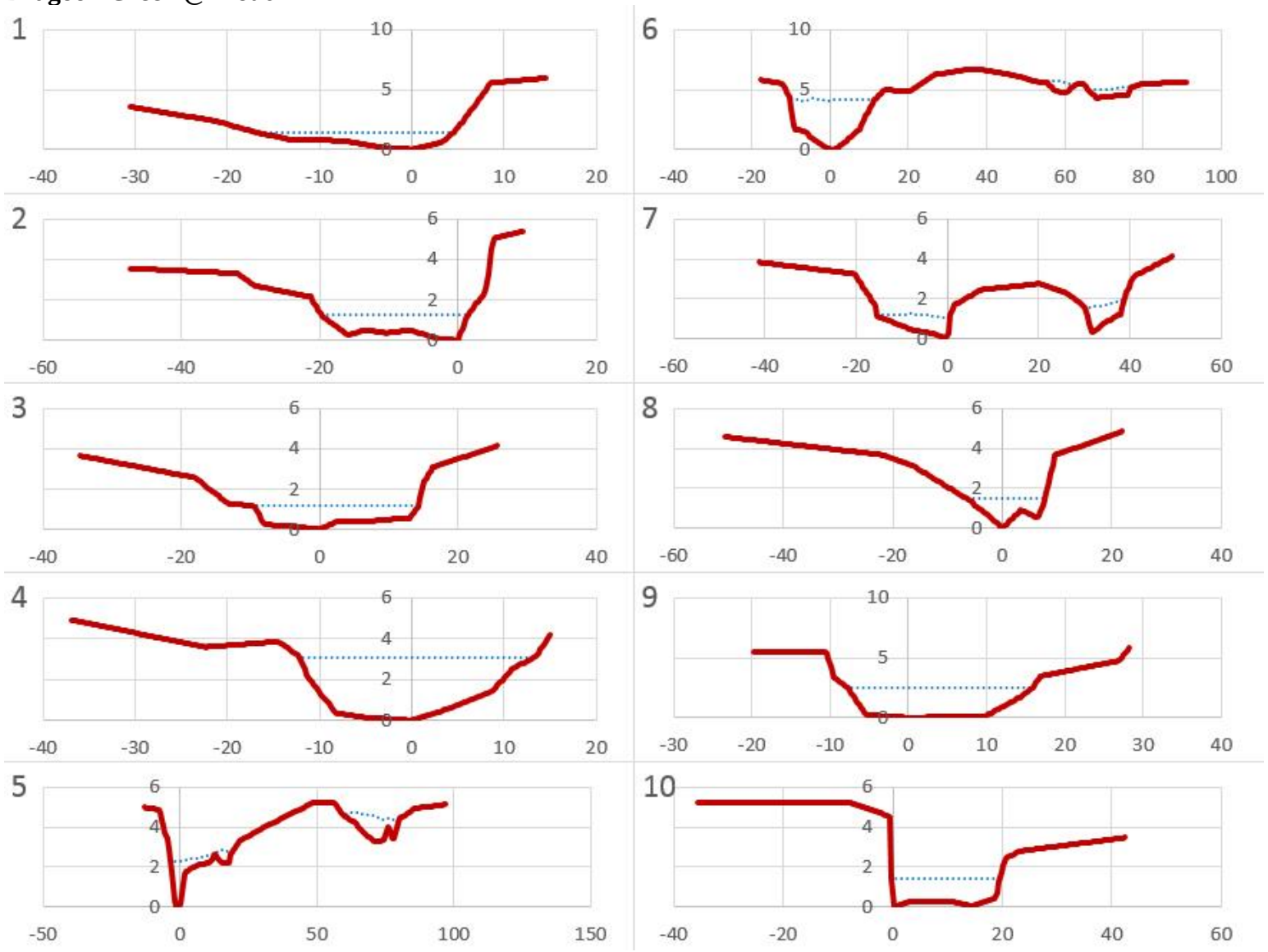
Dragoon Creek @ DNR campground



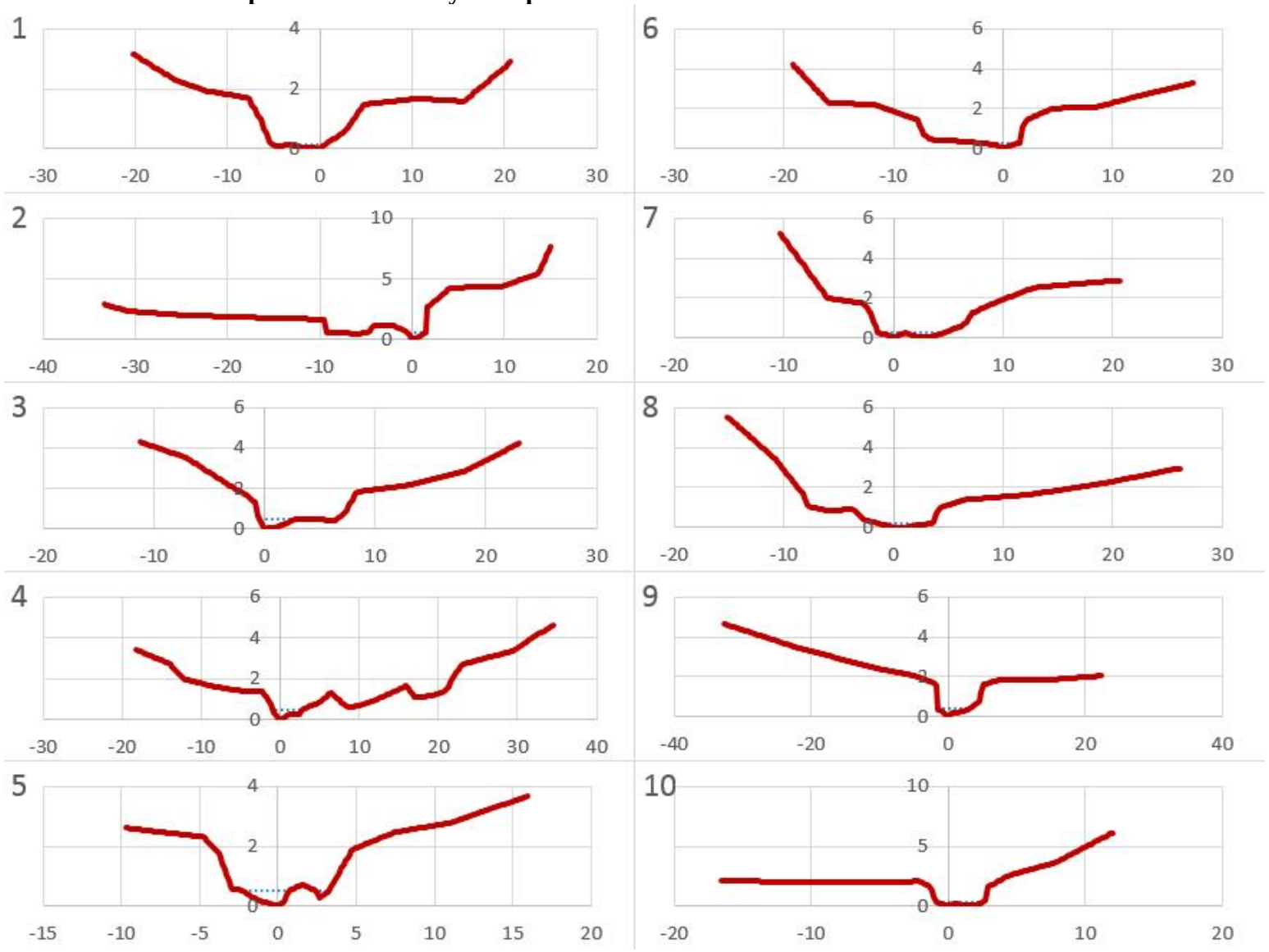
Dragoon Creek @ Chattaroy Rd



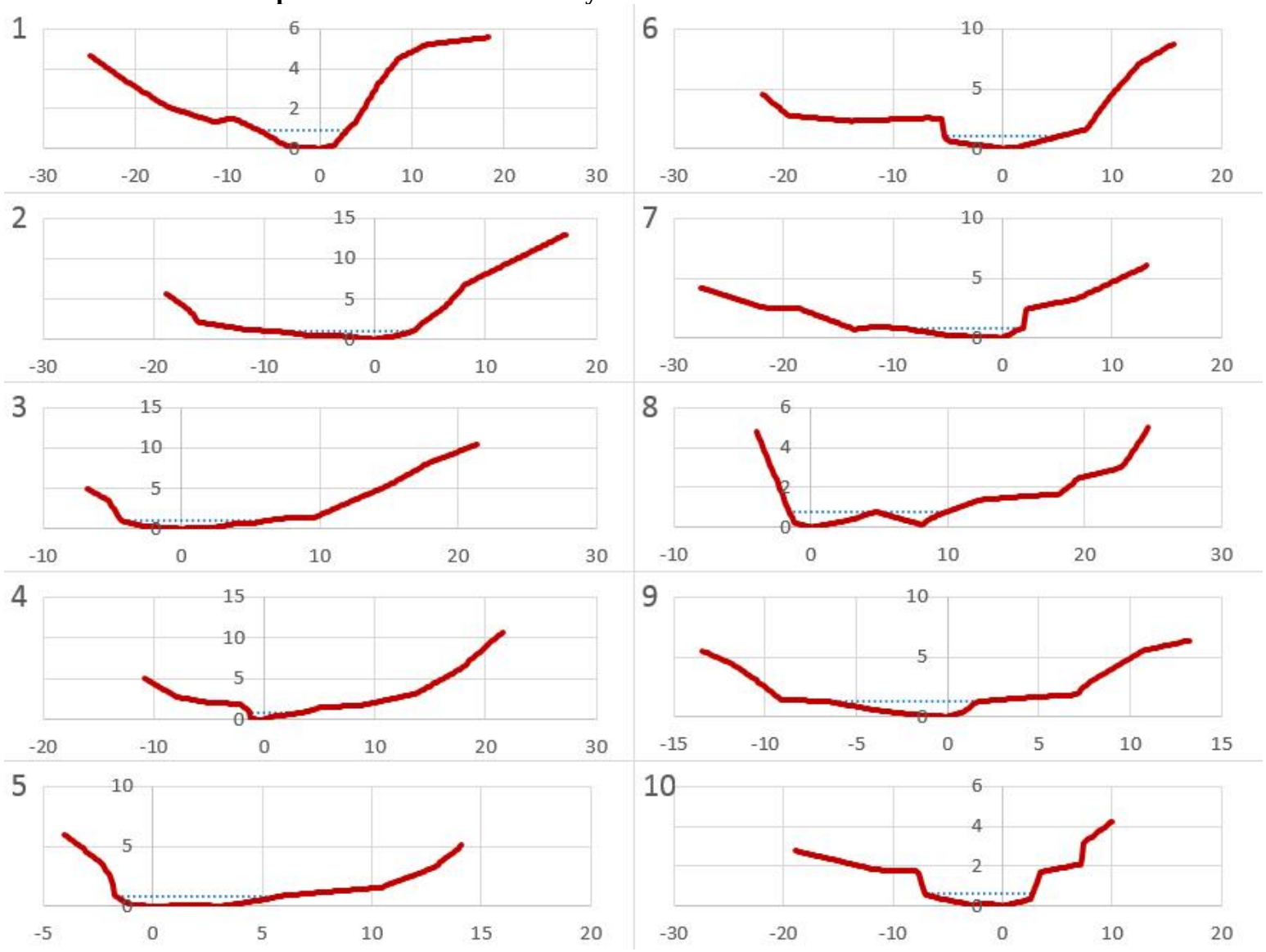
Dragoon Creek @ mouth



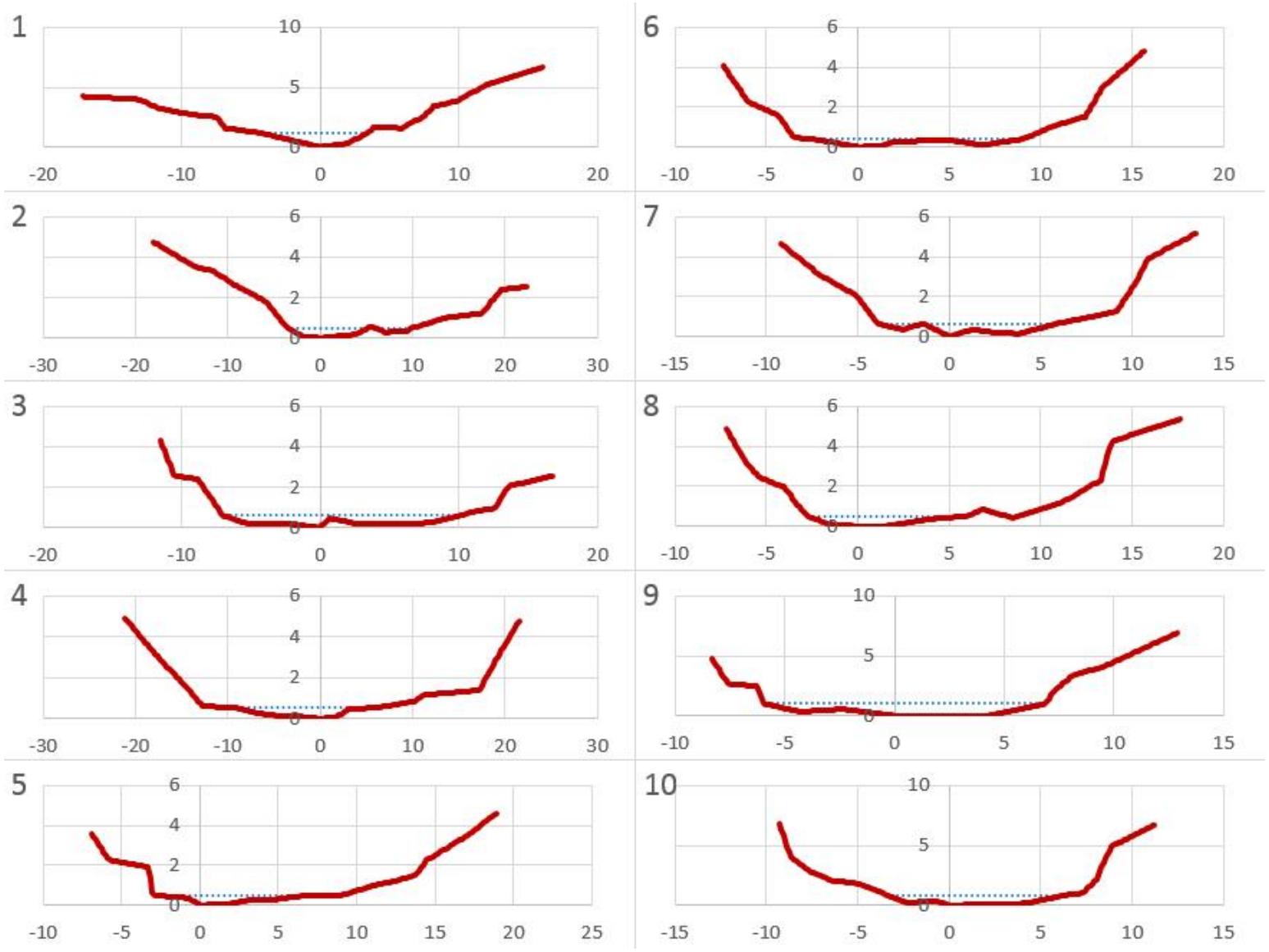
South Fork Little Deep Creek above Day-Mt Spokane Rd



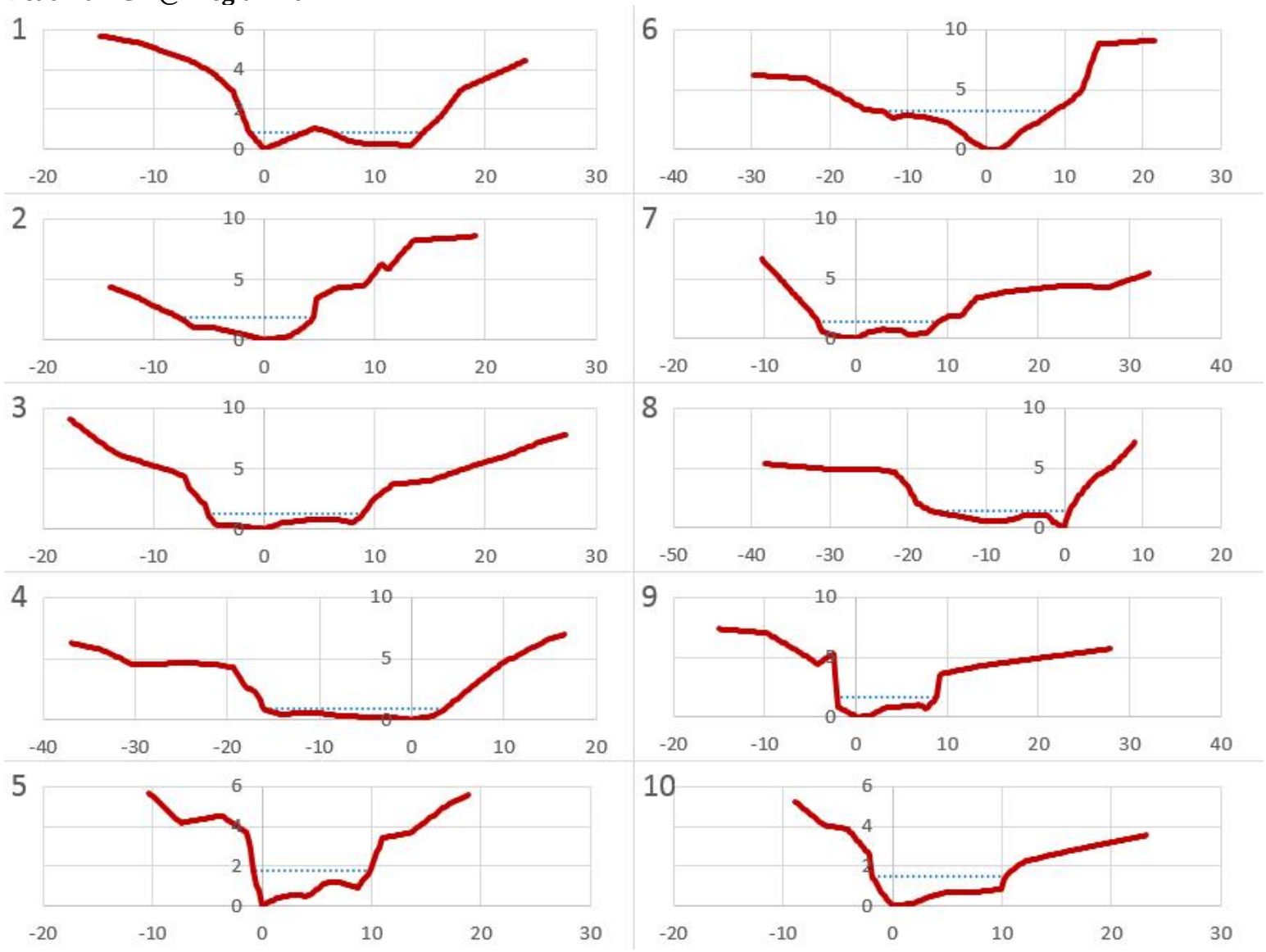
Deadman Creek at Mt Spokane State Park boundary



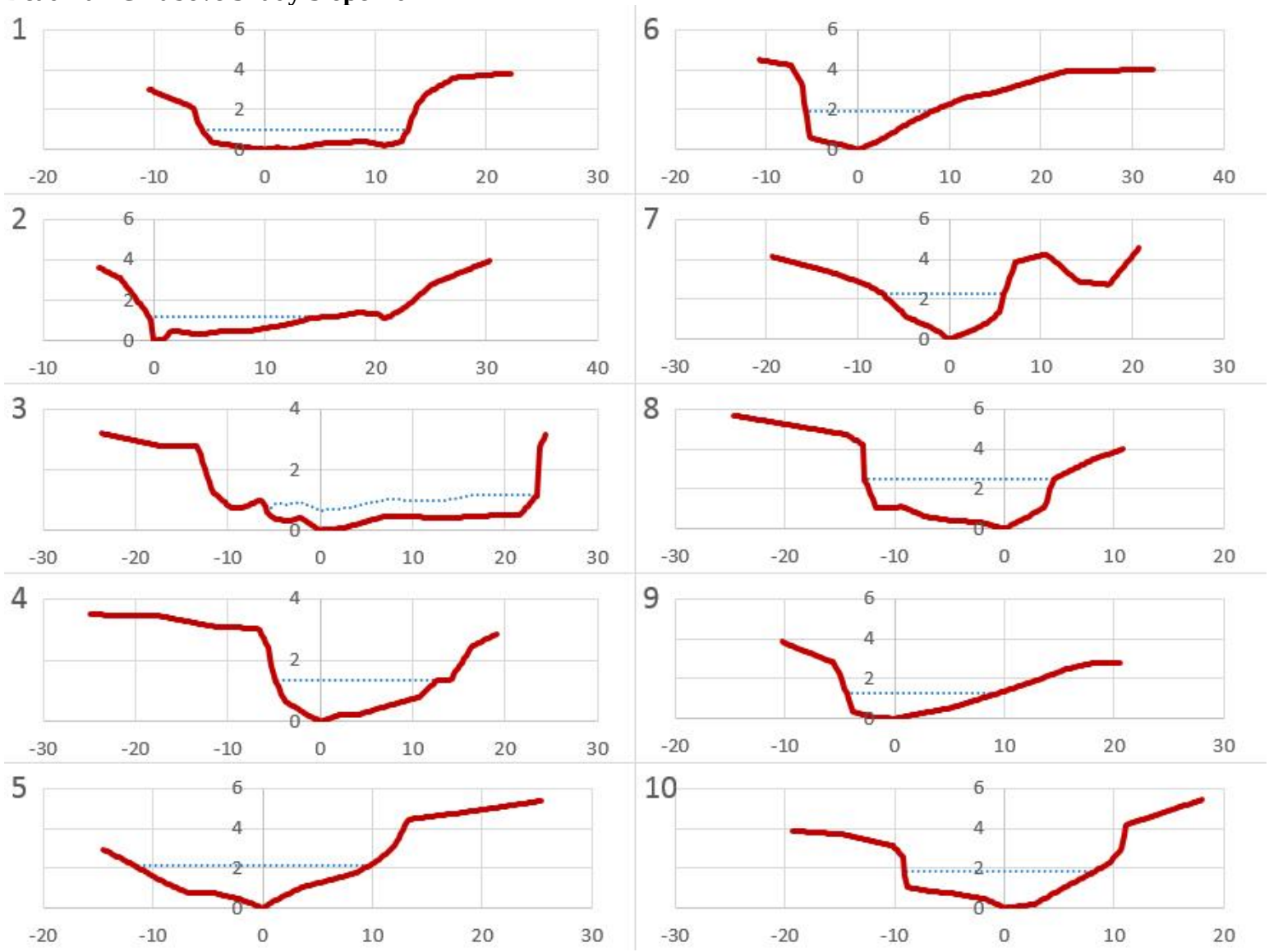
Deadman Creek near Fire Station



Deadman Ck @ Heglar Rd



Deadman Ck above Shady Slope Rd



Lakes data

Table D-18. Lake composite sample information and Secchi depths.

Lake	Location ID	Latitude	Longitude	Layer	Date	Time	Composite sample depths (m)	Secchi depth (m)
Chain	55CHAI-W	48.0546	-117.2196	Epilimnion	9/1/2015	11:45	1,4,7	5.5
				Hypolimnion		11:57	14,22,30	
	55CHAI-E	48.0598	-117.1997	(N/A)		12:58	(no samples)	5.5
Diamond	55DIAM	48.1312	-117.1889	Epilimnion	9/3/2015	10:00	1,5,9	6.3
				Hypolimnion		10:06	12,13,14	
Sacheen	55SACH-W	48.1478	-117.3346	Epilimnion	9/3/2015	11:39	1,2.5,14	5.7
				Hypolimnion		11:59	8,13,18	
	55SACH-E	48.1582	-117.3077	Epilimnion		12:40	1,3,5	4.9
				Hypolimnion		12:52	8,9.5,11	
Horseshoe	55HORS-E	48.1079	-117.4094	Epilimnion	9/2/2015	10:55	1,3,5	2.8
								3.0 (QC)
				Hypolimnion		11:34	8,9.5,11	
	55HORS-W	48.1128	-117.4198	Epilimnion		12:47	1,4,7	3.3
				Hypolimnion		13:27	14,27,40	
Eloika	55ELOI-N	48.0372	-117.3876	Whole lake	9/2/2015	15:23	1,2	visible to bottom
	55ELOI-S	48.0227	-117.3757	Whole lake		15:04	1,2	

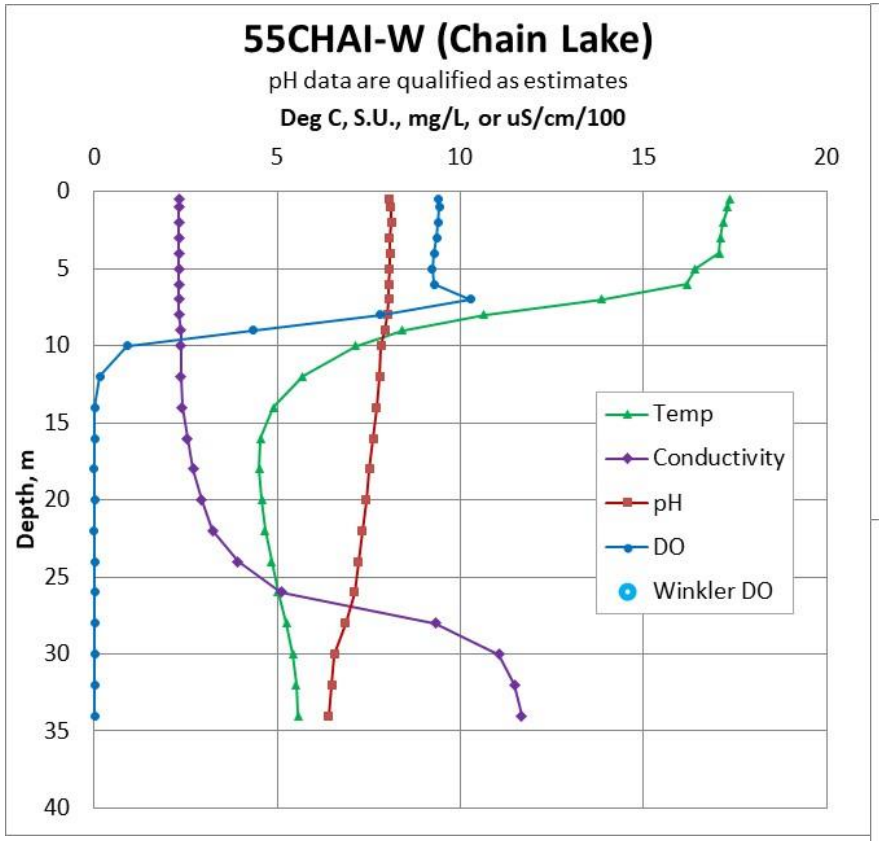
Table D-19. Lake composite sample results.

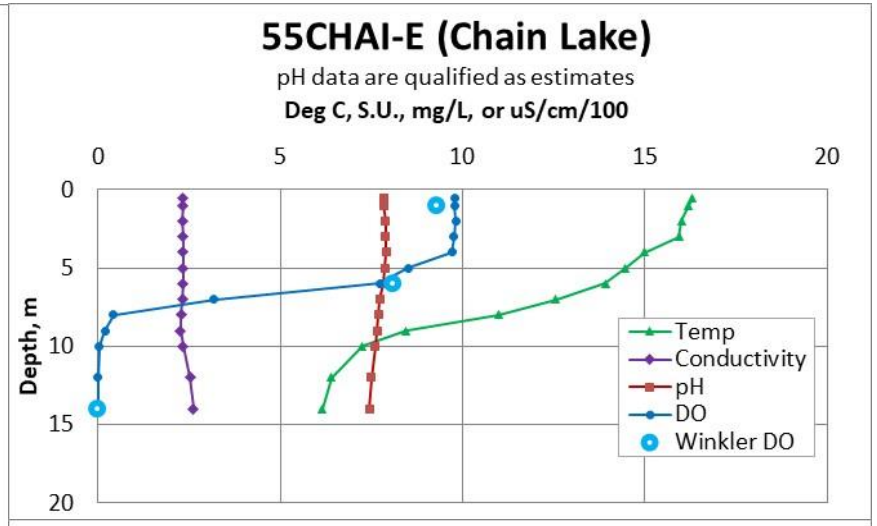
*Data qualifiers are the same as in the **Laboratory Data** section earlier in this appendix.*

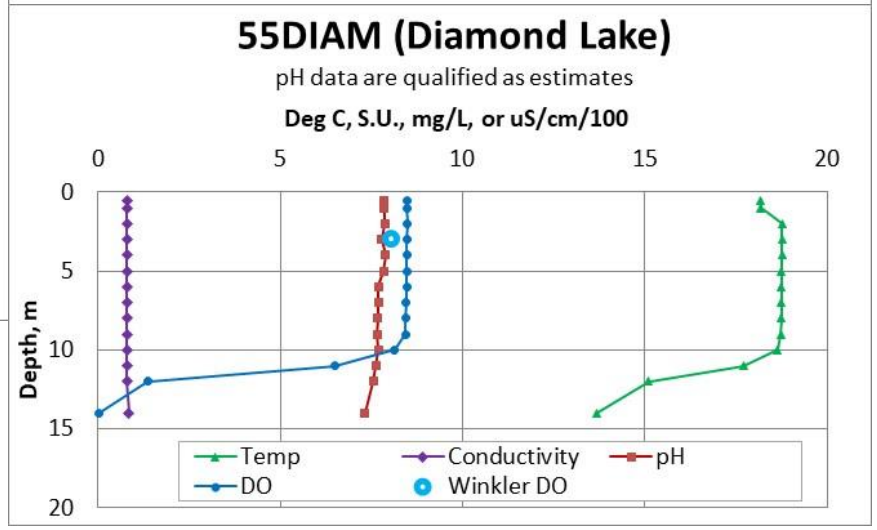
Location	Layer	Date	Time	NH4-N	NO2-3N	TPN	OP	TP	Chl a
Chain Lake									
55CHAI-W	Epi	9/1/2015	11:45	0.015	0.01 U	0.151	0.003 U	0.0167	1.6 J
55CHAI-W	Hypo	9/1/2015	11:57	23.5	0.043	23.5	0.749	3.9	
Diamond Lake									
55DIAM	Epi	9/3/2015	10:00	0.01 U	0.01 U	0.269	0.003 U	0.0058	1.5 J
55DIAM	Hypo	9/3/2015	10:06	0.014	0.01 U	0.245	0.003 U	0.0074	
Sacheen Lake									
55SACH-E	Epi	9/3/2015	12:40	0.01 U	0.01 U	0.216	0.0035	0.0085	3.1
55SACH-E	Hypo	9/3/2015	12:52	0.085	0.01 U	0.323	0.0123	0.0964	
55SACH-W	Epi	9/3/2015	11:39	0.011	0.01 U	0.281	0.0031	0.0117	4.3
55SACH-W	Hypo	9/3/2015	11:59	1.74	0.016	1.77	0.0768	0.497	
Horseshoe Lake									
55HORS-E	Epi	9/2/2015	10:55	0.013	0.01 U	0.274	0.003 UJ	0.0163	10.8 J
55HORS-E (QC)	Epi	9/2/2015	10:55	0.01 U	0.01 U	0.278	0.003 U	0.012	10.2
55HORS-E	Hypo	9/2/2015	11:34	0.736	0.01 U	0.833	0.0381	0.282	
55HORS-E (QC)	Hypo	9/2/2015	11:34	0.535 J	0.01 UJ	0.687 J	0.0312 J	0.213 J	
55HORS-W	Epi	9/2/2015	12:47	0.011	0.01 U	0.197	0.0035 J	0.0098 J	6.9 J
55HORS-W	Hypo	9/2/2015	13:27	0.102	0.108	0.325	0.0078	0.0299	
Eloika Lake									
55ELOI-N	Whole	9/2/2015	15:23	0.013	0.01 U	0.558	0.003 U	0.0276	22.5
55ELOI-S	Whole	9/2/2015	15:04	0.045	0.01 U	0.513	0.003 U	0.0211	5.9

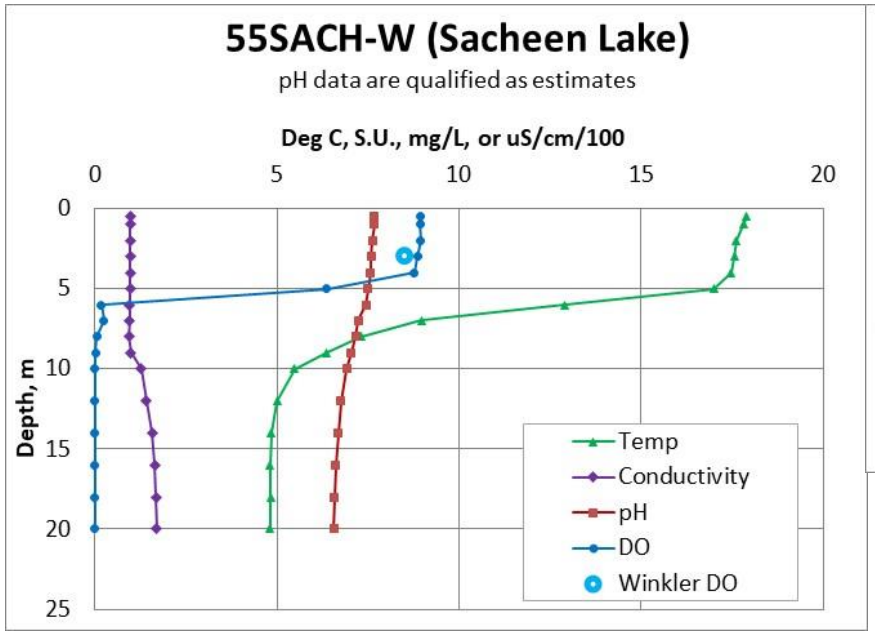
Figure D-7 (Following pages). Lake profile plots.

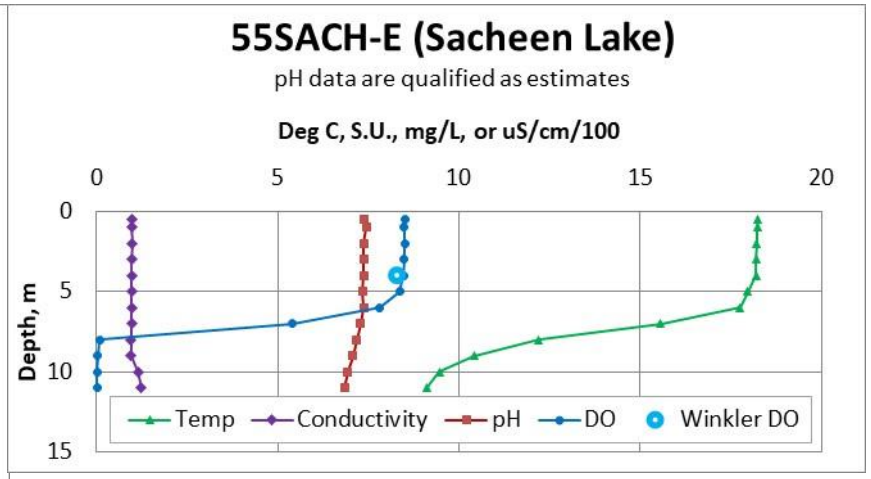
Note: These graphs show conductivity in units of uS/cm/100. This means, for example, that a value of 2 on the graphs equals 200 uS/cm.

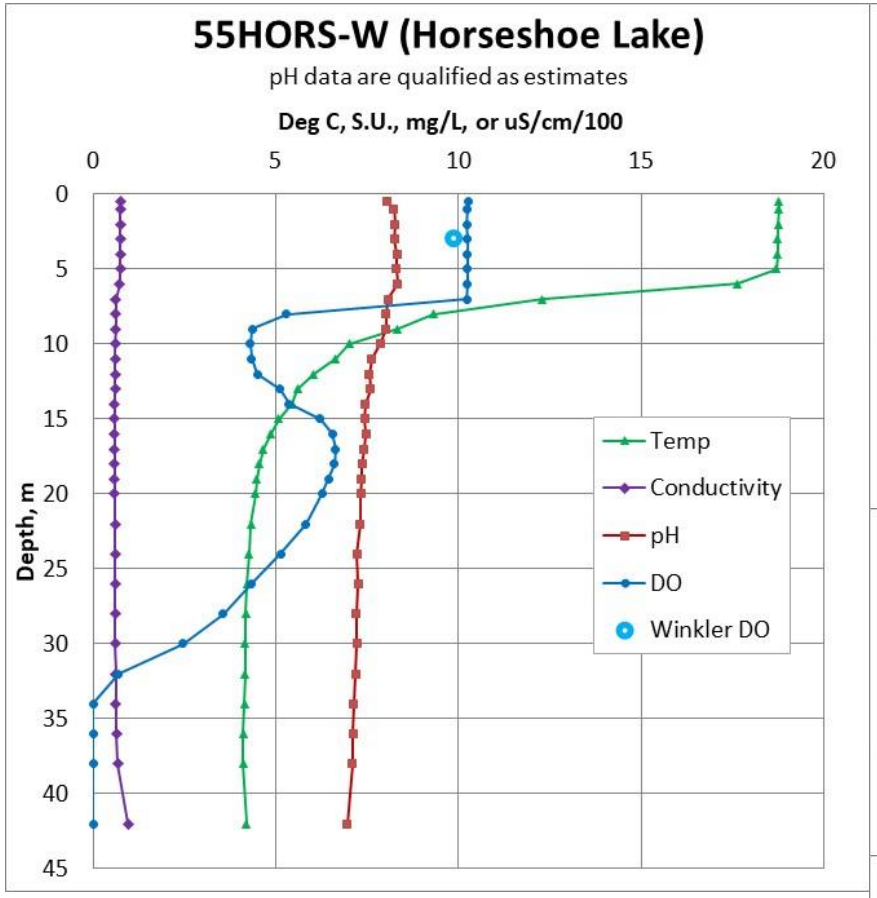


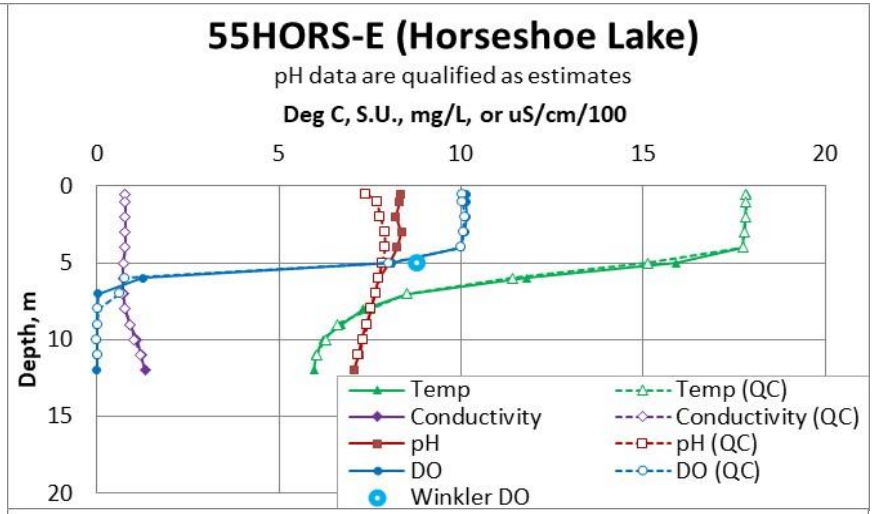


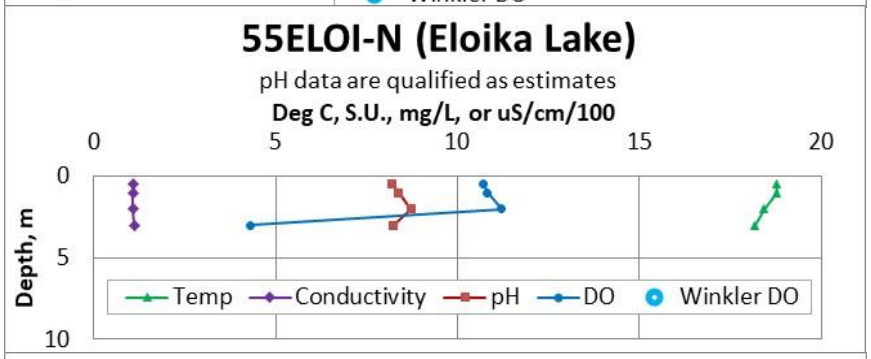


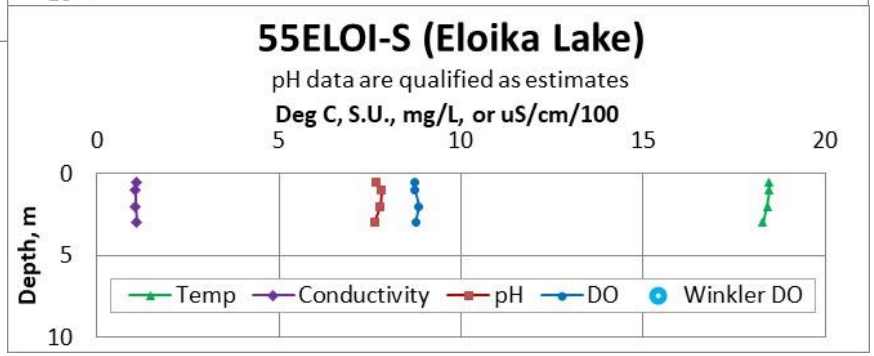

55SACH-W (Sacheen Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
0
5
10
15
20
Depth, m
0
5
10
15
20
25
Temp
Conductivity
pH
DO
Winkler DO


55SACH-E (Sacheen Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
0
5
10
15
20
Depth, m
0
5
10
15
Temp
Conductivity
pH
DO
Winkler DO


55HORS-W (Horseshoe Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
Depth, m
Temp
Conductivity
pH
DO
Winkler DO


55HORS-E (Horseshoe Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
Depth, m
Temp
Conductivity
pH
DO
Winkler DO
Temp (QC)
Conductivity (QC)
pH (QC)
DO (QC)


55ELOI-N (Eloika Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
Depth, m
Temp
Conductivity
pH
DO
Winkler DO


55ELOI-S (Eloika Lake)
pH data are qualified as estimates
Deg C, S.U., mg/L, or uS/cm/100
Depth, m
Temp
Conductivity
pH
DO
Winkler DO

Appendix E. Data Quality

An evaluation of the quality of all data collected by Ecology and SCD during 2010, as well as all data collected by Ecology from the Spokane Hatchery during 2009, is available in a separately published Data Summary Report (Stuart, 2012).

This appendix describes the quality of data that Ecology collected during 2013 and 2015-2016 for the Little Spokane River Dissolved Oxygen and pH TMDL study. This appendix also describes the quality of data obtained from other organizations and agencies which we used to develop this TMDL.

We found nutrient sample data and continuous dissolved oxygen and pH data collected by Washington State University's Washington Water Research Center (WSU/WWRC; Barber et al, 2007) not to be of adequate quality for regulatory decision-making purposes such as TMDL development. We did not use these data. We did use continuous temperature data collected by WSU/WWRC to some degree, and we assess those data below.

We assessed the quality of all data used for the TMDL analysis. Typically this meant comparing quality metrics such as replicate precision statistics or instrument calibration end checks to a target Measurement Quality Objective (MQO). MQO's were established in the QAPPs that defined the data collection for this study (Joy and Tarbutton, 2010; Ross, 2008; Stuart and Pickett, 2015). We found all data to be acceptable for their use in the TMDL analysis, unless otherwise noted.

Sample Data Quality (Ecology 2015-2016)

Ecology took replicate field samples for laboratory parameter analyses. Field replicates consisted of two samples collected from the same location and as close to the same time as possible. Ecology collects field replicates to check the precision of the entire process of sampling and analysis. Tables E-1 and E-2 present the replicate results from 2015-2016. Both the frequency of field replicates and the precision of the replicated samples generally fell within the target levels set in the QAPP. This indicates a high level of precision suitable for TMDL analysis. The frequency of field replicates for alkalinity was slightly less than the 10% level specified in the QAPP. Also, alkalinity and chloride each had one very poor replicate pair, where the replicate result was not close to the primary sample result. We used alkalinity and chloride data with caution, with consideration of unusual or suspicious results.

Laboratory duplicates consisted of two subsamples taken from the same sample container and analyzed separately. These serve as a check on the precision of the lab analysis. Ecology's Manchester Environmental Laboratory standard operating procedure (SOP) calls for duplicating a minimum of 5% of all samples (1/20 samples or 1/analytical batch). We met or exceeded that goal for all parameters except Dissolved Organic Carbon. Results for all parameters met duplicate precision targets (Table E-1).

We analyzed field replicates and laboratory duplicates with result values of less than 5 times the reporting limit (RL) separately. These low-level sample results can have a higher relative variability

than higher sample results. However, for this project, even these low-level duplicates met precision targets for all parameters with the exception of chloride.

Manchester Environmental Laboratory assesses bias for certain parameters through the use of matrix spikes. Assessed bias was within targets for all parameters except dissolved organic carbon (Table E-1). Matrix spike recoveries for dissolved organic carbon were significantly different than 100%. We used dissolved organic carbon data with extreme caution.

Ecology submitted field blanks for analysis along with samples from four sampling runs. In addition, Manchester Laboratory routinely ran lab blanks along with each analytical batch. All field and lab blanks resulted in non-detects, without exception (Table E-3).

Table E-1. Lab precision and bias results from 2015-2016.

Parameter	Number Samples	Number Duplicates	% duplicated	Target Precision	Median %RSD[a]		Target Bias	Average Bias
					< 5x RL	>= 5x RL		
Ammonia-Nitrogen	489	34	7%	<10% RSD	0.0%	0.7%	±5%	-3.4%
Nitrite-Nitrate Nitrogen	489	32	7%	<10% RSD	1.8%	0.5%	±5%	+0.3%
Total Persulfate Nitrogen	489	35	7%	<10% RSD	0.6%	1.0%	±10%	-2.2%
Soluble Reactive Phosphorus (Orthophosphate)	489	42	9%	<10% RSD	2.9%	0.4%	±5%	-2.2%
Total Phosphorus	494	30	6%	<10% RSD	4.0%	0.6%	±5%	-1.0%
Dissolved Organic Carbon	135	3	2%	<10% RSD	0.3%	--	±10%	+26.0%
Total Organic Carbon	135	7	5%	<10% RSD	0.0%	1.4%	±10%	+2.6%
Total Suspended Solids	478	47	10%	<15% RSD	7.9%	2.1%	±10%	--
Chloride	473	29	6%	<5% RSD	8.3%	0.3%	N/A	-1.8%
Alkalinity	53	3	6%	<10% RSD	--	0.3%	N/A	--
Chlorophyll a	72	17	24%	<20% RSD	--	3.4%	N/A	--

[a] We excluded results at the reporting limit (RL) from consideration.

Table E-2. Total precision (field + lab) results from 2015-2016.

Parameter	Number Samples	Number Replicates	% replicated	Target Precision	Median %RSD [a]	
					< 5x RL	>= 5x RL
Ammonia-Nitrogen	489	54	11%	<10% RSD	5.7%	13.6%
Nitrite-Nitrate Nitrogen	489	54	11%	<10% RSD	4.3%	0.5%
Total Persulfate Nitrogen	489	54	11%	<10% RSD	6.0%	1.7%
Soluble Reactive Phosphorus (Orthophosphate)	489	54	11%	<10% RSD	2.6%	1.1%
Total Phosphorus	494	55	11%	<10% RSD	6.3%	1.4%
Dissolved Organic Carbon	135	14	10%	<10% RSD	1.9%	1.2%
Total Organic Carbon	135	16	12%	<10% RSD	0.0%	2.8%
Total Suspended Solids	478	53	11%	<15% RSD	0.0%	7.2%
Chloride	473	52	11%	<5% RSD	8.1%	0.5% [b]
Alkalinity	53	5	9%	<10% RSD	1.9%	1.8% [b]
Chlorophyll a	72	13	18%	<20% RSD	--	3.4%

[a] We exclude results at the reporting limit (RL) from consideration.

[b] Although the Median %RSD for Alkalinity and Chloride were both within target values, these parameters each had one very poor duplicate pair.

Table E-3. Field and laboratory blank results from 2015-2016.

Parameter	Number Samples	Number lab blanks	Number field blanks	Any results other than non-detect?
Ammonia-Nitrogen	489	42	4	none
Nitrite-Nitrate Nitrogen	489	43	4	none
Total Persulfate Nitrogen	489	44	4	none
Soluble Reactive Phosphorus (Orthophosphate)	489	55	4	none
Total Phosphorus	494	44	4	none
Dissolved Organic Carbon	135	11	0	none
Total Organic Carbon	135	11	0	none
Total Suspended Solids	478	93	4	none
Chloride	473	48	4	none
Alkalinity	53	5	0	none
Chlorophyll a	72	17	0	none

Flow Data Quality (Ecology 2013, 2015-2016)

Flow measurements

Ecology performed replicate flow measurements during sampling events, generally whenever we collected replicate samples. We performed replicate flow measurements using the same cross-section as the initial measurement. However, we usually varied the locations of measurement stations along the course the cross-section from those used during the initial flow measurement. We took 41 replicate flow measurements out of 482 total flow measurements (8.5%) during 2015-2016. The median relative percent difference (RPD) of replicate flow measurements was 4.2%; the 90th percentile RPD of replicate flow measurements was 8.7%. The QAPP did not define a measurement quality objective (MQO) for flow precision. However, these results indicate excellent precision of flow measurements.

We did not take replicate flow measurements during 2013. However, we only took17 flow measurements at that time. The protocols and equipment used to measure flow were essentially identical to those used during 2015-2016, and we expect the quality of flow measurements to be approximately the same.

Instantaneous flow data calculated from rating curves

We assessed additional flow data calculated from stage-discharge rating curves, using the additional stage data collected halfway between sampling runs (and occasionally at other times), for quality as follows:

- If all flow and stage measurements used to develop the rating curve were within +/- 10% of the rating curve, then we used data calculated from that rating curve without qualification.
- If some of the flow and stage measurements used to develop the rating curve were not within +/- 10% of the rating curve, if the calculated flow was more than 150% of the highest or less than 50% of the lowest measurement, or if there were any other indications of uncertainty or error, then we qualified the data calculated from that curve as an estimate.
- If there were more than 1-2 flow and stage measurements that were substantial outliers from the rating curve, if there was frequent shifting of the rating curve, or simply a poor relationship between stage and discharge, then we made a determination that all or a portion of the rating curve could not be used to produce reasonably reliable flow estimates. In these cases we did not calculate flow results at all.

Of the 180 flow results that we calculated from rating curves, we used 45 without qualification and qualified 135 as estimates.

Continuous flow gage data

We assessed continuous flow data collected at the three gaging stations operated by Ecology for precision by comparing flow measurements taken at those stations with the continuous record corresponding to the moment in time when the flow measurement was taken (Table E-4). Precision results indicate that gage data is of high quality appropriate for use in TMDL development.

Table E-4. Gaging flow precision results.

Location ID	Gage location	# of flow measurements taken	% RPD	
			Median	90th percentile
55WBLS-03.1	WBLSR @ Eloika Lk Rd	25 (30) [a]	4.7%	13.8%
55DRA-00.3	Dragoon Ck @ Mouth	23	3.5%	12.2%
55DEA-00.2	Deadman Ck blw Little Deep Ck	10	5.1%	9.7%

[a] We took 30 flow measurements at this location during the project, but only 25 of these were taken while the gage was operating.

Hydrolab® Data Quality (Ecology 2013, 2015-2016)

Ecology calibrated all field monitoring equipment according to manufacturer's specifications using certified standards. We calibrated Hydrolab® meters prior to each monitoring event, and checked calibrations after each event to assess calibration drift.

Conductivity and pH accuracy

We assessed conductivity and pH accuracy through calibration post-checks. Table E-5 shows the targets to accept, qualify, or reject data. We used qualified data with caution for TMDL analysis, accounting for the range of possible error indicated by post-check results. We did not use rejected data.

Table E-5. Post-check targets for calibration drift for conductivity and pH.

Parameter	Difference between post-check value and true buffer value to:		
	Accept	Qualify	Reject
Conductivity	≤ 10%	> 10% and ≤ 20%	> 20%
pH	≤ 0.2	> 0.2 and ≤ 0.5	> 0.5

We accepted all conductivity and pH data without qualification, except for the following data, which we qualified due to instrument post-check results being outside the targets specified in Table E-5:

- During the April 21-22, 2015 sampling survey, we qualified conductivity data from one of the two instruments used. This affected about half of the sampling locations, mostly located along the mid-upper Little Spokane River, the West Branch Little Spokane River, and small tributaries in the northern part of the watershed.
- During the July 8, 2015 sampling survey, we qualified all conductivity data.
- During the September 1-3, 2015 lakes sampling event, we qualified all pH data.
- During the August 18-28, 2015 diel Hydrolab® survey, we qualified pH data at 55LSR-13.5 (Little Spokane R @ N Little Spokane Dr), 55WBLS-17.7 (West Branch Little Spokane R @ Harworth Rd), and 55DEA-13.8 (Deadman Ck @ Holcomb Rd). We rejected conductivity data at 55LSR-23.4 (Little Spokane R @ Chattaroy) due to probe malfunction. We rejected all data from 55BEAV-00.5 (Beaver Ck [WBLSR Trib] @ Mouth) due to poor agreement with spot checks for all

parameters, apparently due to the instrument being deployed on the streambed in a location with very active surface/groundwater interactions.

- During the February 22-23, 2016 sampling survey, we qualified pH data from one of the two instruments used. This affected about half of the sampling locations, mostly located along Dragoon, Deer, and Deadman Creeks in the southern part of the watershed.

None of the data qualifications had a significant impact on the analysis for this project.

Dissolved oxygen accuracy

We assessed DO accuracy through comparison with Winkler titration results. We usually took Winkler samples alongside each Hydrolab® used for deployment or spot measurements. For spot measurements, we corrected most DO data using Winkler results. The reason for this is that the technique for DO calibration, which is based on air saturated water or water saturated air (depending on the probe type), can result in a certain degree of bias or mis-calibration. Correction of this data using Winkler creates a uniform standard, and eliminates most or all of this error.

For continuous Hydrolab® deployments during summer 2015, we assessed and/or corrected DO data using a hybrid technique of Winkler titrations and spot check measurements utilizing Luminescent Dissolved Oxgyen (Hach® LDO) technology. During each continuous Hydrolab® survey, we carried an additional calibrated Hydrolab® equipped with LDO from site to site and used to take spot measurements alongside the deployed instruments. We collected a large number (26-28) of Winkler samples alongside these point measurements, and used these to generate an exceptionally high quality correction of the point measurement data if needed (Figure E-1). We then used the corrected point measurements to assess and/or correct the continuous DO measurements from the deployed Hydrolabs®. This method combines the high precision and stability of LDO technology with the overall accuracy and uniform standard provided by Winkler titrations, resulting in the most accurate possible final DO data.

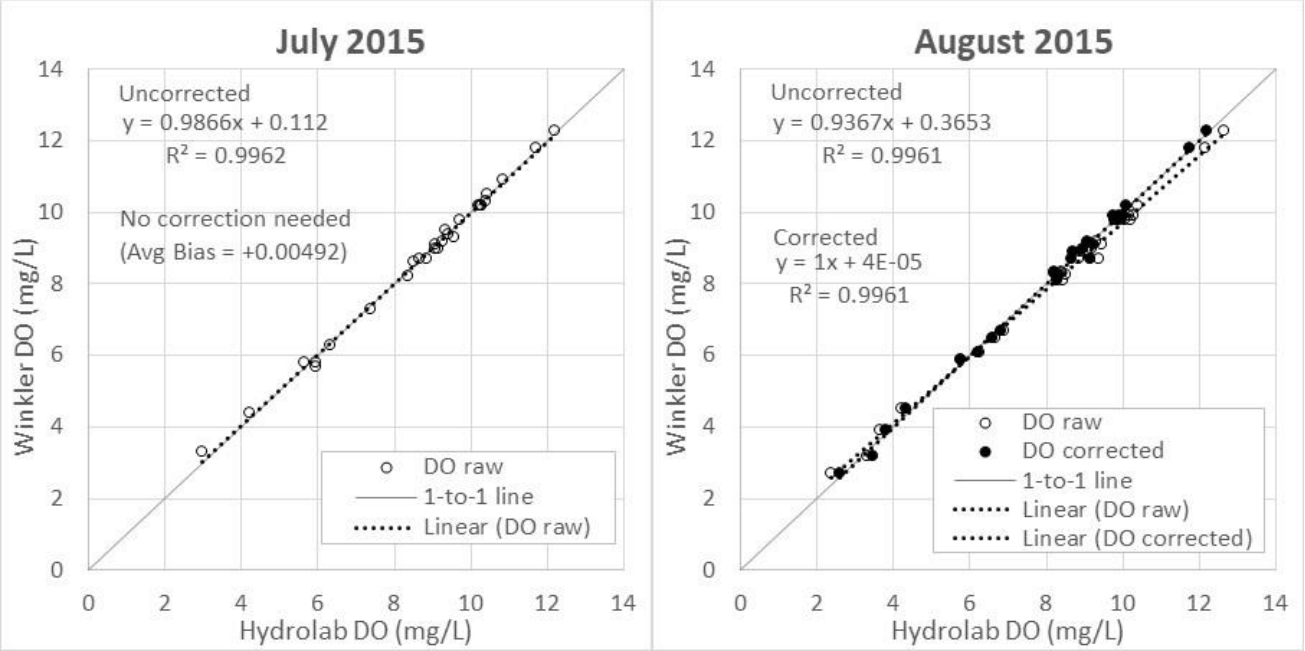


Figure E-1. Raw and corrected spot measurement data used to assess and/or correct continuous DO data during July and August 2015.

Except for the following instances, all other DO data were acceptable without qualification:

- During 2013, we did not collect Winkler samples alongside deployed Hydrolabs®. Instrument post-checks indicate good probe function and DO data seem reasonable, however it is not possible to assess or correct small amounts of error that may be present due to slight mis-calibration inherent to the calibration method. We qualified all continuous DO data from 2013.
- During the June 3, 2015 sampling survey, we did not collect Winklers alongside one of the two instruments used. We qualified instantaneous data, affecting five locations on Deadman Ck.
- During the July 8, 2015 sampling survey, we qualified DO data due to a large (1.2 mg/L) difference between raw instrument and Winkler data, and resulting uncertainty about the correction quality, affecting instantaneous data at two locations.
- During the October 7, 2015 sampling survey, we qualified DO data due to a large (0.9 mg/L) difference between raw instrument and Winkler data, and resulting uncertainty about the correction quality, affecting instantaneous data at two locations.
- During the November 5, 2015 sampling survey, we rejected DO data due to a very large (2.4 mg/L) difference between raw instrument and Winkler data, affecting instantaneous data at two locations.
- During the November 17-19, 2015 sampling survey, we qualified DO data from one of the two instruments used due to poor linearity and wide scatter ($r^2 = 0.67$) when compared against Winkler data, resulting in uncertainty about the correction. This affected instantaneous data at about 2/3 of the sites visited, mostly located along the lower Little Spokane River, Deadman Creek, Dragoon Creek, and parts of the West Branch LSR sub-basin.

None of these qualifications and rejections had a significant impact on the data analysis.

Hydrolab® precision

We took Hydrolab® replicate instantaneous measurements during sampling events at the same locations and times where we collected replicate laboratory samples during 2015-2016. We took replicate measurements using the same instrument as was used to collect the original set of measurements, several minutes after the initial set of measurements was taken. We used these replicate measurements to assess aspects of precision relating to instrument wobble, short-term fluctuations of water quality parameters in the water body, and/or rapidly changing conditions in the water body. Table E-6 presents Hydrolab® precision results. Median precision for all Hydrolab® parameters was within the measurement quality objective (MQO) established in the QAPP (Stuart and Pickett, 2015).

Table E-6. Hydrolab® precision results for 2015-2016.

Parameter	Precision measurement quality objective	Type of MQO	# of replicates	Precision statistic (absolute difference or %RSD [a])	
				Median [b]	90th percentile [c]
Temperature	+/- 0.1°C	absolute diff.	45	0.02	0.126
pH	+/- 0.20 S.U.	absolute diff.	45	0.01	0.182
Conductivity	0.5% RSD	%RSD	45	0.1%	0.4%
Dissolved Oxygen	5% RSD	%RSD	45	0.2%	0.8%

[a] Relative standard deviation

[b] Precision MQO is generally compared to the median statistic.

[c] 90th percentile statistic is presented for reference.

Continuous Temperature Data Quality (Ecology 2015)

We evaluated Ecology continuous air and water temperature data quality in two ways. First, we subjected continuous air and water temperature dataloggers to two-point calibration checks before and after deployment using cold and warm water baths. Second, we compared spot measurements of temperature taken with either a Hydrolab® or with a Cole-Parmer® electronic thermistor to the continuous data. Table E-7 presents calibration and field check results.

Post-deployment calibration bath results indicate that all instruments were functioning within the MQO of +/- 0.2°C. Field checks indicate additional variability, likely related to the fact that temperatures in the field are nearly always changing, sometimes rapidly. Field checks indicate that the continuous water data are likely accurate to approximately +/- 0.5°C accounting for field variability. Field checks for air indicate variability of up to 4°C. Air checks are subject to rapidly changing temperature, wind, and/or sunlight conditions.

Based on these calibration checks, all the continuous water temperature data are acceptable for TMDL development. Continuous air temperature data are likely of a quality consistent with other data collected in like manner (TidbiT® dataloggers deployed inside white PVC shade devices). For this TMDL we did not ultimately use the air temperature data for model inputs, but only for checking against the water temperature data to assess if the water datalogger ever come out of the water. (These comparisons showed that they did not).

Table E-7. Continuous temperature data quality results for 2015-2016.

Location ID	Measurement quality objective	Post-deployment calibration bath results [a]		Number of field checks		Field check result (mean absolute error °C)		Field check result (overall bias °C)	
		Water	Air	Water	Air	Water	Air	Water	Air
55LSR-46.7	+/- 0.2°C	OK	OK	12	3	0.16	0.89	-0.02	+0.89
55LSR-37.5	+/- 0.2°C	OK	OK	3	3	0.04	0.77	+0.02	-0.16
55LSR-13.5	+/- 0.2°C	OK	OK	12	2	0.37	2.53	+0.25	-2.15
55WBLS-03.1	+/- 0.2°C	OK	OK	22	3	0.52	3.97	-0.52	+3.37
55DRA-00.3	+/- 0.2°C	OK	OK	13	4	0.08	0.49	-0.05	+0.41
55DEA-00.2	+/- 0.2°C	OK	-- [b]	3	--	0.15	--	+0.15	--

[a] OK means that for both the cold and warm water baths, the datalogger result was within +/-0.2°C of the temperature measured by a NIST-certified alcohol thermometer.

[b] We did not deploy an air logger at 55DEA-00.2.

Channel Geometry Data Quality (Ecology 2013, 2015)

Time-of-Travel dye study quality

The protocol for conducting time-of-travel dye studies provides a robust method for determining the average amount of time it takes for water to travel through a given reach of a river. We released rhodamine WT dye into the river at an upstream location, and deployed Hydrolab® dataloggers equipped with a specialized probe to measure rhodamine concentrations at one or more locations downstream. We determined the time of travel for a given reach as the time elapsed from dye injection at the upstream location to when the peak dye concentration occurred at the downstream location. Alternately, when multiple dataloggers are used downstream of a single dye injection, we determined the time of travel for a given reach as the time elapsed from when peak dye concentration occurred at an upstream location to the time of peak dye concentration at the downstream location.

This protocol was designed for measuring *average* time-of-travel, and therefore is based on the time of peak concentration, rather than leading edge. This differs significantly from protocols designed to estimate travel of toxic substances, where the emphasis is on human health considerations. Users of this data should take care not to misapply this data for purposes for which it was not intended.

We set Hydrolabs® deployed to measure dye concentration to log every 10 minutes. Dye concentration curves were typically very clear, and the peak concentration easily discernable. Figure E-2 shows an example dye concentration curve. We assessed the accuracy of time of travel calculations as follows (Table E-8):

- For reaches directly downstream of a dye drop location, the time of travel calculation is likely accurate to +/- 5 minutes, because if the peak dye concentration was off by more than 5 minutes, it would have been logged at the next earlier or next later 10-minute interval.
- For reaches between two deployed Hydrolabs®, the time of travel calculation is likely accurate to +/- 10 minutes, because there is +/- 5 minute uncertainty both at the upstream and downstream end of the reach.

- At 55LSR-33.2 (Little Spokane R. @ Eloika Rd.), the dye concentration signal was very "noisy" or "spiky." We estimated the time of peak dye concentration by using a 1-hour rolling average of the data. This estimate is likely accurate to +/- 1 hour. This affects the time of travel estimates for both the reach upstream and downstream of this site.

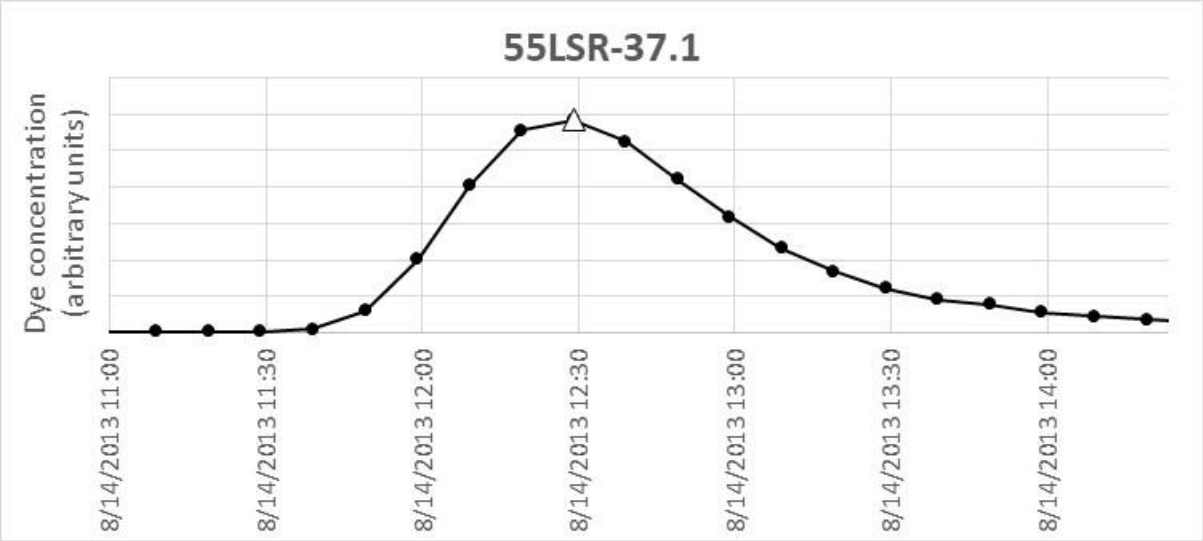


Figure E-2. Example dye concentration curve from time-of-travel study in 2013.
Peak dye concentration is shown with a triangle.

Table E-8. Time of travel data assessed accuracy.

Upstream Location	Downstream Location	Reach length (mi)	Time of Travel (hours)	Assessed accuracy	
				time	percent
55LSR-39.5 [d]	55LSR-37.1	3.35	4.75	± 5 min	± 1.8%
55LSR-37.1	55LSR-33.2	4.65	6.50	**± 1 hour**	**± 15%**
55LSR-33.2	55LSR-31.8	1.60	2.58	**± 1 hour**	**± 39%**
55LSR-31.8	55LSR-23.4	8.15	16.58	± 10 min	± 1.0%
55LSR-23.4 [d]	55LSR-19.8	2.90	3.25	± 5 min	± 2.6%
55LSR-19.8	55LSR-16.0	3.90	5.25	± 10 min	± 3.2%
55LSR-16.0	55LSR-13.5	2.65	4.08	± 10 min	± 4.1%
55LSR-13.5	55LSR-10.3	2.65	2.50	± 10 min	± 6.7%
55LSR-10.3 [d]	55LSR-07.5	3.35	3.70	± 5 min	± 2.3%
55LSR-07.5	55LSR-03.9	4.05	4.00	± 10 min	± 4.2%
55LSR-03.9	55LSR-01.1	3.50	3.83	± 10 min	± 4.3%

[d] Dye drop location.

Channel survey data quality

We assessed the precision of vertical distance measurements taken with the laser rangefinder by comparing them to measured depths. At each point in a channel cross-section that was in the wetted portion of the channel, we measured water depth using a rod, along with the vertical distance

measurement. For channel cross sections in pools or other locations where flow is fairly laminar, it is reasonable to assume that the water surface is at the same elevation for all points in the cross section. For these locations, we reconciled surveyed vertical distances with measured depths by assuming a level water surface and overlaying the vertical distances with the measured depths in such a way as to eliminate overall bias between the two (Figure E-3).

Then, for each point measured, we calculated the absolute error as the difference between the vertical distance according to the measured depth and the vertical distance measured by the laser. We calculated Median absolute error to be 0.07 ft, and the 90th percentile of absolute error as 0.20 ft.

Even though we assessed laser vertical precision using the wetted portion of the channel, these results actually apply only to the dry portion of the channel. This is the portion of the cross-section where we exclusively used the laser vertical distance measurement. For the wetted portion of the channel, we used rod measured depths preferentially over laser measurements. We measured depths using the rod to the nearest 0.05 ft.

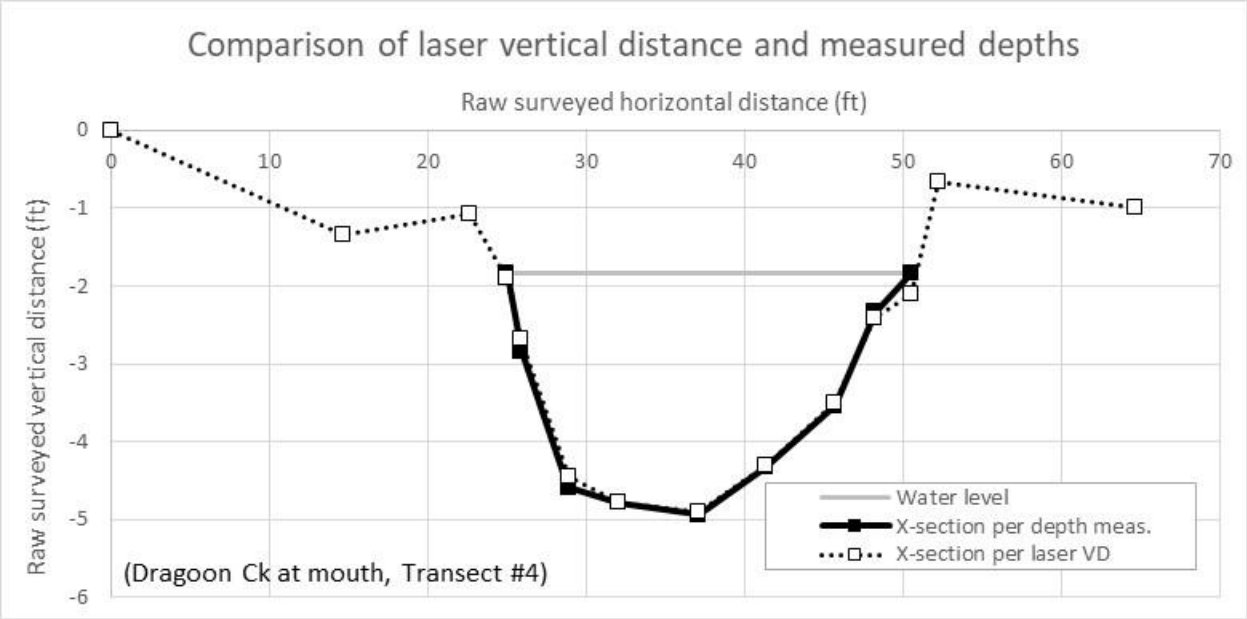


Figure E-3. Illustration of the small discrepancies in cross-section profiles according to laser vertical distances vs. measured depths.

It is likely that error in horizontal distances was similar to error in vertical distances, because the laser rangefinder depends on accurate horizontal distance measurements to calculate vertical distance. If there had been significant errors in horizontal distance measurements, these would have resulted in faulty vertical distance measurements as well; however, as previously described, vertical distance measurements were generally quite good (Figure E-3).

Periphyton Data Quality (Ecology 2010, 2015)

Periphyton biomass quality (2010)

We assessed the precision of periphyton biomass data collected during 2010 by comparing replicates. We collected one replicate periphyton biomass sample during each of the two synoptic surveys (20% replication rate). The average RPD for Chlorophyll a areal biomass was 18.4%, while the average RPD for Ash Free Dry Weight areal biomass was 14.9%. Given the inherently variable nature of peiphyton biomass data, these replicate values are reasonable. We used these data to inform the general range of expected periphyton biomass values, but did not calibrate the QUAL2Kw model exactly to the data points.

Periphyton taxonomy quality (2015)

We used the following periphyton taxonomy data in our analysis:

- Data collected as part of Ecology's ambient biological monitoring program
- Data collected specifically for this project using the same set of protocols (Adams, 2010).

Rithron Associates, Inc., in Missoula, MT, analyzed all samples. Rithron follows strict QA/QC protocols. We consider these data to be of good quality.

Groundwater Data Quality

Groundwater data used in this study were collected by external organizations. We consider all these data to be of adequate quality for the way in which they were used during the study.

Washington Department of Health

We obtained some groundwater nitrate data for the mid-upper watershed from Washington Department of Health (DOH) monitoring of drinking water wells. DOH follows standardized sampling procedures and uses Ecology certified laboratories for analytical testing. The following data sheets specify DOH sample precedures:
https://www.doh.wa.gov/Portals/1/Documents/Pubs/331-219.pdf
https://www.doh.wa.gov/Portals/1/Documents/Pubs/331-222.pdf

Spokane County

We obtained groundwater phosphorus data for the Spokane Valley-Rathdrum Prairie Aquifer (SVRPA) primarily from Spokane County's Groundwater Monitoring Program. We used data collected from 2009-2012. Spokane County's QAPP can be found at:
https://www.spokanecounty.org/DocumentCenter/Home/View/3787

Spokane County regularly collects replicate samples and field blanks. Replicate and blank results can be found here:
https://www.spokanecounty.org/Archive.aspx?AMID=62

U.S. Geological Survey

We also used U.S. Geological Survey (USGS) groundwater data for phosphorus and nitrate concentrations in wells in the mid-upper watershed. USGS uses standard protocols for all its work. However, many of these data were collected during previous decades, as far back as the 1970s. Laboratory analytical methods have changed and testing capabilities have improved over time. Testing methods for phosphorus were not as good in past decades as at present. We used these data cautiously, in a weight-of-evidence manner with reference to corresponding surface water data.

Spokane Hatchery survey data

The Ecology 2009 survey and the Anchor QEA 2014-15 survey were both conducted under reviewed and approved Quality Assurance Project Plans (Ross, 2008; Joy and Tarbutton, 2010).

Data quality results from the 2009 survey are available in a previously published Data Summary report (Stuart, 2012). We determined data from this survey to be of acceptable quality, with consideration given to greater uncertainty with qualified data.

Anchor QEA sample data quality

Table E-9 presents lab precision and bias results. Table E-10 presents total precision results. Table E-11 presents laboratory blank results. All parameters met their targets for precision and bias, except for settleable solids, for which only one field replicate was collected and no target was set. We recommend that any subsequent users of this dataset treat the settleable solids data with caution. This parameter was not important to our TMDL analysis. All laboratory blanks resulted in non-detects, without exception.

Table E-9. Lab precision and bias results from Anchor QEA Spokane Hatchery sampling 2014-2015.

Parameter	Number Samples	Number Duplicates	% duplicated	Target Precision [a]	Median %RSD [b]		Target Bias [c]	Average Bias
					< 5x RL	>= 5x RL		
Ammonia-Nitrogen	72	6	8%	<20% RSD	1.8%	--	±20%	+1.7%
Nitrite-Nitrate Nitrogen	72	6	8%	<20% RSD	--	0.8%	±20%	-3.0%
Total Nitrogen	72	6	8%	<20% RSD	--	2.1%	±20%	-3.2%
Soluble Reactive Phosphorus	72	6	8%	<20% RSD	--	0.0%	±20%	+1.7%
Total Phosphorus	72	6	8%	<20% RSD	0.0%	1.3%	±20%	+4.3%
Dissolved Organic Carbon	48	3	6%	<20% RSD	0.9%	--	±20%	+7.2%
Total Organic Carbon	48	3	6%	<20% RSD	1.2%	0.5%	±20%	+1.4%
Total Suspended Solids	72	6	8%	<20% RSD	--	0.0%	±20%	0.0%
Settleable Solids	72	0	0%	N/A [3]				
Biochemical Oxygen Demand 5-day	48	3	6%	<20% RSD	--	4.9%	±20%	--

[a] Defined in the original Ecology QAPP for the Little Spokane DO-pH TMDL (Joy and Tarbutton, 2010). WDFW sampling in 2014-2015 followed this same QAPP.

[b] We excluded results at the reporting limit (RL) from consideration.

[c] The QAPP did not define MQO's for Settleable Solids, as Ecology had not used this parameter during the 2009 sampling.

Table E-10. Total precision (field + lab) results from Anchor QEA Spokane Hatchery sampling 2014-2015.

Parameter	Number Samples	Number Replicates	% replicated	Target Precision [a]	Median %RSD [b]	
					< 5x RL	>= 5x RL
Ammonia-Nitrogen	72	4	6%	<20% RSD	9.3%	--
Nitrite-Nitrate Nitrogen	72	6	8%	<20% RSD	--	0.9%
Total Nitrogen	72	6	8%	<20% RSD	--	2.3%
Soluble Reactive Phosphorus	72	6	8%	<20% RSD	--	0.0%
Total Phosphorus	72	6	8%	<20% RSD	0.0%	3.8%
Dissolved Organic Carbon	48	4	8%	<20% RSD	1.9%	5.6%
Total Organic Carbon	48	4	8%	<20% RSD	6.6%	0.5%
Total Suspended Solids	72	6	8%	<20% RSD	11.2%	8.5%
Settleable Solids	72	1	1%	N/A [c]	-- [d]	--
Biochemical Oxygen Demand 5-day	48	0	0%	<20% RSD	--	--

[a] Defined in the original Ecology QAPP for the Little Spokane DO-pH TMDL (Joy and Tarbutton, 2010). WDFW sampling in 2014-2015 followed this same QAPP.

[b] We excluded results at the reporting limit (RL) from consideration.

[c] The QAPP did not define MQO's for Settleable Solids, as Ecology had not used this parameter during the 2009 sampling.

[d] The only replicate for Settleable Solids was at the detection limit, so we could not calculate %RSD.

Table E-11. Laboratory blank results from Anchor QEA Spokane Hatchery sampling 2014-2015.

Parameter	Number Samples	Number lab blanks	Any results other than non-detect?
Ammonia-Nitrogen	72	6	none
Nitrite-Nitrate Nitrogen	72	6	none
Total Nitrogen	72	6	none
Soluble Reactive Phosphorus	72	6	none
Total Phosphorus	72	6	none
Dissolved Organic Carbon	48	3	none
Total Organic Carbon	48	3	none
Total Suspended Solids	72	6	none
Settleable Solids	72	5	none
Biochemical Oxygen Demand 5-day	48	3	none

Anchor QEA Hydrolab® data quality

We assessed conductivity, pH, and dissolved oxygen accuracy through calibration post-checks. This differs slightly from the method we used to assess Ecology data. Since Anchor QEA did not collect Winkler DO samples, it was necessary to assess Hydrolab® DO data using saturation post-checks. Table E-12 shows the targets to accept, qualify, or reject data.

Table E-12. Post-check targets for calibration drift for Anchor QEA Spokane Hatchery Hydrolab® data.

Parameter	Difference between post-check value and true buffer value to:		
	Accept	Qualify	Reject
Conductivity	≤ 5% [a]	> 5% and ≤ 10%	> 10%
pH	≤ 0.2	> 0.2 and ≤ 0.5	> 0.5
Dissolved oxygen	≤ 4%	> 4% and ≤ 20%	> 20%

[a] Defined in the original Ecology QAPP for the Little Spokane DO-pH TMDL (Joy and Tarbutton, 2010). WDFW sampling in 2014-2015 followed this same QAPP. This MQO value differs from the one used for the 2015-2016 sampling effort (10%).

We accepted all data without qualification, except for the following data which we qualified due to instrument post-check results being outside the targets specified in Table E-12:

- We qualified all DO data *except* for during the November 20, 2014 sampling survey.
- During the October 20, 2014 sampling survey, we qualified all pH data.

None of the data qualifications had a significant impact on the analysis for this project.

Representativeness of Spokane Hatchery data

To understand data representativeness issues at the Spokane Hatchery, it is important to consider the following factors:

- All source water comes from Griffith Spring, which is an outflow from the Spokane Valley/Rathdrum Prairie Aquifer. A portion of the spring water is diverted to the hatchery, while the rest continues past the hatchery in a by-pass channel
- Within the hatchery, the water travels through a complex array of trenches, ponds, tanks, and raceways.
- Eight separate outfalls release wastewater from the hatchery to an oxbow slough, which is an off-channel area in the Little Spokane River floodplain. This report will refer to this area as "Griffith Slough".
- An old structure (apparently an old dam) creates some backwater, although the flow mostly by-passes the structure through a gap. The structure separates an area near the outfalls (which Hatchery staff call a "constructed wetland") from the outlet to the river. Solids from the hatchery appear to have settled in this confined area.
- The Griffith Spring by-pass flow mixes with the outfall flows in Griffith Slough. The combined flows then pass the structure at one end and continue down the slough to the river.

The Ecology 2009 surveys did not sample all of the outfalls. Therefore that dataset cannot be considered representative of total discharge to the LSR.

Temporal representativeness is uncertain due to the intermittent nature of activities at the hatchery that generate loading. WDFW reports that routine cleaning operations occur daily for troughs, twice a week for raceways, and weekly for ponds (WDFW, 2015a). The procedures for cleaning suggest that releases of waste occur intermittently during cleaning processes. The timing of cleaning relative to the sampling surveys is also unclear. This complexity of synchronizing sampling with cleaning operations makes representative sampling of hatchery effluent difficult.

Anchor QEA (2015) conducted 5 surveys between June 2014 and February 2015 when they sampled the outfalls, the source water, Griffith Slough, and the Little Spokane River downstream of Griffith Slough. Ecology conducted sampling in 2009 which included 16 surveys which monitored the source water, two outfalls, and the combined discharge in Griffith Slough. This represents only a small amount of effluent sampling data relative to the complexity of the facility and its operations. Therefore, the characterization of the effluent may be poorly representative and accuracy of loading estimates from the hatchery are uncertain.

Meteorological Data

We obtained meterological data from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) records for the Deer Park Airport (KDEW) site. NWS uses standard protocols to insure data quality. Information quality guidelines for NWS can be found here: http://www.cio.noaa.gov/services_programs/IQ_Guidelines_011812.html

Appendix F. Watershed analysis detailed documentation

Flow balances

As described in the body of the report and illustrated in Figure 22, we selected reaches for calculating flow balances based on sites where flow measurement data were available. We assigned reaches for the mainstem LSR, and for three major tributaries: West Branch LSR, Dragoon Creek, and Deadman Creek. For calculating the flow balance, we treated each reach as a "mixed tank" where we added or subtracted upstream flows, tributary and point source inflows, water withdrawals, and evaporation to the gaged upstream flow. We then compared the resulting downstream flow estimated from this mass balance approach to the flow at the downstream location. In the dry season, we assigned the remaining "residual" to groundwater. In the wet season, we added an estimate of groundwater flows (calculated from dry season conditions) to the mass balance, and the assigned the residual surface runoff.

The following is a detailed list of the headwaters, tributary, point sources, and downstream stations that defined the reaches:

- Mainstem LSR:
    - Headwaters: 55LSR-46.7 (Scotia)
    - 55LSR-39.5 (Friedeger Road)
    - 55LSR-37.5 (Elk Park: USGS *Little Spokane River at Elk, WA*, 12427000)
    - 55LSR-37.1 (Elk-Chattaroy Road)
        - Dry Creek and Sheets Creeks (55DRY-00.4 and 55SHE-00.6 – measured separately, then combined)
        - Otter Creek (55OTT-00.3)
        - WBLSR (see below)
        - Bear Creek (55BEAR-00.4)
    - 55LSR-23.4 (Chattaroy)
        - Deer Creek (55DEE-00.1)
        - Dragon Creek (see below)
        - Colbert Landfill NPDES
    - 55LSR-13.5 (Little Spokane Drive above Deadman Creek)
        - Deadman Creek (see below)
    - 55LSR-11.0 (Near US 395: USGS *Little Spokane River at Dartford*, 12431000)
        - Dartford Creek (55DAR-00.2)
        - Spokane Hatchery NPDES
    - 55LSR-3.9 (Rutter Parkway: USGS *Little Spokane River near Dartford*, 12431500)
    - 55LSR-01.1 (Mouth, Hwy 291)
- West Branch LSR
    - Headwaters: 55MOO-02.9 (Moon Creek, Highway 211)
    - 55WBLS-17.7 (Harworth Road)
        - Buck Creek (55BUC-00.3)
    - 55WBLS-11.1 (below Horseshoe Lake
        - Beaver Creek (55BEAV-00.5)

    - 55WBLS-07.7 (Fan Lake Road)
    - 55WBLSR-03.1 (below Eloika Lake)
- Dragoon Creek
    - Headwaters: 55DRA-17.0 (Dahl Road)
        - Spring Creek (55SPR-00.4)
    - 55DRA-16.4 (Highway 395 nr Deer Park)
    - 55DRA-13.2 (above West Dragoon Creek)
        - West Branch Dragoon Creek (55WBDR-00.1)
    - 55DRA-04.3 (North Road)
    - 55DRA-00.3 (mouth, at Crescent Road)
- Deadman Creek
    - Headwaters: 55DEA-20.2 (Park Boundary)
    - 55DEA-13.8 (Holcomb Road)
    - 55DEA-05.9 (Bruce Road)
        - Little Deep Creek (55LDP-00.1)
    - 55DEA-00.2 (near mouth - North Little Spokane Drive)

Survey weather conditions

The 2015-16 monitoring surveys included a very dry summer period bracketed by wetter spring and winter conditions. We evaluated conditions before and during each monitoring date to understand the hydrologic context of each survey and whether surveys likely took place under dynamic or steady-state flow conditions. We assessed precipitation and snowmelt for the prior four days, and the trend in flow conditions for the prior 3 days (Table F-1).

Table F-1. Hydrologic context for 2015-2016 survey dates

Survey Dates	Meteorological conditions	Mean Daily Flow (cfs) [a]	Percentile Flow level [b]	Flow dynamics
Feb 17-18, 2015	Snowmelt	469	67%	Strongly Declining
Mar 17-18, 2015	Snowmelt, Antecedent Precipitation	413	28%	Strongly Declining
Apr 21-22, 2015	Dry	275	13%	Declining
May 19-20, 2015	Dry	171	10%	Strongly Declining
June 3, 2015[c]	Antecedent Precipitation	244	38%	Strongly Rising
June 16-17, 2015	Dry	127	4%	Declining
July 21-22, 2015	Dry	82	5%	Declining
Aug 18-19, 2015	Dry	80	6%	Steady
Sep 22-23, 2015	Dry	96	8%	Steady
Oct 20-21, 2015	Antecedent Precipitation	102	5%	Slightly rising
Nov 17, 19, 2015	Antecedent Precipitation	150	14%	Rising
Jan 19-20, 2016	Antecedent Precipitation	301	67%	Strongly Rising
Feb 22-23, 2016	Antecedent Precipitation	682	81%	Strongly Declining
Mar 16-17, 2016	Antecedent Precipitation	1035	88%	Strongly Declining

[a] Average of flow for the survey dates, USGS Little Spokane River at Dartford (12431000)

[b] Percentile of flow on survey dates compared to flows on those dates from the 1929-2018 record.

[c] Special Deadman Creek survey.

In 2015, the core summer dry season was July through September. However, a longer dry period occurred from April through October. Although April and May were dry, the flow balance analysis suggests that some runoff was still occurring in parts of the watershed during this time. Conversely, although some rain fell in October, there is little evidence of it causing runoff. And although conditions several days before the February and March 2016 surveys were dry, heavy rain had fallen within the prior week and the hydrology indicates that runoff was still actively occurring. These patterns are consistent with low soil moisture at the end of an exceptionally dry summer and high soil moisture after winter rain events.

Evaporation

We obtained daily evaporation data from a standard evaporation pan from the National Weather Service Office in Spokane[4]. NOAA (1982) provides a methodology for converting pan evaporation to estimates of evaporation in the field. We multiplied pan evaporation rates by the surface area of the reaches, calculated with dimensions obtained from GIS. We then adjusted the rate for each reach by an evaporation coefficient. We applied evaporation coefficients of 0.5 to river reaches, 0.6 for upstream lakes in the West Branch LSR, and 0.7 for the Eloika Lake reach. NOAA (1982) suggests 0.7 as a default value for lakes; we chose lower values to reflect wind sheltering on small lakes or river/stream channels. Note that this method applies only to evaporation from the water surface and not to evapotranspiration from vegetation.

Withdrawals

Direct measurements of water withdrawals were not available, so we estimated potential withdrawals for each reach by the amounts permitted for use under existing water rights and permits. Based on discussions with Ecology Water Resources Program staff, we estimated that 20% of the permitted withdrawal volumes might be used during the growing season. We applied this fraction to Ecology's certificated surface withdrawals to derive the estimate used in the flow balance. There is significant uncertainty associated with this estimate, but it represents a small fraction of instream flows (about 6% of flows at Dartford in July 2015). We discuss this further in the **Flow Balances** section of Appendix G.

We assigned the withdrawals to each reach based on their location reported by Ecology's water rights records. We assumed surface withdrawals to be predominantly for irrigation, and pro-rated them by month for a typical May through October growing season, based on local agricultural information. For this flow balance, we did not separately quantify irrigation return flows, on the assumption that if any surface flows existed they would be small and difficult to estimate. Therefore, if any agricultural return flows existed, they would have been captured as part of tributary or ground water inflows.

NPDES point source flows

We obtained NPDES effluent flows from Colbert Landfill from their Discharge Monitoring Reports (DMRs). Effluent flows from the Colbert Landfill are small, about 1 cfs, or ~1.2% of flows at Dartford in July and August.

[4] http://www.wrh.noaa.gov/otx/get_pan.php?wfo=otx&sid=otx&pil=RR3&stn=OTX

There are two municipal NPDES stormwater permits that have the potential to discharge to the LSR or its tributaries:Spokane County, and the Washington State Department of Transportation (WSDOT). Spokane County reports that they have no outfalls to the Little Spokane River under their permit. WSDOT conducted an inventory of their discharges under their permit (WSDOT, 2013) and found "no evidence of excessive fertilization or nutrient loading observed." Since Spokane County and WSDOT stormwater flows are likely a very small fraction of all runoff, we did not explicitly account for these contributions in our watershed mass balance analysis.[5]

The Spokane Hatchery has multiple outfalls, so determining effluent flows is difficult. Anchor QEA (2015) measured flows at the WDFW Spokane Hatchery during the surveys conducted in the fall of 2014 and February 2015 – this is the most reliable source of effluent flow data. Hatchery staff explained that effluent flows are a function of fish stocking levels, which vary seasonally. Therefore we needed an estimate of flow for each survey.

As part of their NPDES General Permit requirements, WDFW reports the average fish stocking level and the total amount of feed used for each month to Ecology in their DMRs. We developed a regression to predict flow from flows measured by Anchor QEA and fish stocking levels reported in the DMRs for the months of Anchor QEA's surveys. We then estimated hatchery flows for each 2015-16 survey using this regression along with the reported monthly fish stocking levels for the Ecology survey months.

Although the regression is weak and the exact flows are uncertain, the results provide reasonable estimates of discharge that account for seasonal variabililty reported by hatchery staff.

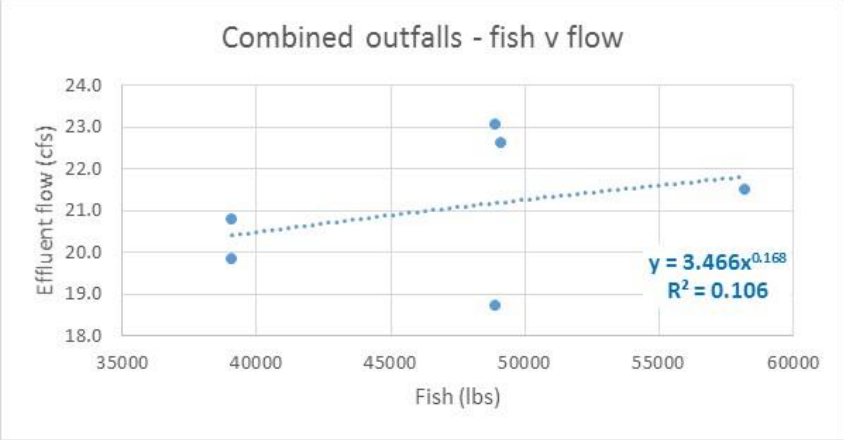


Figure F-1. Relationship between fish and effluent flow for Spokane Hatchery.

Groundwater

Direct measurements of groundwater levels were not available to develop site-specific calculations of groundwater inflows or outflows. Therefore, we derived these values from the flow balances during the dry summer periods. During the dry season, and especially in the very dry year of 2015, the flow exchange remaining after accounting for other inflows and outflows can be assumed to be mostly groundwater. Conditions in 2015 allowed for an analysis of the pattern of seasonal groundwater flow

[5] We calculated the wasteload allocations for these permits separately from this analysis, using a different methodology. See the **Wasteload Allocations** section of the main report, as well as Appendix M, for details.

from the flow balances for the core summer months (July-September) as compared to the longer April through October dry period that occurred in 2015.

We estimated inflow or outflow of groundwater for each reach from the flow balance for each dry season survey as: the sum of upstream and tributary flows, minus evaporation and withdrawals, taking into account lake level changes. In other words, groundwater flows were the residual of the flow balance during the dry months. For the wet months when the residual became much larger than the dry season values, we determined an estimate of groundwater flows from the dry season patterns.

To determine wet season groundwater flows, we evaluated the dry season results. In general, the groundwater flows determined from the dry season flow balances typically followed one of several patterns: 1) fairly constant inflows through the dry season; 2) steady inflows that tended to decline in the spring and increase in the fall; or 3) inflows that shifted to outflows in early summer, increased as outflows through mid-summer, and then decreased until shifting back to inflows in the fall.

Where dry season ground water inflows were relatively steady, we set groundwater flows during the wet season to the highest value found in the dry season. However, in several cases we improved the flow balance by fitting the groundwater inflows to a cosine function that provided a seasonally varying estimate of inflows.

Surface runoff

For the wet season, we added the groundwater estimate to the flow balance, and considered the remaining residual to be surface runoff.

For conditions during the 2015-16 surveys, surface runoff appeared to occur mostly during February and March 2015; and January, February and March 2016; with some runoff is a few tributary reaches in April, May, and November 2015. The June 3, 2015 survey of Deadman Creek was unusual, in that it followed an intense storm event that clearly produced runoff.

We assumed surface runoff to be negligible during the surveys in the dry months, when no antecedent precipitation occurred, and the flow residuals fit a pattern consistent with groundwater hydrology. We determined runoff rates from the remaining flow balance residuals for wet season months after accounting for estimated ground water inflows. The flow balance calcualtions estimate that, out of 18 reaches, runoff occurred in:

- 17 reaches during the March 2016 survey
- 15 reaches in February 2015, March 2015, and February 2016
- 11 reaches in January 2016
- 8 reaches in April 2015
- 3 reaches in November 2016
- 1 reach in May 2015.

The differences between reaches likely reflect the variability in the hydrology of the area draining to each reach, due to differences in topography, geology, vegetation, drainage patterns, and human development. We did not evaluate these effects in this study.

Lake volume changes

The West Branch LSR flows through five of the six largest lakes in the LSR basin (by volume) with the mainstem LSR flowing though the sixth (Chain Lake). Lakes can affect the flow balances by storing or releasing flows, with the outlet of a lake frequently serving as a natural control on flows. When inflows rise more rapidly than the lake outlet can release flow the lake will store water and rise, and when inflows are below outflow rates the lake will release water so that water levels fall.

A search for lake elevation information found data for Sacheen Lake and Eloika Lake. The primary control at Sacheen Lake is the combination of culverts and beaver dams. As beavers build up their dams in the spring, lake levels rise, and when local residents clear the barriers, the lake falls and the culverts control outflow.

The Sacheen Lake homeowners association monitors lake levels as part of managing outlet flows (and beaver blockages) to meet a target lake elevation. A local resident who takes those measurements provided lake level data for this study (Hood, 2016). Making the assumption that lake surface area changed little for the small changes in elevation observed (a reasonable asssuption given Sacheen Lake's rocky shoreline), we calculated water storage changes from the surface area and lake level change over each week, and converted the storage changes into release or retention rates in cubic feet per second.

Spokane Conservation District (SCD, 2016) collected lake surface elevation data at Eloika Lake for two years (April 2007 – April 2009). SCD and Ecology collected flow data above and below the lake (55WBLS-07.7 – Fan Lake Road; 55WBLS-03.1 – below Eloika Lake) for periods including both the 2007-2009 dates with lake level data and the 2015-16 surveys. We analyzed the relationship of lake elevation changes to inflows and outflows for 2007-09 in order to find a predictive equation for lake volume changes during the 2015-16 surveys.

We developed the following approach:

- We determined the relationship between rate of change in lake volume and rate of change in surface elevation from data provided by Spokane County (2009a).
- We found strong regression relationships between the rate of change in lake outflow and the rate of change in lake volume when flows were greater than 15 cfs (Figure F-2). Essentially this shows that rising lake volumes drive rising outflows and falling lake volumes drive declining outflows. Therefore, the change in the measured outflow can be used to predict the change in lake volume.
- When flows downstream of Eloika Lake were above 15 cfs during the 2015-16 surveys, we used these regressions to calculate change in lake volume, which we converted to cfs and added to the flow balance.
- When flows were below 15 cfs downstream of Eloika Lake (June through October surveys), we evaluated the flow balance residuals to see if patterns suggested the role of groundwater versus lake elevation changes. Conditions in August through October indicated that the lake volume was holding constant and that the residual was representing groundwater inflows of about 4 cfs. For June and July, we applied Eloika Lake volume changes iteratively until the residual representing groundwater was in about the same range as August-October levels.

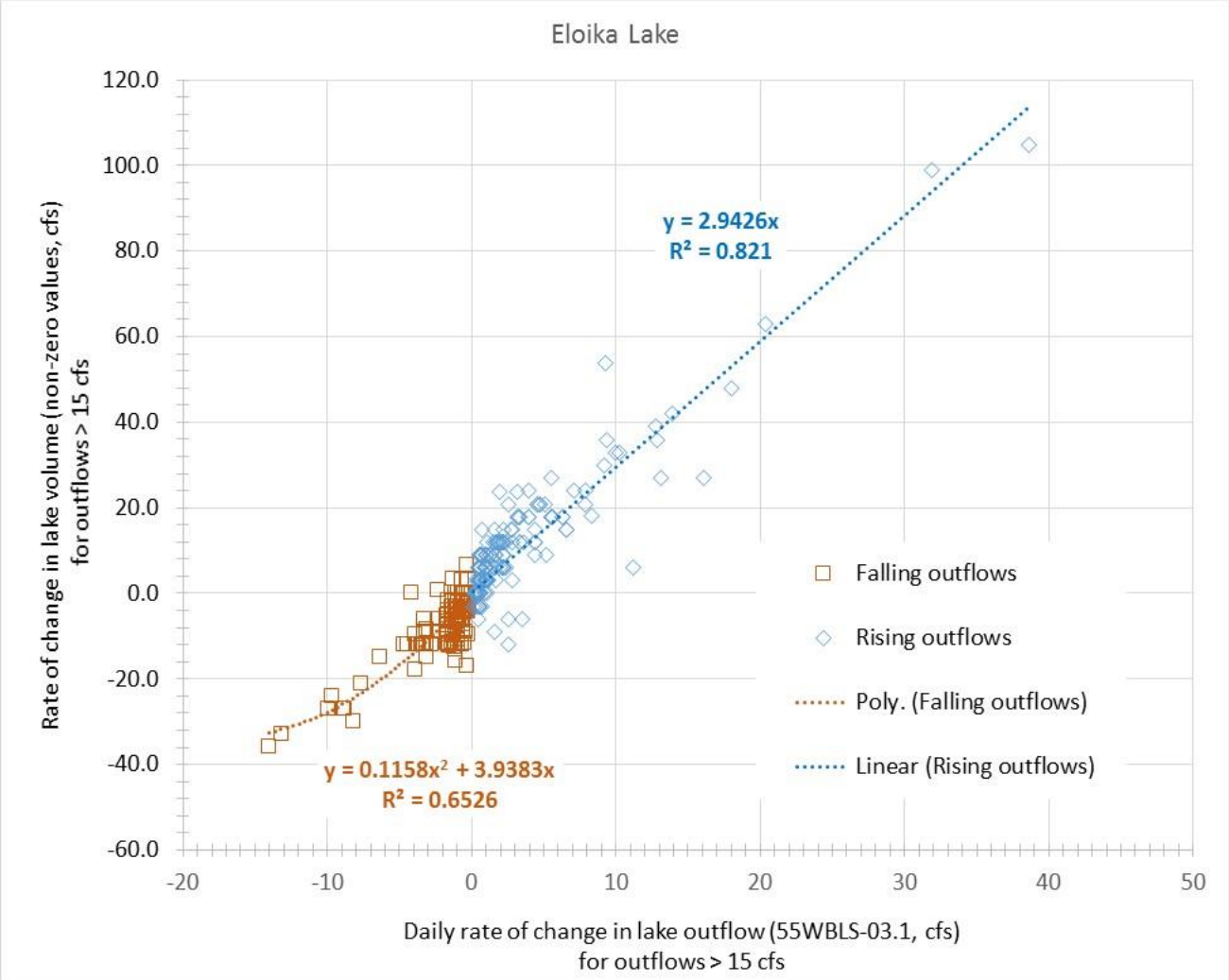


Figure F-2. Eloika Lake regression relationships between lake outflow rate of change and lake volume rate of change (for outflows greater than 15 cfs, and non-zero volume change rates).

Although Diamond Lake is the largest lake in terms of surface area and volume, we did not include it in this watershed analysis because it is upstream of the Moon Creek monitoring station, which is the upstream boundary of the West Branch LSR flow balance. For the other three lakes – Trout, Horseshoe, and Chain Lakes – we did not include estimates of lake volume changes because these lakes are smaller and no lake level data were available. Therefore, the estimates of groundwater and surface runoff for the reaches that include these lakes may be biased high or low.

Uncertainty in the flow balance

Some observations about the flow balance and uncertainty:

- During the dry season, we assigned residuals from the flow balance for each survey and reach to groundwater. Therefore in the dry season the ground water value represents a combination of actual flows and uncertainty.

- During the wet season, we assigned residuals from the flow balance for each survey and reach to surface runoff. Therefore in the wet season the runoff value represents a combination of actual flows and uncertainty.
- The uncertainty factor in these residuals combine natural variability and the variability in measurements or estimation methods. In the wet season dynamic flows add an additional source of variability that may be relative large.

Tables of Flow balance results

Tables F-2 through F-5 show the complete flow balance for the watershed analysis. Note that for certain locations and surveys, we included an "unsteady flow factor" in the balance to account for non-steady flow conditions where upstream and downstream flows were at different points in the hydrograph. Also note that in these tables, we indicate inflows using blue font and outflows using red font. We show measured flows at the end of the reach in black font highlighted yellow.

Table F-2. Calculated flow balances for mainstem Little Spokane River, 2015-16 survey conditions (all flows in cfs).

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
55LSR-46.7 (Scotia – headwaters)	28.0	29.0	28.0	27.0	23.0	22.0	22.0	19.0	20.0	23.0	24.0	27.0	30.0
Runoff	2.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	11.1
Groundwater	19.0	19.0	19.1	13.3	13.3	11.5	9.9	14.3	15.1	9.0	12.0	19.0	19.0
Withdrawals	0.0	0.0	0.0	-0.2	-0.2	-0.4	-0.4	-0.3	-0.1	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T
55LSR-39.5 (Frideger Road)	49.0	51.0	47.0	40.0	36.0	33.0	31.5	33.0	35.0	32.0	36.0	52.0	60.1
Runoff	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	11.0	3.0	8.9
Groundwater	0.0	0.0	-4.0	-0.8	-0.8	-0.6	-2.2	-0.8	-1.9	0.0	0.0	0.0	0.0
Withdrawals	0.0	0.0	0.0	-0.1	-0.2	-0.3	-0.3	-0.2	-0.1	0.0	0.0	0.0	0.0
Evaporation	T	T	T	T	T	-0.1	T	T	T	T	T	T	T
55LSR-37.6 (USGS @Elk)	55.0	51.0	43.0	39.0	35.0	32.0	29.0	32.0	33.0	38.0	47.0	55.0	69.0
Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Groundwater	2.0	4.0	7.0	7.0	5.0	0.5	3.0	1.5	-1.0	3.0	-5.0	5.0	2.0
Withdrawals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	T	T	T	T	T	T	T	T	T	T	T
55LSR-37.1 (Elk)	57.0	55.0	50.0	46.0	40.0	32.5	32.0	33.5	32.0	41.0	42.0	60.0	71.0
Dry Ck/Sheets Ck	7.4	7.7	11.8	2.7	4.6	3.6	3.3	4.2	4.8	6.0	4.6	16.6	24.4
Otter Ck	11.0	10.0	9.3	7.2	7.3	5.8	6.3	6.2	7.5	8.2	9.3	10.0	11.5
WBLSR	140.0	61.5	47.8	18.7	12.7	3.4	1.1	4.4	5.5	23.4	44.2	202.0	280.0
Bear Ck	6.6	7.2	3.6	1.7	0.8	0.3	0.3	1.0	2.0	3.2	7.6	9.3	11.0
Runoff	32.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	69.5	68.0
Groundwater	9.2	11.2	9.9	12.0	12.5	5.7	7.0	5.4	2.4	3.2	6.7	9.6	11.2
Withdrawals	0.0	0.0	0.0	-0.3	-0.4	-0.6	-0.6	-0.4	-0.1	0.0	0.0	0.0	0.0
Unsteady flow factor										*-10.0*			
Evaporation [a]	-0.1	-0.1	-0.4	-0.4	-0.5	-0.7	-0.4	-0.2	-0.1	T	T	-0.1	-0.1
55LSR-23.4 (Chattaroy)	263.1	158.0	132.0	87.5	77.0	50.0	49.0	54.0	54.0	75.0	120.0	301.0	477.0

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Deer Ck	24.0	22.0	16.5	6.4	2.2	0.2	0.1	0.1	0.1	5.9	6.4	51.0	65.0
Dragoon Ck	56.0	72.7	31.0	23.4	16.0	13.9	11.3	13.6	18.8	26.4	54.7	140.0	158.0
Colbert Landfill NPDES	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Runoff	11.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	42.3	2.3	59.4
Groundwater	24.0	24.0	21.1	14.2	15.7	14.6	19.0	25.1	22.0	24.0	24.0	24.0	24.0
Withdrawals	0.0	0.0	0.0	-0.8	-1.1	-1.6	-1.6	-1.2	-0.4	0.0	0.0	0.0	0.0
Evaporation [a]	T	-0.1	-0.3	-0.4	-0.5	-0.7	-0.4	-0.2	-0.1	T	T	T	-0.1
55LSR-13.5 (LSR Dr.)	380.0	293.2	202.0	132.0	111.0	78.0	79.0	93.0	96.0	134.0	249.0	520.0	785.0
Deadman Ck.	65.9	77.6	37.3	17.4	10.2	6.4	6.0	6.7	8.0	9.1	54.2	96.6	143.0
Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.4	99.0
Groundwater	11.1	33.2	31.8	17.8	5.0	-3.0	-4.7	-8.5	3.1	12.9	20.8	33.0	33.0
Withdrawals	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	T	T	T	T	T
55LSR-11.0 (USGS at Dartford)	457.0	404.0	271.0	167.0	126.0	81.0	80.0	91.0	107.0	156.0	324.0	701.0	1060.0
Dartford Ck	3.4	2.4	2.7	2.6	2.8	2.3	2.4	2.6	2.2	2.7	3.0	3.4	5.2
Spokane Hatchery	21.8	21.9	20.7	19.9	18.5	19.4	20.5	21.8	20.4	19.9	21.0	21.6	21.8
Runoff	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Groundwater	241.8	239.8	255.0	259.9	259.2	256.0	244.4	245.8	248.5	234.5	232.0	240.0	239.1
Evaporation [a]	T	-0.1	-0.3	-0.4	-0.5	-0.7	-0.4	-0.2	-0.1	T	T	T	-0.1
55LSR-03.9 (USGS near Dartford)	744.0	673.0	549.0	449.0	406.0	358.0	347.0	361.0	378.0	413.0	580.0	966.0	1326.0
Runoff	1.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	85.7
Groundwater	8.5	8.3	7.7	6.3	5.7	5.0	4.9	5.1	5.3	5.8	8.1	8.5	8.3
55LSR-01.1 (Hwy 291)	754.4	682.4	556.7	455.3	411.7	363.0	351.9	366.1	383.3	418.8	588.1	979.5	1420.0

[a] T = Trace – evaporation between 0.0 and -0.05 cfs

Table F-3. Calculated flow balances for West Branch Little Spokane River, 2015-16 survey conditions (all flows in cfs).

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Moon Ck (headwaters)	12.0	9.1	2.3	1.6	1.1	0.5	0.6	0.9	0.9	2.9	2.3	11.0	18.5
Runoff	18.4	8.6	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.9	41.6
Groundwater	12.0	12.0	12.0	11.5	8.5	5.0	4.6	4.0	3.9	6.6	11.6	12.0	12.0
Withdrawals	0.0	0.0	0.0	-0.3	-0.4	-0.6	-0.6	-0.4	-0.1	0.0	0.0	0.0	0.0
Evaporation	-0.3	-0.6	-2.1	-2.6	-2.9	-3.8	-2.4	-1.4	-0.7	-0.2	-0.2	-0.3	-0.6
Sacheen Lake level [a]	0.9	0.9	3.2	-1.5	6.7	-0.9	1.9	-0.9	-0.9	0.7	-0.7	-0.6	-0.6
55WBLS-17.7 (Harworth Rd)	43.0	30.0	21.0	8.7	13.0	0.1	4.1	2.2	3.0	10.0	13.0	62.0	71.0
Buck Ck	23.0	15.0	10.0	4.8	3.7	0.7	0.4	0.6	0.9	2.7	11.0	47.0	76.0
Runoff	28.2	15.5	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	39.3	52.5
Groundwater	5.0	5.0	5.0	5.5	3.6	3.7	3.5	3.7	3.5	5.1	5.0	5.0	5.0
Withdrawals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unsteady flow factor							*-5.0*	*-3.5*	*-4.0*				
Evaporation	-0.2	-0.5	-1.7	-2.0	-2.3	-2.9	-1.8	-1.1	-0.5	-0.2	-0.1	-0.3	-0.5
55WBLS-11.1 (blw Horseshoe Lk)	99.0	65.0	42.0	17.0	18.0	1.6	1.2	1.9	2.9	17.7	36.0	153.0	204.0
Beaver Ck	8.5	4.8	3.2	0.9	0.5	0.2	0.1	0.1	0.2	2.4	4.2	26.5	34.0
Runoff	2.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.3	17.0	27.5
Groundwater	1.5	1.5	1.5	1.2	3.1	1.4	1.3	1.6	1.4	1.5	1.5	1.5	1.5
Withdrawals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unsteady flow factor		*-4.0*											
Evaporation [b]	T	T	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T	T
55WBLS-07.7 (Fan Lk Rd)	111.0	68.0	47.0	19.0	21.5	3.1	2.5	3.6	4.4	23.0	42.0	198.0	267.0
Runoff	8.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.8	15.7
Groundwater	4.5	4.5	4.5	4.5	3.8	4.0	4.0	3.9	2.6	2.1	4.6	4.5	4.5
Withdrawals	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation	-0.7	-1.3	-4.8	-5.9	-6.5	-8.6	-5.3	-3.1	-1.5	-0.5	-0.3	-0.7	-1.3
Eloika Lake level [a]	17.0	-11.8	0.0	1.2	-6.0	5.0	0.0	0.0	0.0	-1.2	-2.1	-20.6	-5.9
55WBLS-03.1 (Eloika Lk Rd)	140.0	61.5	47.8	18.7	12.7	3.4	1.1	4.4	5.5	23.4	44.2	202.0	280.0

[a] Rate of change in lake volume, in cubic feet per second

[b] T = Trace – evaporation between 0.0 and -0.05 cfs

Table F-4. Calculated flow balances for Dragoon Creek, 2015-16 survey conditions (all flows in cfs).

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Dragoon 17.0 (headwaters)	16.0	16.0	5.3	2.7	2.3	0.6	0.3	1.4	1.1	2.6	11.0	44.0	83.0
Spring Creek	4.2	4.4	3.6	3.6	2.6	2.4	2.0	2.2	2.2	3.4	3.6	5.6	8.0
Runoff	1.3	2.1	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.9	21.9	2.5
Groundwater	0.5	0.5	0.5	0.5	0.2	0.3	0.2	0.3	0.6	0.0	0.5	0.5	0.5
Withdrawals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	T	T	T	T	T	T	T	T	T	T	T
55DRA-16.4 (Hwy 395 nr Deer Park)	22.0	23.0	11.0	8.4	5.1	3.2	2.5	3.8	3.9	6.0	16.0	72.0	94.0
Runoff	6.0	9.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	2.0	4.0
Groundwater	2.0	2.0	2.0	1.5	1.7	1.3	1.1	1.1	1.6	1.6	2.0	2.0	2.0
Withdrawals	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
Unsteady flow factor												*-4.0*	
Evaporation [a]	T	T	T	T	-0.1	-0.1	T	T	T	T	T	T	T
55DRA-13.2 (abv WB Dragoon Ck)	30.0	34.0	15.0	9.8	6.7	4.3	3.4	4.8	5.4	7.6	23.0	72.0	100.0
West Branch Dragoon Ck	13.0	21.0	8.2	5.9	3.7	2.1	2.4	4.0	5.4	8.2	15.0	31.0	46.0
Runoff	1.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0
Groundwater	10.1	9.6	8.9	7.3	5.2	5.4	5.9	5.7	8.4	7.2	10.0	10.0	9.6
Withdrawals	0.0	0.0	0.0	-0.3	-0.4	-0.6	-0.6	-0.5	-0.1	0.0	0.0	0.0	0.0
Unsteady flow factor													*-15.5*
Evaporation [a]	T	T	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	T	T	T	T	T
55DRA-04.3 (North Rd)	54.0	67.0	32.0	22.5	15.0	11.0	11.0	14.0	19.0	23.0	48.0	138.0	140.0
Runoff	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	14.5
Groundwater	2.0	3.5	-0.9	1.0	1.1	3.1	0.4	-0.3	-0.2	3.4	3.5	2.0	3.5
Withdrawals	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T
55DRA-00.3 (mouth)	56.0	72.7	31.0	23.4	16.0	13.9	11.3	13.6	18.8	26.4	54.7	140.0	158.0

[a] T = Trace – evaporation between 0.0 and -0.05 cfs

Table F-5. Calculated flow balances for Deadman Creek, 2015-16 survey conditions (all flows in cfs).

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Deadman 20.2 (headwaters)	18.0	12.0	8.7	4.5	3.0	1.4	0.7	0.6	1.0	1.4	2.9	11.0	25.0
Runoff	16.0	25.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.1	41.0	44.0
GW 20.2-13.8	4.0	4.0	4.0	3.7	1.1	0.3	0.0	0.2	0.1	0.8	4.0	4.0	4.0
Withdrawals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T	T
55DEA-13.8 (Holcomb Rd)	38.0	41.0	21.5	8.1	4.0	1.6	0.6	0.8	1.1	2.2	29.0	56.0	73.0
Runoff	5.4	15.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	24.1
GW 13.8-5.9	6.3	6.0	4.5	2.5	1.0	-0.2	-0.1	-0.1	0.3	0.5	5.9	6.3	6.0
Withdrawals	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
Unsteady flow factor											*-3.9*		
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T
55DEA-05.9 (Bruce Rd)	49.7	62.1	28.0	10.5	4.8	1.2	0.4	0.6	1.4	2.7	31.0	70.0	103.0
Little Deep Ck	12.0	22.5	6.8	2.0	0.9	0.9	0.9	0.9	1.1	0.9	14.0	21.0	32.0
Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	2.0
GW 5.9-0.2	4.2	3.5	2.6	5.1	4.8	4.7	5.1	5.4	5.6	5.5	6.0	5.6	6.0
Withdrawals	0.0	0.0	0.0	-0.1	-0.2	-0.3	-0.3	-0.2	-0.1	0.0	0.0	0.0	0.0
Unsteady flow factor		*-10.5*											
Evaporation [a]	T	T	-0.1	-0.1	-0.1	-0.1	-0.1	T	T	T	T	T	T
55DEA-00.2 (blw Little Deep Ck)	65.9	77.6	37.3	17.4	10.2	6.4	6.0	6.7	8.0	9.1	54.2	96.6	143.0

[a] T = Trace – evaporation between 0.0 and -0.05 cfs

Phosphorus load balances

We assigned TP concentrations for each of the various inflows and outflows using several methods based on the mass balance and hydrology. We evaluated local factors such as surficial geology and land uses to interpret the results, but did not use these factors in the analysis itself.

Headwaters and tributaries

We used observed concentrations, based on the 2015-2016 survey data.

Spokane Hatchery

We calculated net concentrations of TP from combined outfalls from the 2014-15 survey data (Anchor QEA, 2015). The net concentration is the loading added by the hatchery – the total loading in the combined outfalls minus intake water loading at the same flow. We developed a regression to predict TP net concentrations from net concentrations measured by Anchor QEA and fish stocking levels reported in the DMRs for the months of Anchor QEA's surveys (Figure F-3). We then estimated hatchery net concentrations for each 2015-16 survey using this regression applied to the reported monthly fish feed use for the Ecology survey months.

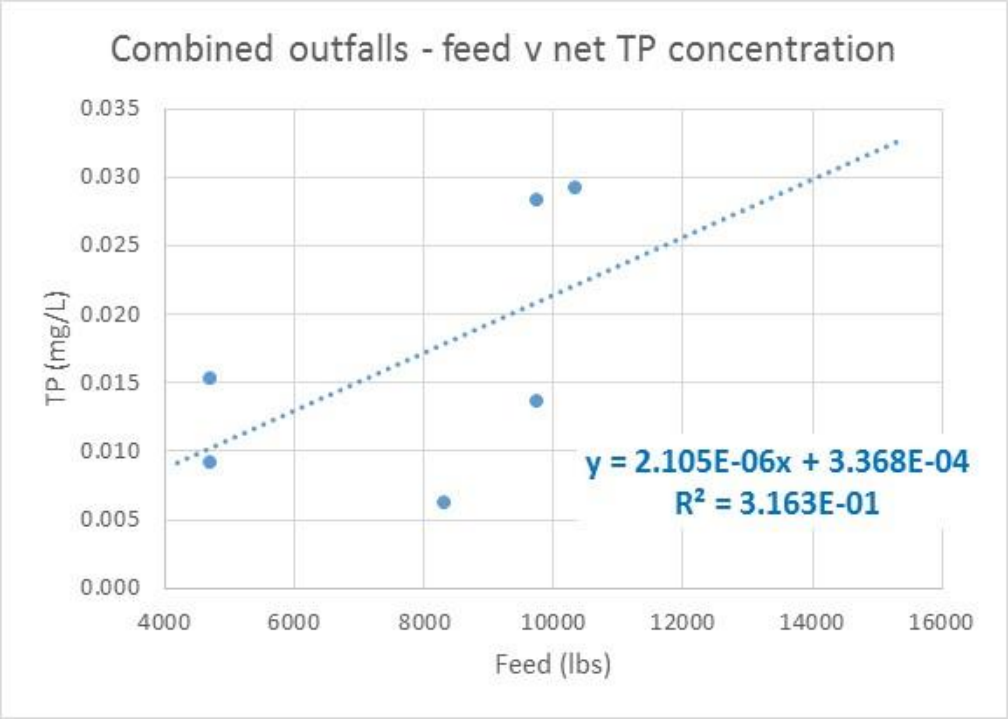


Figure F-3. Feed used vs. outfall net TP concentration at Spokane Hatchery

Groundwater

- First, for each reach, we applied a single groundwater concentration to all surveys, using values based on local well data or baseflow water quality at stations considered to be relatively unaffected by human activities.
- Next, for inflows above Dartford which are not part of the Spokane Valley – Rathdrum Prairie (SVRP) Aquifer, we adjusted each reach-specific groundwater concentration until the average of source/sink/uncertainty terms for each reach's load balance during the low flow surveys was close to zero. When making this adjustment, we constrained the minimum groundwater concentration to not be lower than TP concentrations found in headwaters, relatively pristine creeks, and wells in the basin.
- We set the concentration for groundwater inflows from the SVRP to 0.008 mg/L. This value is similar to the average value reported from monitoring of wells and springs in the area, and also minimizes the average source/sink/uncertainty terms at the LSR mouth.

Runoff

After assigning groundwater loading, we calculated a unique runoff concentration for each survey and reach that allowed the runoff load to fulfill the load balance for the reach so that the corresponding TP source/sink/uncertainty term was near zero.

Groundwater outflows, direct withdrawals, and source/sink/uncertainty outflows

We removed a fraction of the summed upstream load proportional to the percent of the river flow lost in each outflow in each reach.

Uncertainty in load calculations

The sources of uncertainty from the flow balance carry forward into the load balance, since loads are calculated from flows. In addition, there are other sources of uncertainty in the load balance:

- TP concentration measurments are subject to the variability inherent in a single grab from dynamic conditions, and the timing of measurements that may include variability over a longer time frame.
- Simplifying assumptions made for estimates of concentrations introduce uncertainty.
- The absence of nutrient dynamics (interactions of nutrients with biological, physical, and chemical processes) means that processes such as respiration and settling may be captured to some degree in the mathematics of the method, but may also add uncertainty to the flow balance.

Some implications of these sources of uncertainty include:

- All estimates of nutrient sources must be considered to have "confidence bands" around them. These confidence bands have not been quantified, but we considered them qualitatively.
- In particular, surface runoff loads may represent both runoff and uncertainty, while unknown loads may actually represent surface runoff. And either may represent either overland flow, channel erosion, or a direct discharge not related to runoff processes.

- We took the overall likelihood of uncertainty into account qualitatively in developing conclusions from the analysis.

Tables of TP load balance results

Tables F-6 through F-9 show the complete total phosphorus load balance for the watershed analysis. Note that in these tables, like the flow balance tables:

- Input loads appear in blue font and outflow loads in red font. Categories of sources (row titles) are shaded with colors for readability.
- Calculated loads at the end of the reach are in black font highlighted yellow.
- For certain locations and surveys, the "source/sink/uncertaintly" term is highlighted in orange where a load appeared to represent an unknown source (see Separating natural background uncertainty from unknown human loads below).

Table F-6. Total Phosphorus Load Balances for mainstem Little Spokane River (loads in kg/day, concentrations in mg/L)

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
55LSR-46.7 (Scotia)	**1.42**	**1.68**	**1.40**	**1.00**	**0.77**	**0.57**	**0.4**	**0.43**	**0.39**	**2.97**	**1.95**	**1.62**	**1.64**
Runoff load	**0.10**	**0.15**	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	**0.29**	**0.54**
Runoff concentration	*0.020*	*0.020*										*0.020*	*0.020*
Groundwater *(0.008 mg/L)*	**0.37**	**0.37**	**0.37**	**0.26**	**0.26**	**0.22**	**0.19**	**0.28**	**0.30**	**0.18**	**0.23**	**0.37**	**0.37**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	(0.19)	(0.70)	(0.10)	(0.04)	(0.11)	(0.13)	(0.07)	(0.06)	**0.04**	(2.26)	(1.13)	(0.45)	(0.56)
55LSR-39.5 (Frideger Rd)	1.70	1.50	1.67	1.21	0.91	0.65	0.55	0.65	0.73	0.88	1.06	1.83	2.00
Runoff load	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.40	0.22	0.55
Runoff concentration	*0.015*									*0.015*	*0.015*	*0.030*	*0.025*
Groundwater *(0.031 mg/L)*	**0.15**	**0.31**	**0.41**	**0.51**	**0.37**	**0.03**	**0.20**	**0.10**	(0.06)	**0.23**	(0.16)	**0.38**	**0.15**
Withdrawals	0.00	0.00	(0.14)	(0.03)	(0.02)	(0.02)	(0.04)	(0.02)	(0.04)	0.00	0.00	0.00	0.00
source/sink/uncertainty	(0.17)	**0.39**	**0.22**	(0.13)	**0.22**	**0.03**	(0.27)	(0.06)	**0.07**	(0.02)	**0.08**	**0.04**	**0.01**
55LSR-37.1 (Elk)	1.91	2.19	2.15	1.56	1.47	0.69	0.43	0.66	0.70	1.30	1.39	2.48	2.71
Dry Ck/Sheets Ck	**0.95**	**1.07**	**0.52**	**0.20**	**0.23**	**0.17**	**0.15**	**0.15**	**0.17**	**0.31**	**0.21**	**2.67**	**3.88**
Otter Ck	**0.99**	**1.56**	**0.70**	**0.41**	**0.32**	**0.27**	**0.31**	**0.30**	**0.37**	**0.59**	**0.98**	**1.51**	**2.18**
WBLSR	**7.12**	**2.96**	**2.12**	**0.88**	**0.52**	**0.13**	**0.04**	**0.12**	**0.23**	**1.00**	**1.66**	**13.85**	**14.59**
Bear Ck	**0.40**	**0.63**	**0.22**	**0.12**	**0.08**	**0.03**	**0.02**	**0.04**	**0.07**	**0.14**	**0.74**	**1.12**	**0.89**
Runoff load	**6.81**	**6.65**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.07**	**7.49**	**8.82**
Runoff concentration	*0.087*	*0.490*									*0.077*	*0.044*	*0.053*
Groundwater *(0.013 mg/L)*	**0.28**	**0.34**	**0.30**	**0.37**	**0.38**	**0.17**	**0.21**	**0.16**	**0.08**	**0.10**	**0.21**	**0.30**	**0.34**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.07**	**0.02**	**2.61**	**0.50**	(0.20)	(0.21)	(0.21)	(0.03)	(0.15)	(1.14)	**0.00**	**0.05**	**0.08**
55LSR-23.4 (Chattaroy)	18.54	15.42	8.62	4.02	2.79	1.24	0.94	1.40	1.47	2.31	6.25	29.46	33.49
Deer Ck.	**3.95**	**4.83**	**2.08**	**0.75**	**0.23**	**0.01**	**0.0**	**0.00**	**0.00**	**0.41**	**0.72**	**11.06**	**13.33**
Dragoon Ck	**7.82**	**11.72**	**2.15**	**2.16**	**1.64**	**0.93**	**0.6**	**0.52**	**0.63**	**2.11**	**6.61**	**31.05**	**36.96**
Colbert Landfill NPDES	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**	**0.092**
Runoff load	**5.04**	**2.01**	0.00	0.00	0.00	0.00	0.0	0.00	0.00	**0.17**	**5.17**	**0.06**	**2.32**

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Runoff concentration	*0.183*	*0.06*								*0.010*	*0.050*	*0.010*	*0.016*
Groundwater *(0.013 mg/L)*	**0.76**	**0.76**	**0.69**	**0.47**	**0.52**	**0.49**	**0.63**	**0.82**	**0.72**	**0.76**	**0.76**	**0.76**	**0.76**
Withdrawals	0.00	0.00	0.00	(0.04)	(0.05)	(0.06)	(0.04)	(0.03)	(0.01)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.24**	**0.03**	**0.47**	(0.23)	(0.20)	**0.45**	**2.94**	(0.52)	**0.04**	(0.06)	(0.05)	(1.36)	**0.05**
55LSR-13.5 (N LSR Dr)	36.45	34.86	14.08	7.20	5.00	3.13	5.12	2.25	2.91	5.80	19.56	71.12	87.00
Little Deep Ck	**2.01**	**6.66**	**1.62**	**0.35**	**0.07**	**0.07**	**0.1**	**0.06**	**0.05**	**0.06**	**3.90**	**3.72**	**6.18**
Deadman Ck	**9.57**	**13.62**	**5.81**	**2.58**	**1.18**	**0.36**	**0.3**	**0.29**	**0.36**	**0.57**	**8.40**	**12.39**	**18.82**
Dartford Ck	**0.32**	**0.29**	**0.20**	**0.24**	**0.29**	**0.19**	**0.1**	**0.21**	**0.18**	**0.28**	**0.39**	**0.52**	**1.54**
Spokane Hatchery	**1.18**	**1.11**	**1.10**	**0.90**	**0.57**	**0.90**	**1.10**	**1.73**	**0.71**	**0.46**	**0.80**	**1.08**	**1.59**
Runoff load	**14.48**	**44.58**	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	**46.67**	**57.39**
Runoff concentration	*0.270*	*2.980*										*0.338*	*0.127*
Groundwater *(0.008 mg/L)*	**5.12**	**5.51**	**5.76**	**5.56**	**5.28**	**5.05**	**4.79**	**4.74**	**5.03**	**4.96**	**5.11**	**5.51**	**5.49**
Withdrawals	0.00	0.00	0.00	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.01**	**0.06**	(0.23)	**3.24**	**2.31**	(0.13)	(3.72)	(0.04)	**0.00**	**1.08**	(3.63)	(0.01)	**0.20**
55LSR-01.1 (Hwy 291)	69.13	106.69	28.35	20.07	14.69	9.57	7.75	9.25	9.24	13.21	34.53	141.02	178.22

Table F-7. Total Phosphorus Load Balances for West Branch Little Spokane River (loads in kg/day, concentrations in mg/L)

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Moon Ck (headwaters)	**0.41**	**0.41**	**0.09**	**0.06**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.13**	**0.08**	**0.43**	**0.01**
Runoff load	**0.72**	**0.33**	**0.14**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.66**	**2.14**
Runoff concentration	*0.016*	*0.016*	*0.010*									*0.017*	*0.021*
Groundwater *(0.015 mg/L)*	**0.44**	**0.44**	**0.44**	**0.42**	**0.31**	**0.18**	**0.17**	**0.15**	**0.14**	**0.24**	**0.43**	**0.44**	**0.44**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.02)	(0.07)	(0.04)	(0.02)	(0.01)	0.00	0.00	0.00	0.00
Sacheen Lake storage/release	**0.03**	**0.04**	**0.11**	(0.05)	**0.23**	(0.02)	**0.05**	(0.03)	(0.03)	**0.03**	(0.03)	(0.02)	(0.02)
source/sink/uncertainty	**0.0**	(0.0)	(0.1)	(0.1)	(0.6)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	**0.0**
55WBLS-17.7 (Harworth Rd.)	1.65	1.18	0.68	0.33	0.01	0.01	0.10	0.05	0.07	0.38	0.44	2.50	2.59
Buck Ck	**2.05**	**1.30**	**0.67**	**0.38**	**0.33**	**0.05**	**0.02**	**0.03**	**0.05**	**0.21**	**0.97**	**6.05**	**9.39**
Runoff load	**0.76**	**0.38**	**0.19**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.17**	**0.96**	**1.28**
Runoff concentration	*0.011*	*0.010*	*0.010*								*0.010*	*0.010*	*0.010*
Groundwater *(0.015 mg/L)*	**0.18**	**0.18**	**0.18**	**0.20**	**0.13**	**0.13**	**0.08**	**0.14**	**0.11**	**0.19**	**0.18**	**0.18**	**0.18**
Withdrawals	0.00	0.00	0.00	0.00	0.00	0.00	(0.16)	(0.14)	(0.14)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.0**	(0.1)	(0.3)	(0.3)	**0.1**	(0.2)	(0.0)	(0.0)	(0.0)	**0.7**	(0.5)	(1.4)	(0.9)
55WBLS-11.1 (blw Horseshoe Lk)	4.65	2.93	1.44	0.58	0.54	0.04	0.03	0.05	0.09	1.52	1.28	8.27	12.53
Beaver Ck	**0.86**	**0.49**	**0.23**	**0.05**	**0.02**	**0.01**	**0.01**	**0.01**	**0.00**	**0.28**	**0.41**	**3.60**	**3.69**
Runoff load	**0.05**	**0.02**	**0.18**	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**	**0.01**	**0.42**	**0.67**
Runoff concentration	*0.010*	*0.010*	*0.200*							*0.010*	*0.020*	*0.010*	*0.010*
Groundwater *(0.042 mg/L)*	**0.15**	**0.15**	**0.15**	**0.12**	**0.32**	**0.14**	**0.13**	**0.16**	**0.14**	**0.15**	**0.15**	**0.15**	**0.15**
Withdrawals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
source/sink/uncertainty	(0.5)	(0.6)	**0.0**	**0.1**	**0.0**	(0.1)	(0.1)	**0.2**	**0.0**	(0.1)	(0.0)	(0.2)	(4.4)
55WBLS-07.7 (Fan Lk Rd)	5.21	3.03	2.05	0.88	0.89	0.12	0.07	0.44	0.25	1.87	1.85	12.26	12.67
Runoff load	**1.00**	**0.48**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.05**	**2.30**
Runoff concentration	*0.050*	*0.095*										*0.060*	*0.060*
Groundwater *(0.010 mg/L)*	**0.11**	**0.11**	**0.11**	**0.11**	**0.09**	**0.10**	**0.10**	**0.10**	**0.06**	**0.05**	**0.11**	**0.11**	**0.11**
Withdrawals*	0.00	0.00	0.00	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	0.00	0.00	0.00	0.00

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Eloika Lake storage/release	**0.87**	(0.57)	0.00	**0.05**	(0.23)	**0.15**	0.00	0.00	0.00	(0.09)	(0.09)	(1.42)	(0.31)
source/sink/uncertainty	(0.1)	(0.1)	(0.0)	(0.2)	(0.2)	(0.2)	(0.1)	(0.4)	(0.1)	(0.8)	(0.2)	(0.1)	(0.2)
55WBLS-03.1 (Eloika Lk Rd)	7.12	2.96	2.12	0.88	0.52	0.13	0.04	0.12	0.23	1.00	1.66	13.85	14.59

Table F-8. Total Phosphorus Load Balances for Dragoon Creek (loads in kg/day, concentrations in mg/L)

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Dragoon 17.0 (Dahl Rd – headwaters)	**3.25**	**4.19**	**0.66**	**0.44**	**0.90**	**0.13**	**0.06**	**0.80**	**0.41**	**0.59**	**1.94**	**10.07**	**19.68**
Spring Ck	**0.33**	**0.41**	**0.17**	**0.19**	**0.10**	**0.06**	**0.04**	**0.06**	**0.05**	**0.17**	**0.27**	**0.60**	**1.07**
Runoff load	**0.16**	**0.31**	**0.16**	**0.24**	0.00	0.00	0.00	0.00	0.00	0.00	**0.13**	**5.20**	**0.73**
Runoff concentration	*0.050*	*0.060*	*0.040*	*0.060*							*0.060*	*0.097*	*0.120*
Groundwater *(0.010 mg/L)*	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**
Withdrawals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.02**	**0.01**	**0.01**	**0.01**	(0.16)	**0.04**	**0.03**	(0.50)	(0.12)	(0.11)	**0.01**	**0.02**	**0.03**
55DRA-16.4 (Hwy 395 nr Deer Park)	3.8	4.9	1.0	0.9	0.8	0.2	0.1	0.4	0.4	0.7	2.4	15.9	21.5
Runoff load	**1.12**	**1.68**	**0.05**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.58**	**0.70**	**0.93**
Runoff concentration	*0.076*	*0.076*	*0.010*								*0.129*	*0.144*	*0.095*
Groundwater *(0.060 mg/L)*	**0.10**	**0.10**	**0.10**	**0.07**	**0.08**	**0.06**	**0.05**	**0.05**	**0.08**	**0.08**	**0.10**	**0.10**	**0.10**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.01**	(0.00)	(0.20)	**0.06**	**0.14**	**0.11**	(0.01)	(0.19)	(0.00)	**0.01**	**0.00**	(0.87)	**0.00**
55DRA-13.2 (abv WB Dragoon Ck)	5.0	6.7	1.0	1.0	1.0	0.4	0.2	0.2	0.4	0.7	4.0	15.8	22.6
West Branch Dragoon Ck	**2.00**	**4.03**	**0.82**	**0.78**	**0.53**	**0.28**	**0.24**	**0.35**	**0.50**	**0.95**	**2.17**	**6.51**	**9.69**
Runoff load	**0.47**	**0.12**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**7.22**	0.00
Runoff concentration	*0.200*	*0.020*										*0.118*	
Groundwater *(0.010 mg/L)*	**0.25**	**0.23**	**0.22**	**0.18**	**0.13**	**0.13**	**0.15**	**0.14**	**0.21**	**0.18**	**0.24**	**0.24**	**0.23**
Withdrawals	0.00	0.00	0.00	(0.03)	(0.05)	(0.05)	(0.03)	(0.02)	(0.01)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.01**	(0.02)	**0.02**	**0.27**	**0.09**	(0.09)	**0.10**	(0.08)	(0.49)	**0.07**	(0.52)	**0.02**	(0.25)
55DRA-04.3 (North Rd)	7.7	11.1	2.0	2.2	1.8	0.7	0.6	0.6	0.6	1.9	5.9	29.8	32.2
Runoff load	0.00	**0.54**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.54**	0.00	**4.62**
Runoff concentration		0.100									0.070		0.130
Groundwater *(0.015 mg/L)*	**0.07**	**0.07**	(0.06)	**0.07**	**0.07**	**0.07**	**0.07**	(0.01)	(0.01)	**0.07**	**0.07**	**0.07**	**0.07**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	0.00	0.00	0.00	0.00

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
source/sink/uncertainty	**0.03**	**0.04**	**0.19**	(0.13)	(0.17)	**0.18**	(0.10)	(0.06)	(0.01)	**0.11**	**0.06**	**1.16**	**0.03**
55DRA-00.3 (mouth)	7.8	11.7	2.1	2.2	1.6	0.9	0.6	0.5	0.6	2.1	6.6	31.0	37.0

Table F-9. Total Phosphorus Load Balances for Deadman Creek (loads in kg/day, concentrations in mg/L)

Input, output, or reach end name	2015 Feb 17-18	2015 Mar 17-18	2015 Apr 21-22	2015 May 19-20	2015 June 16-17	2015 July 21-22	2015 Aug 18-19	2015 Sep 22-23	2015 Oct 20-21	2015 Nov 17, 19	2016 Jan 19-20	2016 Feb 22-23	2016 Mar 16-17
Deadman 20.2 (Park Boundary – headwaters)	**1.24**	**0.87**	**0.66**	**0.39**	**0.26**	**0.14**	**0.07**	**0.06**	**0.09**	**0.12**	**0.23**	**0.91**	**2.88**
Runoff load	**1.92**	**4.47**	**0.89**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**4.76**	**6.22**	**7.22**
Runoff concentration	*0.049*	*0.073*	*0.041*								*0.088*	*0.062*	*0.067*
Groundwater *(0.070 mg/L)*	**0.69**	**0.69**	**0.69**	**0.63**	**0.19**	**0.05**	(0.004)	**0.04**	**0.03**	**0.14**	**0.69**	**0.69**	**0.69**
Withdrawals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.00**	**0.02**	**0.03**	(0.11)	(0.02)	**0.03**	**0.02**	(0.00)	**0.03**	(0.05)	**0.03**	**0.02**	(0.03)
55DEA-13.8 (Holcomb Rd)	**3.85**	**6.04**	**2.27**	**0.91**	**0.43**	**0.23**	**0.09**	**0.10**	**0.15**	**0.21**	**5.70**	**7.84**	**10.75**
Runoff load	**2.28**	**5.75**	**3.47**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.51**	**1.24**
Runoff concentration	*0.172*	*0.155*	*0.700*									*0.080*	*0.021*
Groundwater *(0.050 mg/L)*	**0.77**	**0.73**	**0.56**	**0.31**	**0.12**	(0.02)	(0.010)	(0.01)	**0.04**	**0.06**	**0.72**	**0.77**	**0.73**
Withdrawals	0.00	0.00	0.00	(0.01)	(0.01)	(0.02)	(0.017)	(0.01)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**0.04**	**0.03**	**0.02**	**1.52**	**0.79**	**0.22**	**0.01**	(0.01)	(0.05)	**0.11**	**0.98**	**0.09**	**0.06**
55DEA-05.9 (Bruce Rd)	**6.94**	**12.55**	**6.32**	**2.74**	**1.33**	**0.41**	**0.08**	**0.07**	**0.14**	**0.37**	**7.39**	**10.21**	**12.78**
Runoff load	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.78**	0.00	**5.95**
Runoff concentration											*0.100*		*1.200*
Groundwater *(0.009 mg/L)*	**0.09**	**0.08**	**0.06**	**0.11**	**0.11**	**0.10**	**0.11**	**0.12**	**0.12**	**0.12**	**0.13**	**0.12**	**0.13**
Withdrawals*	0.00	0.00	0.00	(0.03)	(0.03)	(0.03)	(0.011)	(0.01)	(0.00)	0.00	0.00	0.00	0.00
source/sink/uncertainty	**2.54**	**0.99**	(0.57)	(0.24)	(0.23)	(0.12)	**0.09**	**0.11**	**0.10**	**0.08**	**0.09**	**2.06**	(0.03)
55DEA-00.6 (Shady Slope Rd)	**9.57**	**13.62**	**5.81**	**2.58**	**1.18**	**0.36**	**0.26**	**0.29**	**0.36**	**0.57**	**8.40**	**12.39**	**18.82**
Little Deep Ck	**2.01**	**6.66**	**1.62**	**0.35**	**0.07**	**0.07**	**0.07**	**0.06**	**0.05**	**0.06**	**3.90**	**3.72**	**6.18**
55DEA-00.2 (blw Little Deep Ck)	**11.58**	**20.28**	**7.43**	**2.93**	**1.25**	**0.43**	**0.33**	**0.35**	**0.41**	**0.63**	**12.30**	**16.12**	**25.00**

Separation of human and natural background loading

To analyze how human activities may have affected TP loading in the LSR watershed, we developed a natural background conditions mass balance. This analysis included estimation of flows and TP concentrations absent the influence of human activities.

Natural Background flows

We estimated natural background flows by adjusting the flow balance for observed conditions as follows:

- Removing surface withdrawals (restoring those flows to the stream)
- Removing the Colbert Landfill point source inflow. The flows from the Spokane Hatchery remained in the balance, as natural spring inflows.
- Increasing groundwater inflows to represent instream flows without the effect of groundwater pumping. We discuss the approach for these calculations below.

Natural Background Groundwater inflows

Evidence from watershed studies indicated that pumping from wells near the river and its tributaries reduces baseflows in the LSR and some of its tributaries. The WRIA 55-57 Watershed Plan (Spokane County, 2006) modeled the basin's water balance and found that, at the gage "at Dartford":

> *The peak monthly decrease in streamflow is about 13 cfs (8.4 mgd) in January, five months after peak pumping. The minimum decrease in streamflow of about 6 cfs (4 mgd) occurs in June and July.*

For our analysis, to estimate the reduction in groundwater inflows by date over the year, we fit the decrease in groundwater inflow noted in this watershed plan to a sinusoidal curve by date that peaked in January at 13 cfs, and reached a minimum of 6 cfs in late June. We then used the equation for the curve to estimate the flow deficit on the dates of the 2015-16 surveys.

Since this groundwater deficit is based on flow leaving the basin, we needed a method to allocate the deficit to the stream reaches in the flow balances. To accomplish this, we performed an analysis comparing the location and volume of groundwater rights to reaches in the flow balance:

- Using GIS, we selected groundwater rights that fell within 500 ft buffer along the modeled streams.
- We determined the instantaneous extraction volume allowed under each identified permit ("Qi").
- We summed the Qi values for these rights by reach.
- We divided the Qi sum for each reach by the basin total of all of the Qi values for selected rights.
- Out of 31 reaches, we selected a subset of 10 reaches representing 95% of the basin's selected Qi values.
- We then added the Qi subtotals for each of those 10 reaches together. We assigned each reach its percentage of the total of the 10 reaches.

- For each survey date, we applied these reach percentages to the flow deficit curve determined from the Watershed Plan. This calculation resulted in groundwater inflow deficit values for each of the 10 reaches during each survey.
- We added these values back into the flow balances for each survey date in each of these 10 reaches.

As a qualitative check on this methodology, we compared the 10 reaches identified with reduced inflows to a series of metrics. Spokane County conducted a groundwater inventory study (Spokane County, 2009b), in which they mapped the Little Spokane River and its tributaries for well yield, well level, well depth, and losing reaches. We tagged metrics from this study as aligning with the deficit allocation if the conditions near one of the 10 selected reaches showed a high well yield, shallow water levels, or shallow well depths. We also tagged an observed drawdown effect noted in the study as a metric. A losing reach in the watershed analysis flow balance provided an additional metric. All but one of the 10 reaches (the exception being Bear Creek) aligned with at least 1, and often 2 or 3 of these metrics.

Natural background TP concentrations

With a natural background flow balance established, it was next necessary to estimate natural background TP concentrations in tributaries, surface runoff, and groundwater.

For tributaries and surface runoff, we selected reference concentrations based on several approaches, including using relatively low values during runoff conditions from a relatively undeveloped watershed, or from breakpoints between relatively low and high concentrations during surveys when runoff was occurring. We selected TP concentration values from similar areas of the basin to provide some comparability to geology and soil conditions. If observed values during the survey were lower than estimated background values, we left existing values unchanged.

For groundwater in the LSR and tributaries upstream of Deadman Creek (RM 13.1), we selected values that reflected low values from wells in the area or the lowest values during surveys under baseflow conditions from locations with relatively little development. We set concentrations used in the load balance for observed conditions that were higher than the background values to background, while leaving lower values unchanged. For the SVRP aquifer, we used the background concentrations from the Spokane River DO TMDL (Moore and Ross, 2010).

Separating natural background uncertainty from unknown human loads

We also evaluated the source/sink/uncertainty terms to assess which represented only uncertainty, and to isolate those that may represent unidentified loads. We set the background range of uncertainty, to separate it from potential unidentified loads, based on whether:

- The source/sink/uncertainty load was less than 0.50 kg (selected from a break-point in the data), or
- The load represented less than 10% of the load at downstream end of the reach where it occurred, or
- A similar negative load occurred upstream or downstream, which would suggest an offsetting imbalance in the calculation.

Table F-10 provides a summary of the concentration values for these sources used in the mass balances for current conditions (2015-16 surveys) and background concentrations. Values for each location in this table represent:

- For tributaries, the maximum observed concentration for current conditions and the estimated background concentration.
- For surface runoff, the maximum estimated concentration from the observed conditions mass balances and the estimated background concentration.
- For groundwater, the estimated current and background concentrations used for all dates.

Table F-10. Estimated natural background groundwater and surface water total phosphorus concentrations for the Little Spokane River and its major tributaries used in the natural background load balance, with comparisons to maximum concentrations used for the observed load balance (2015-2016 survey conditions).

Source	Type	Observed (maximum) [a] TP (mg/L)	Natural Background TP (mg/L)	Basis of natural background concentration value
Mainstem Little Spokane River				
LSR 46.7 (Scotia)	Headwaters	**0.053**	0.025	Highest value outside of the 2 months with highest values (~90th %ile)
LSR 46.7-39.5	Surface runoff	0.020	0.020	Assumed all natural – lower than natural selected for headwaters.
LSR 46.7-39.5	Groundwater	0.008	0.008	10th %ile of data from 8 wells in the upper LSR watershed monitored by USGS , 1999 (all natural)
LSR 39.5-37.1	Surface runoff	**0.030**	0.015	Same as Moon Creek (WBLSR headwaters - 55MOO-02.9) – based on proximity
LSR 39.5-37.1	Groundwater	**0.031**	0.025	USGS well data from Otter Creek basin (maximum of two values)
Dry and Sheets Creeks	Tributary	**0.097**	0.050	Median value from upper Deer Ck (55DEE-05.9) – based on proximity
Otter Creek	Tributary	**0.078**	0.020	10th %ile of data collected in Otter Creek
Bear Creek	Tributary	**0.049**	0.030	Median value from Beaver (55BEAV-00.5)
LSR 37.1-23.4	Surface runoff	**0.490**	0.015	Same as Moon Creek (WBLSR headwaters - 55MOO-02.9) – based on proximity
LSR 37.1-23.4	Groundwater	0.013	0.013	Assumed all natural (low compared to well data)
Deer Creek	Tributary	**0.090**	0.050	Median value from upper Deer Ck (55DEE-05.9). Based on geology, land use, and distribution of values.
LSR 23.4-13.5	Surface runoff	**0.183**	0.020	Based on boundary between low and high values
LSR 23.4-13.5	Groundwater	0.013	0.013	Assumed all natural (low compared to well data
Dartford Creek	Tributary	**0.121**	0.050	Highest value outside of the 3 months with highest values (75th %ile)
LSR 13.5-1.1	Surface runoff	**2.980**	0.050	Same as Dartford Creek – based on proximity
LSR 13.5-1.1	Groundwater	**0.008**	0.004	SVRP aquifer background concentrations from Spokane River DO TMDL
West Branch Little Spokane River				
Moon Ck	Headwaters	**0.019**	0.015	Median value from Moon Creek (WBLSR headwaters - 55MOO-02.9). Based on geology, land use, and distribution of values.
Moon-WBLSR 17.7	Surface runoff	**0.021**	0.015	Same as Moon Creek (WBLSR headwaters - 55MOO-02.9) – based on proximity
Moon-WBLSR 17.7	Groundwater	0.015	0.015	Median value from Moon Creek (WBLSR headwaters)
Buck Creek	Tributary	**0.053**	0.030	Median value from Beaver (55BEAV-00.5)
WBLSR 17.7-11.1	Surface runoff	**0.011**	0.011	Assumed all natural (low compared to other reference locations)
WBLSR 17.7-11.1	Groundwater	0.015	0.015	Median value from Moon Creek (WBLSR headwaters)
Beaver Creek	Tributary	**0.055**	0.030	Median value from Beaver (55BEAV-00.5)
WBLSR 11.1-7.7	Surface runoff	**0.200**	0.020	Assumed all natural (low compared to other reference locations)

Source	Type	Observed (maximum) [a] TP (mg/L)	Natural Background TP (mg/L)	Basis of natural background concentration value
WBLSR 11.1-7.7	Groundwater	**0.042**	0.015	Median value from Moon Creek (WBLSR headwaters)
WBLSR 7.7-03.1	Surface runoff	**0.095**	0.030	Median value from Beaver (55BEAV-00.5)
WBLSR 7.7-03.1	Groundwater	0.010	0.010	Assumed all natural (low compared to well data)
Dragoon Creek				
Dragoon 17.0	Headwaters	**0.233**	0.030	Median value from Beaver (55BEAV-00.5)
Spring Creek	Tributary	**0.055**	0.030	Median value from Beaver (55BEAV-00.5)
Dragoon 17.0-16.4	Surface runoff	**0.120**	0.030	Median value from Beaver (55BEAV-00.5)
Dragoon 17.0-16.4	Groundwater	0.010	0.010	Assumed all natural (low compared to well data
Dragoon 16.4-13.2	Surface runoff	**0.144**	0.030	Median value from Beaver (55BEAV-00.5)
Dragoon 16.4-13.2	Groundwater	0.020	0.020	assumed all natural (low compared to well data
West Branch Dragoon Creek	Tributary	**0.086**	0.040	10th %ile for WB Dragoon
Dragoon 13.2-4.3	Surface runoff	**0.200**	0.040	10th %ile for WB Dragoon
Dragoon 13.2-4.3	Groundwater	0.010	0.010	assumed all natural (low compared to well data
Dragoon 4.3-0.3	Surface runoff	**0.130**	0.040	10th %ile for WB Dragoon
Dragoon 4.3-0.3	Groundwater	0.015	0.015	assumed all natural (low compared to well data
Deadman Creek				
Deadman 20.2	Headwaters	**0.047**	0.040	Highest value outside of the 2 months with highest values (90th %ile)
Deadman 20.2-13.8	Surface runoff	**0.088**	0.040	Same as Deadman headwaters (55DEA-20.2)
Deadman 20.2-13.8	Groundwater	**0.070**	0.040	Same as Deadman headwaters (55DEA-20.2)
Deadman 13.8-5.9	Surface runoff	**0.700**	0.050	Median value from upper Deer Ck (55DEE-05.9)
Deadman 13.8-5.9	Groundwater	**0.050**	0.015	Estimate based on blend of headwaters (30%) and SVRP (70%) levels
Deadman 5.9-0.6	Surface runoff	**1.070**	0.050	Median value from upper Deer Ck (55DEE-05.9)
Deadman 5.9-0.6	Groundwater	**0.009**	0.004	SVRP aquifer background concentration from Spokane River DO TMDL
Little Deep Creek	Tributary	**0.121**	0.050	Median value from upper Deer Ck (55DEE-05.9). Similar to average of median values for South Fork Little Deep (55SFLD-01.1) and Deadman Headwaters (55DEA-20.2)

[a] **Bold** indicates that the value for current conditions is greater than the natural background value for that location.

Appendix G. QUAL2Kw model inputs and calibration

QUAL2Kw Modeling Framework

We used the QUAL2Kw 6.0 modeling framework (Pelletier and Chapra, 2008) to develop the loading capacity for nutrients and to make predictions about water quality under various scenarios. The QUAL2Kw model framework and complete documentation are available at http://www.ecy.wa.gov/programs/eap/models.html.

The QUAL2Kw 6.0 modeling framework has the following characteristics:

- One dimensional. The channel is well-mixed vertically and laterally. Also includes up to two optional transient storage zones connected to each main channel reach (surface and hyporheic transient storage zones).
- The option to use steady-state flow routing or non-steady, non-uniform flow using kinematic wave flow routing. Repeating diel or fully continuous simulation with time-varying boundary conditions for periods of up to one year.
- Dynamic heat budget. The heat budget and temperature are simulated as a function of meteorology on a continuously varying or repeating diel time scale.
- Dynamic water-quality kinetics. All water quality state variables are simulated on a continuously varying or repeating diel time scale for biogeochemical processes.
- Heat and mass inputs. Point and non-point loads and abstractions are simulated.
- Phytoplankton and bottom algae in the water column, as well as sediment diagenesis, and heterotrophic metabolism in the hyporheic zone are simulated. Phytoplankton transport can be turned off to use the phytoplankton model to simulate macrophytes instead.
- Variable stoichiometry. Luxury uptake of nutrients by the bottom algae (periphyton) is simulated with variable stoichiometry of N and P.

For this study, we used the repeating diel version of the model, which employs steady-state flow routing. We collected most of the data for this modeling effort during 2010, before the continuous simulation option became available. Therefore, we had tailored the 2010 data collection to the requirements of the repeating diel version. Adequate data were not available to support a continuous simulation. Because the modeled reach has a relatively short time of travel (2-3 days) and flow conditions do not change very rapidly during the summertime, the quasi-steady state assumptions of the repeating diel model are acceptable for this application.

Figure G-1 shows a schematic of the model kinetics and mass transfer processes in QUAL2Kw. Table G-1 lists these processes as well as the state variables.

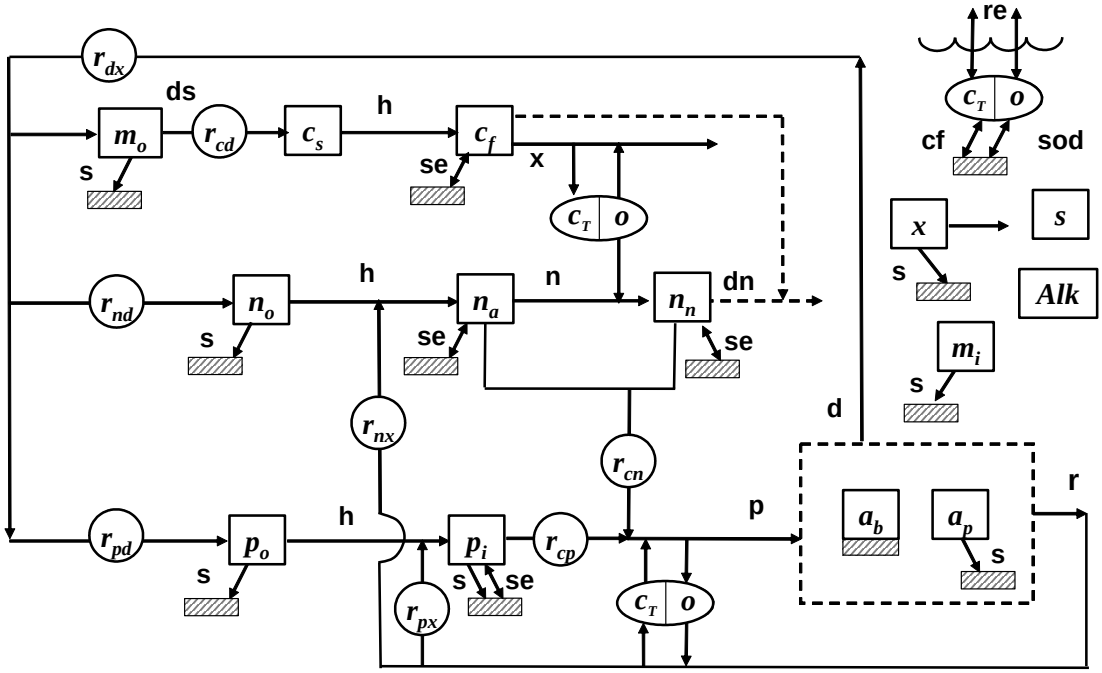


Figure G-1. Model kinetics and mass transfer processes in QUAL2Kw.

Table G-1. Processes and state variables in QUAL2Kw.

State Variables			
Variable	Symbol	Units	Measured as
Conductivity	*s*	μmhos	COND
Inorganic suspended solids	m_i	mgD/L	TNVSS
Dissolved oxygen	*o*	mgO_2/L	DO
Slow-reacting CBOD	c_s	mg O_2/L	r_{oc} * DOC
Fast-reacting CBOD	c_f	mg O_2/L	r_{oc} * DOC
Organic nitrogen	n_o	μgN/L	TN – NO_3N NO_2N– NH_4N
Ammonia nitrogen	n_a	μgN/L	NH_4N
Nitrate nitrogen	n_n	μgN/L	NO_3N+NO_2N
Organic phosphorus	p_o	μgP/L	TP - SRP
Inorganic phosphorus	p_i	μgP/L	SRP (Orthophosphate)
Phytoplankton	a_p	μgA/L	Chlorophyll *a*
Detritus	m_o	mgD/L	r_{dc} (TOC – DOC)
Alkalinity	*Alk*	mg$CaCO_3$/L	ALK
Total inorganic carbon	c_T	mole/L	Calculation from pH and alkalinity
Bottom algae biomass	a_b	gD/m^2	Periphyton biomass dry weight
Bottom algae nitrogen	IN_b	mgN/m^2	Periphyton biomass N
Bottom algae phosphorus	IP_b	mgP/m^2	Periphyton biomass P

Kinetic Processes	
Process	Symbol
dissolution	ds
hydrolysis	h
oxidation	x
nitrification	n
denitrification	dn
photosynthesis	p
death	d
respiration/excretion	r

Mass Transfer Processes	
Process	Symbol
reaeration	re
settling	s
sediment oxygen demand	SOD
sediment exchange	se
sediment inorganic carbon flux	cf

Note: in Figure G-1 and Table G-1, r_{xx} refers to a stoichiometric ratio. The letters used in the subscripts are: c = carbon; d = dry weight; n = nitrogen; p = phosphorus. The same letters (in caps) are used in the Units column in Table G-1.

Segmentation and Channel Geometry

The QUAL2Kw model of the Little Spokane River simulates the portion of the river between the outlet of Chain Lake (Fridger Rd; 55LSR-39.5) and the confluence with the Spokane River. The model conceptualizes this length of river as 41 model segments, each 1.609km (1 mile) in length.

We calculated channel geometry for each model segment as power functions relating width, depth, and velocity to flow:

$$W=aQ^b \qquad D=cQ^f \qquad V=kQ^m$$

Where:

W = width (m)	a = width coefficient	b = width exponent
D = depth (m)	c = depth coefficient	f = depth exponent
V = velocity (m/s)	k = velocity coefficient	m = velocity exponent
Q = flow (cms)		

These power functions are related by the continuity equation:

$$Q = WDV = (aQ^b)(cQ^f)(kQ^m)$$

Therefore:

$$b + f + m = 1 \quad \text{and} \quad ack = 1$$

We based the power functions for each model segement upon the following:

- Width – We digitized wetted edges from National Agriculture Imagery Program (NAIP) 2006 orthophotos at a 1:2000 scale using ArcGIS. We calculated widths from digitized edges using TTools (Ecology, 2015). These orthophotos were taken on July 2, 2006 during early summer moderate flow conditions (202 cfs at USGS Dartford gage).
- Velocity – We calculated velocities from time-of-travel dye study results. We collected these data August 12-15, 2013 during typical summertime flow conditions (142 cfs at USGS Dartford gage.)
- Depth – Given width and velocity, we calculated depths from the continuity equation shown above.

We chose exponents for width, depth, and velocity based on analysis of flows measured by the USGS at the three gaging stations on the Little Spokane River. The resulting power functions mean that width, depth, and velocity will scale appropriately based on flow. For example, even though we built the width functions around orthophotos taken at a 202 cfs at Dartford flow condition, they can still be used for the August 19, 2015 model run, with an 80 cfs at Dartford flow condition. QUAL2Kw will use the width power functions to estimate a correspondingly narrower channel width corresponding to the lower flow conditions.

Table G-2 shows the power functions for each model segment.

Table G-2. Power functions used to define channel geometry in QUAL2Kw model of the Little Spokane River.

Model Segment	Location	Width Coefficient	Width Exponent	Depth Coefficient	Depth Exponent	Velocity Coefficient	Velocity Exponent
0	LSR @ Fridger Rd (55LSR-39.5)	3.748	0.100	0.664	0.440	0.402	0.460
1		6.572	0.100	0.550	0.440	0.277	0.460
2		5.260	0.100	0.568	0.440	0.335	0.460
3		5.925	0.100	0.489	0.440	0.345	0.460
4	LSR @ Elk (55LSR-37.1)	5.917	0.100	0.605	0.440	0.280	0.460
5		6.064	0.100	0.638	0.440	0.258	0.460
6		6.529	0.100	0.559	0.440	0.274	0.460
7	Dry Ck (55DRY-00.4)	5.105	0.100	0.621	0.440	0.315	0.460
8	Otter Ck (55OTT-00.3); LSR @ E Eloika Rd (55LSR-33.2)	5.374	0.100	0.580	0.440	0.321	0.460
9	W Branch LSR (55WBLS-03.1)	8.848	0.100	0.490	0.440	0.231	0.460
10	LSR @ Deer Park-Milan Rd (55LSR-31.8)	9.308	0.100	0.512	0.440	0.210	0.460
11		13.626	0.100	0.558	0.440	0.131	0.460
12	LSR abv Bear Ck (55LSR-29.5)	11.729	0.100	0.566	0.440	0.151	0.460
13		12.463	0.100	0.612	0.440	0.131	0.460
14	Bear Ck (55BEAR-00.4)	11.582	0.100	0.597	0.440	0.145	0.460
15		13.048	0.100	0.599	0.440	0.128	0.460
16	LSR @ Riverway Rd (55LSR-25.4)	11.029	0.100	0.613	0.440	0.148	0.460
17		7.806	0.100	0.615	0.440	0.208	0.460
18	LSR @ Chattaroy (55LSR-23.4)	12.038	0.100	0.573	0.440	0.145	0.460
19	Deer Ck (55DEE-00.1) [Shift DS]*	8.382	0.100	0.438	0.440	0.272	0.460
20	Dragoon Ck (55DRA-00.3)	9.662	0.100	0.350	0.440	0.295	0.460
21	Colbert Landfill outfall (55COLB-LAND)	12.234	0.100	0.361	0.440	0.227	0.460
22		12.764	0.100	0.473	0.440	0.166	0.460
23	LSR @ LSR Dr in Buckeye (55LSR-18.0)	9.848	0.100	0.466	0.440	0.218	0.460
24		12.291	0.100	0.495	0.440	0.164	0.460
25	LSR @ E Colbert Rd (55LSR-16.0)	12.771	0.100	0.371	0.440	0.211	0.460
26		13.015	0.100	0.509	0.440	0.151	0.460
27	LSR @ N LSR Dr (55LSR-13.5) [Shift US]*	11.662	0.100	0.525	0.440	0.163	0.460
28	Deadman Ck (55DEA-00.2)	12.255	0.100	0.451	0.440	0.181	0.460
29	LSR @ Pine River Park (55LSR-11.7)	10.176	0.100	0.425	0.440	0.231	0.460
30	LSR @ Dartford USGS gage (55LSR-11.0); LSR @ N Dartford Dr (55LSR-10.3)	8.120	0.100	0.270	0.440	0.456	0.460
31	Dartford Ck (55DAR-00.2) [Shift DS]*; Waikiki Springs	12.318	0.100	0.434	0.440	0.187	0.460
32	Spokane Country Club springs (55WAI-00.0)	16.770	0.100	0.465	0.440	0.128	0.460
33	LSR at W Waikiki Rd (55LSR-07.5) [shift US]*	11.538	0.100	0.449	0.440	0.193	0.460
34	Griffith Spring; Spokane Hatchery (55GRI-00.0)	19.211	0.100	0.406	0.440	0.128	0.460
35	LSR blw Griffith Spring (55LSR-06.8)	13.854	0.100	0.395	0.440	0.183	0.460
36		20.046	0.100	0.396	0.440	0.126	0.460
37		15.570	0.100	0.396	0.440	0.162	0.460
38	LSR @ Rutter Pkwy (Painted Rocks) (55LSR-03.9)	18.520	0.100	0.443	0.440	0.122	0.460
39		16.572	0.100	0.474	0.440	0.127	0.460
40		16.486	0.100	0.473	0.440	0.128	0.460
41	LSR @ Mouth (55LSR-01.1)	16.147	0.100	0.462	0.440	0.134	0.460

*Occasionally, a point source or a tributary happened to fall in the same segment as a sampling site located upstream of that points source or tributary. In these cases, in the model, we either moved the sampling site to the next segment upstream, or moved the point source or tributary to the next segment downstream. This avoids the pitfall of having downstream inputs influencing model predictions for an upstream sampling site.

Model run dates

We set up and ran the QUAL2Kw model for five different dates:

- July 28, 2010 – Ecology synoptic survey. Typical summertime flow conditions.
- August 25, 2010 – Ecology synoptic survey. Lower than normal summertime flow conditions.
- August 13, 2013 – Ecology time of travel survey, with high-resolution diel DO and pH data. Typical summertime flow conditions.
- July 22, 2015 – Ecology synoptic survey. Approximately 20-year low-flow (7Q20) conditions.
- August 19, 2015 – Ecology synoptic survey. Approximately 20-year low-flow (7Q20) conditions.

Flow Balances

The flow balances describe the volumes of water entering and exiting the model domain, and the "balance" of water remaining in the model domain, representing mainstem river flow. The primary ways in which water enters and leaves the model domain are:

- Water enters the model domain at the upstream model boundary (LSR @ Frideger Rd; 55LSR-39.5)
- Water enters at tributary mouths and point sources
- Water enters or leaves the model domain as diffuse inputs or abstractions over a given reach, representing groundwater gains or losses.

Table G-3 summarizes the flow balances for the five model run dates. Unless otherwise indicated, observed flows and tributary flows are based on gaging data from USGS, Ecology, and Spokane CD, and flow measurements taken by Ecology during sampling. All other circumstances are explained by footnotes. We also used seepage data collected by Ecology's Water Resources Program during 2004, and by Spokane Conservation District (SCD) during 2009 and 2010 to inform specified flow values for locations with no data for the specific model date. We present flow balances in cubic feet per second (cfs); we converted these values to cubic meters per second (cms) for input to the model. We estimated groundwater inputs and abstractions from the residuals in the flow balance.

Note that, compared to the watershed analysis flow balance, we developed this flow balance for a different modeling platform with a different analysis structure, so the methodology differs and exact flow amounts may be slightly different. However, the flows for major tributaries and at the LSR monitoring sites are the same.

Table G-3. Flow balances for the five QUAL2Kw model run dates.

Values shown represent flow in cfs.

Location	July 28, 2010				August 25, 2010				August 13, 2013				July 22, 2015				August 19, 2015			
	Observed mainstem flow	Specified mainstem flow [a]	Tributary flow	Residual inflow/outflow between stations	Observed mainstem flow	Specified mainstem flow [a]	Tributary flow	Residual inflow/outflow between stations	Observed mainstem flow	Specified mainstem flow [a]	Tributary flow	Residual inflow/outflow between stations	Observed mainstem flow	Specified mainstem flow [a]	Tributary flow	Residual inflow/outflow between stations	Observed mainstem flow	Specified mainstem flow [a]	Tributary flow	Residual inflow/outflow between stations
55LSR-39.5 (Fridger Rd)	33	33			29	29			39	38			33	33			32	32		
55LSR-37.1 (Elk)	35	35		+2	34	34		+5	43	43		+5	33	33		0	32	32		0
Dry Ck			1.75				1.95				3				1.4				1.5	
Otter Ck			7.3 [c]				7.3 [c]				8.3				5.8				6.3	
55LSR-33.2 (Eloika Rd)	53	53		+8.95	46	46		+2.75	62	62		+7.7		45		+4.8		45.5		+5.7
WBLSR			24 [d]				11 [h]				16				3.1				1.1	
55LSR-31.8 (DP-Milan Rd)		75		-2	53	53		-4	76	76		-2		46.17		-1.93		45.2		-1.4
55LSR-29.5 (Abv Bear Ck)		77		+2		57		+4		81		+5		49.67		+3.5		48.7		+3.5
Bear Ck			1.05				1.3				1.5				0.33				0.3	
55LSR-25.4 (Riverway Rd)	78.5	78.5		+0.45	59	59		+0.7	83	83		+0.5		50		0		49		0
55LSR-23.4 (Chattaroy)	83.5	83.5		+5		59		0	79	79		-4	50	50		0	49	49		0
Deer Ck			3				0.74				3 [i]				0.17				0.07	
Dragoon Ck			17 [e]				13.9 [h]				19				13				12	
Colbert Landfill			1.4 [f]				1 [f]				1.15[f]				1 [j]				1 [j]	
55LSR-18.0 (Buckeye)	110	110		+5.1	89.5	89.5		+14.86	117	117		+14.85		73		+8.83		72.5		+10.43
55LSR-16.0 (Colbert Rd)	111.5	116		+6	90	95		+5.5	125	121		+4		76		+3		76		+3.5
55LSR-13.5 (N LSR Dr)	120	120		+4	99	99		+4	124	124		+3	78	78		+2	79	79		+3
Deadman Ck			13				7.6				13				6.4				6	
55LSR-11.5 (Pine R Park)		133		0		106.6		0		137		0		81		-3.4		80		-5
55LSR-11.0 (Dartford gage)	138	138		+5	108	108		+1.4	142	142		+5	81	81		0	80	80		0
Dartford Ck			3.05				2.75				3.8				2.3				2.4	
Topo. gap abv Waikiki springs [b]		151		+9.95		115		+4.25		156		+10.2		93		+9.7		92		+9.6
Waikiki Sprs			10 [g]				10 [g]				10 [g]				10 [g]				10 [g]	
Spokane CC Sprs			1.9				2.55				2.55[j]				2 [k]				2 [k]	
55LSR-10.3 (Waikiki Rd)		325		+162.1		290		+162.45	335	335		+166.45		272		+167		269		+165
Griffith Sprs			21				18.5				18.5[j]				18.5[j]				18.5[j]	
St Georges School		405		+59		367		+58.5		436		+82.5		357		+66.5		347		+59.5
55LSR-03.9 (Painted Rocks)	405	405		0	367	367		0	436	436		0	357	357		0	347	347		0
55LSR-01.1 (Mouth/Hwy 291)		383		-22		345		-22		414		-22		335		-22		325		-22

[a] It is not possible to directly specify mainstem flows in QUAL2Kw except at the upstream boundary conditions. What we mean here by "specified mainstem flows" is that these are the flows we used to calculate the diffuse inputs and abstractions over each reach. Where available, this is almost always the same as the measured flow data value. Where data is not available, we set values to retain approximate proportionality of gains/losses with dates where more data are available. In a few instances, we chose values that differ from measured data. For example, between 55LSR-18.0 and 55LSR-13.5, there is significant disagreement in the data about whether most of the flow gain happens between RM 18.0 – 16.0, or between RM 16.0 – 13.5. This is likely due to measurement error, but it is unclear where. The flow values we specified for 55LSR-16.0 represent a compromise between the "versions of the story" told by the 2010 and 2013 flow measurement datasets.

[b] This represents the point where the Little Spokane River flows through a gap in a low bedrock ridgeline that crosses the valley at about USGS river mile 9.8, approximately halfway between Dartford Creek and Waikiki Springs. This is likely the upstream limit of the reach where large quanitities of groundwater enter the Little Spokane River from the Spokane Valley-Rathdrum Prairie Aquifer.

[c] Used flow measured 6/16/15. Flow measurements taken at Otter Ck. during 2010 were of poor quality.

[d] Used gaged flow from 6/12/15. We did not measure flow at 55WBLS-03.1 during 2010.

[e] Used gaged flow from 6/11-12/15. We did not measure flow at 55DRA-00.3 during 2010.

[f] Flow reported by facility

[g] Cline, 1969; page 28.

[h] Used gaged flow from 6/26/15. We did not measure flow at 55WBLS-03.1 or 55DRA-00.3 during 2010.

[i] Used value of 3 cfs (same as July 28, 2010) rather than measured value of 0.13 cfs. We discovered afterward that the location of the flow cross-section at 55DEE-00.1 was bypassed by a significant flow diversion/return. Comparing to 2010 and 2015 data, the measured value does not make sense given the overall flow condition of the watershed, and likely indicates that a majority of the flow bypassed the flow measurement location.

[j] No data. Used value from August 2010.

[k] No data. Estimate 2 cfs, which is near the low end of known values.

We further modified the residual inflows and outflows between stations using an assumption that surface water withdrawals remove some water from the system during the summer months. There is an understanding among water managers that not all surface water rights in the Little Spokane basin are actually used, and that likely only a small fraction are used. The actual quantity is unknown, and any estimate will have significant uncertainty associated with it. In the absence of definitive data, we selected an estimate for surface withdrawals of 20% of those certificate surface water rights which specifically name the Little Spokane River or a tributary as a source. This is equivalent to a total of 8.2 cfs. For comparison, Spokane County (2006) estimated that 6398 AF/yr are used for irrigation in the Little Spokane Watershed. If half of that volume came from surface withdrawals, and irrigation occurred over six months, this would equate to 8.8 cfs (Covert, 2016).

Table G-4 indicates the volumes of surface withdrawals simulated in each flow balance reach and each tributary.

Table G-4. Surface water withdrawals simulated in the QUAL2Kw model.

Mainstem Reach	Total withdrawals (cfs)
Upstream of Frideger Rd	0.36
Frideger Rd - Elk	0.32
Elk – Eloika Rd	0.05
Eloika Rd – Milan	0.02
Milan – Abv Bear Ck	0.14
Abv Bear Ck – Riverway Rd	0.30
Riverway Rd – Chattaroy	0.11
Chattaroy – Buckeye	0.60
Buckeye – Colbert Rd	0.54
Colbert Rd – N LSR Dr	0.51
N LSR Dr – Pine R Park	0.16
Pine R Park – Dartford gage	0
Dartford gage – Topo gap	0.02
Topo gap – Waikiki Rd	0.03
Waikiki Rd – St George's	0.12
St George's – Painted Rocks	0.02
Painted Rocks – Hwy 291	0.13

Tributary	Total withdrawals (cfs)
Tribs US of Fridger Rd	0.05
Dry Ck	0.07
Otter Ck	0
WB Little Spokane R	1.63
Bear Ck	0.30
Deer Ck	0.45
Dragoon Ck	1.70
Deadman Ck	0.51
Dartford Ck	0.08
Total (mainstem & tributaries):	**8.2**

Boundary Condition Inputs

The boundary conditions in a water quality model are a description of streamflow and water quality at locations where water enters the model domain. Boundary inputs occur in the following locations:

- Upstream boundary at LSR @ Frideger Rd (55LSR-39.5)
- 8 tributary mouths
- Griffith Slough, which includes water from Griffith Springs as well as discharge from a point source, the Spokane Hatchery
- 2 additional surface springs
- One additional point source, the Colbert Landfill outfall
- Diffuse groundwater inputs

Tables G-5 through G-9 summarize the boundary condition inputs for the QUAL2Kw model of the Little Spokane River. We generally took inputs directly from Ecology sample and measurement data collected during synoptic surveys, during the same week (and usually within a day or so) of the model run date. We calculated inputs from sample data according to the "measured as" column in Table G-1. For all other situations, footnotes provide explanations of how we chose input values. Where the table indicates a range of values, this indicates a parameter that has a diel fluctuation; we show the daily minimum and maximum values.

We did not use the QUAL2Kw model variables CBODslow, phytoplankton, pathogen, and generic constituent. The **Rate Parameters** section provides explanation of how we bypassed the CBODslow variable.

Table G-5. Boundary condition inputs for July 28, 2010 QUAL2Kw model run.

Boundary condition		Flow (cms)	Temperature (C)	Conductivity (uS/cm 25C)	Inorganic Solids (mgD/L)	Dissolved Oxygen (mg/L)	CBOD fast (mgO2/L) [gg]	Organic N (ugN/L)	Ammonia N (ugN/L)	Nitrate-Nitrite N (ugN/L)	Organic P (ugP/L)	Inorganic P (ugP/L)	Detritus (mgD/L)	Alkalinity (mgCaCO3/L)	pH (s.u.)
LSR @ Fridger Rd (upstream boundary)		0.934	21.18 – 25.48	212.33	0.5	3.84 – 8.93	4.98	141.25	5	11.75	5.6	7.05	0.69	106.5	7.16 – 7.86
Dry Ck		0.0496	11.11 – 12.94	227.19	4	9.34 – 9.81	4.17	87	5	983	5.85	22.7	0	109.5	7.98 – 8.17
Otter Ck		0.2067[a]	10.47 – 12.73	189.27	1	9.42 – 9.96	2.15	0	5	1670	0.45	21.9	0	82.55	7.99 – 8.22
W Branch LSR		0.6796[b]	21.73 – 26.37	94.50	0.5	7.49 – 8.17 [p]	15.33	424.5	28.5	5	17.85	6.7	1.63	42.15	7.98 – 8.17 [dd]
Bear Ck		0.0297	17.11 – 22.71 [g]	309.50	8.5	9.34 – 9.81 [q]	6.73	214.5	5	1050.5	22.48	29.28	0.69	147	7.98 – 8.17 [dd]
Deer Ck		0.0850	14.40 – 17.69	88.64	2	9.34 – 9.81 [q]	7.53	95.5	5	307.25	7.75	53.08	0.5	39.68	7.15 – 7.40
Dragoon Ck		0.4814[c]	15.71 – 20.39	319.61	0.5 [m]	8.43 – 9.29	5.18	5 [m]	5	2730	2.7 [m]	38.4	0.56	144	8.11 – 8.46
Colbert Landfill outfall		0.0396[d]	11.37	505.00	0.5	10.12	1.35	130	5	4745	0	24.8	0	233	8.16
Deadman Ck		0.3681	14.38 – 18.84	256.54	2	8.21 – 9.02	6.25	114.75	5	568.5	40.88	53.1	0	116	8.04 – 8.28
Dartford Ck		0.0864	12.89 – 15.14	523.50	7	9.64 – 10.50	2.69	0	10	9105	0	40.1	0	218	8.30 – 8.42
Waikiki Springs		0.2832[e]	10.29 [h]	368 [h]	0 [n]	9.52 [i]	0 [n]	134 [s]	0 [t]	3069 [h]	1.12 [h]	2.94 [h]	0 [n]	132 [i]	7.60 [h]
Spokane CC Springs		0.0538	11.38 [i]	320	0.5	9.29	1.35	0	5	1480	0	5.85	0	142	8.02
Griffith Slough (includes spring & hatchery)		0.5947	13.74 [j]	329.5	0.5	12.05	1.35	0	46.25	1690	0	17.6	0	146.25	8.24
Diffuse groundwater	Frideger Rd - Milan	0.3205[f]	10.97 [k]	210	2.5 [o]	6.5 [r]	0 [n]	0 [n]	0 [t]	800 [u]	6.4 [w]	25 [y]	0 [n]	100 [bb]	7.00 [ee]
	Milan – N LSR Dr	0.7008[f]	10.97 [k]	210	2.5 [o]	6.5 [r]	0 [n]	0 [n]	0 [t]	800 [u]	2.56 [w]	10 [z]	0 [n]	100 [bb]	7.00 [ee]
	N LSR Dr – Mouth (SVRPA)	6.6947[f]	10.97 [k]	368, 352 [l]	2.5 [o]	6.5 [r]	0 [n]	0 [n]	0 [t]	1184 [v]	1.1 [x]	7.94 [aa]	0 [n]	141 [cc]	7.85 [ff]

[a] Used flow measured 6/16/15. Flow measurements taken at Otter Ck. during 2010 were of poor quality.

[b] Used gaged flow from 6/12/15. We did not measure flow at 55WBLS-03.1 during 2010.

[c] Used gaged flow from 6/11-12/15. We did not measure flow at 55DRA-00.3 during 2010.

[d] Flow reported by facility

[e] Cline, 1969; page 28.

[f] Groundwater inflow volumes are based on flow balances and account for estimated surface withdrawals. See **Flow Balances** section.

[g] Based on regression between water temperatures monitored by WSU during 2004-2006, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2010.

[h] Mean value recorded by Spokane County, 2009-2012.

[i] Average value from Spokane CC Springs, for both July and August 2010.

[j] Average value recorded during June - September, 2009.

[k] Mean value recorded by Ecology during monitoring of Griffith Spring above the hatchery intake during 2009, as a reference site for Spokane-Rathdrum Prairie Aquifer (SVRPA) as a part of the Hangman Creek TMDL study.

[l] For the portion of this reach upstream of Waikiki Rd, we used the value from Waikiki Springs (368 uS/cm). For the portion of the reach downstream, we used the value from Griffith Springs (352 uS/cm).

[m] Used result from August 2010 synoptic. Strange July result does not make sense with values observed further downstream.

[n] No data. Spring water/groundwater likely contains little or no ISS, CBOD, Organic N, or detritus.

[o] Dummy input used to approximate observed instream TSS. We do not assume that this represents groundwater; more likely it represents bank erosion or other non-point source.

[p] Calculated inputs based on the assumption that DO at the mouth of WBLSR tracks saturation point.

[q] Used values from Dry Ck. We did not monitor diel DO at Bear Ck during 2010, and we rejected data from Deer Ck during QC.

[r] Estimated value, chosen to match instream values downstream. Because of the overwhelming influence of the SVRPA in the lower portion of the river, it is possible to infer the DO value of the aquifer water with reasonable confidence. We assumed the same value applies to upper basin groundwater.

[s] Average value from Griffith Spring above hatchery intake, during 2009 Spokane Hatchery monitoring.

[t] Assume zero. Due to the oxygenated state of this groundwater, it is reasonable to assume that substantially all the DIN is in the form of nitrate-nitrite.

[u] Reasonable point in distribution of upper watershed well-monitoring values, which span a large range from 80 ug/L to 3730ug/L.

[v] Average value from Spokane County sampling of SVRPA wells in and north of the Hillyard trough, which is the portion of the SVRPA that leads to the Little Spokane. This included the following wells, during 2009-2012: 1.) Holy Cross, Rhoades & Washington MW (6330J01); 2.) Franklin Park, City MW (6331J01); 3.) Spokane Fish Hatchery Well (6211K01); 4.) Whitworth WD #2, Well 21 (6320D01); and 5.) N. Spokane Irrig. Dist. #4 (6328H01). We excluded one other well in this area from the average, as values from that well differed substantially from the other five.

[w] Calculated value, assumed ratio of organic P:inorganic P in upper watershed is same as for SVRPA.

[x] Average value from Spokane County sampling at Spokane Fish Hatchery Well (6211K01), 2009-2012. This value, added to the inorganic P value of 7.94, results in a TP value of 9.04, which is nearly identical to the current conditions TP value of 9 ug/L used for the SVRPA in the Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010).

[y] Average of USGS well sampling values from the Otter Ck. basin.

[z] USGS well sampling value near Bear Lake.

[aa] Average value from Ecology sampling of Griffith Spring above the hatchery intake.

[bb] No data. We chose this value to match instream alkalinity values in upper watershed.

[cc] Average of values from the Spokane CC springs and Griffith Spring.

[dd] Used values from Dry Ck. We did not collect diel pH at WBLSR or Bear Ck during 2010.

[ee] No data. We chose this value to improve upper watershed instream diel pH predictions. This value is typical for groundwater in grantic-rock aquifers (Ortiz, 2004; min 6.5, median 7.2, max 7.7). Use of a higher value, such as the one used for SVRPA, resulted in poor ability to predict upper watershed pH.

[ff] Average of values from Waikiki Springs, Spokane CC springs, and Griffith Springs. This also happens to be the Griffith Springs value.

[gg] We calculated CBODfast values by multiplying DOC results * (2.69 mgO_2/1 mgC). We did not use the CBODslow category, rather we set rate parameters to “pass through” all CBODslow to CBODfast. However, note that the material represented by CBODfast in this model is not actually fast-reacting (labile) material. It is actually slow-reacting (recalcitrant) material. See **Rate Parameters** section below for more information.

Table G-6. Boundary condition inputs for August 25, 2010 QUAL2Kw model run.

Boundary condition		Flow (cms)	Temperature (C)	Conductivity (uS/cm 25C)	Inorganic Solids (mgD/L)	Dissolved Oxygen (mg/L)	CBOD fast (mgO2/L) [ff]	Organic N (ugN/L)	Ammonia N (ugN/L)	Nitrate-Nitrite N (ugN/L)	Organic P (ugP/L)	Inorganic P (ugP/L)	Detritus (mgD/L)	Alkalinity (mgCaCO3/L)	pH (s.u.)
LSR @ Fridger Rd (upstream boundary)		0.821	18.01 – 22.42	224.69	0.5	5.73 – 10.83	3.9	129.25	5	5	4.5	4.03	0.81	107.75	7.61 – 8.45
Dry Ck		0.0552	9.19 – 12.09	262	2	9.71 – 10.57	1.35	75	5	1085	1.75	18.45	0	113.5	7.95 – 8.06
Otter Ck		0.2067[a]	9.31 – 12.52	193.37	0.5	9.86 – 10.57	1.35	50	5	1515	2.6	20.6	0	79.2	7.58 – 7.83
W Branch LSR		0.3115[b]	17.04 – 22.00	107.4	1	8.12 – 8.98 [o]	17.49	485.5	10.5	16	21.8	4.4	2.63	43.35	7.95 – 8.06 [cc]
Bear Ck		0.0368	12.13 – 17.73 [f]	327	5	9.71 – 10.57 [p]	8	210	5	666.5	18.5	15.83	0.88	157	7.95 – 8.06 [cc]
Deer Ck		0.0210	10.24 – 15.22	124.46	0.75	8.73 – 10.28	5.11	95.75	12	498.75	2.13	45.2	0.81	57.35	7.47 – 7.64
Dragoon Ck		0.3936[b]	12.36 – 16.88	339.63	0.5	8.74 – 9.84	4.1	5	5	3067.5	2.7	32.53	0.94	150.75	8.09 – 8.29
Colbert Landfill outfall		0.0283[c]	11.15	541.5	0.5	10.16	1.35	0	5	4720	0	24.9	0	230	8.32
Deadman Ck		0.2152	10.73 – 15.85	372	0.5	8.87 – 10.24	2.08	87.25	5	855.75	9.28	28.68	0.88	154.25	8.00 – 8.26
Dartford Ck		0.0779	10.81 – 13.57	529.01	4	9.53 – 10.09	2.15	0	5	8540	0.55	36.2	0	220	8.42 – 8.56
Waikiki Springs		0.2832[d]	10.29 [g]	368 [g]	0 [m]	9.52 [h]	0 [m]	134 [r]	0 [s]	3069 [g]	1.12 [g]	2.94 [g]	0 [m]	132 [h]	7.60 [g]
Spokane CC Springs		0.0722	11.38 [h]	335	0.5	9.71	1.35	0	5	1515	0	4.05	0	122	8.14
Griffith Slough (includes spring & hatchery)		0.5239	13.74 [i]	329.5 [k]	0.5 [k]	12.05 [k]	1.35 [k]	0 [k]	46.25 [k]	1690 [k]	0 [k]	17.6 [k]	0 [k]	146.25[k]	8.24 [k]
Diffuse groundwater	Frideger Rd - Milan	0.2299[e]	10.97 [j]	210	1.2 [n]	6.5 [q]	0 [m]	0 [m]	0 [s]	800 [t]	6.4 [v]	25 [x]	0 [m]	100 [aa]	7.00 [dd]
	Milan – N LSR Dr	0.8852[e]	10.97 [j]	210	1.2 [n]	6.5 [q]	0 [m]	0 [m]	0 [s]	800 [t]	2.56 [v]	10 [y]	0 [m]	100 [aa]	7.00 [dd]
	N LSR Dr – Mouth (SVRPA)	6.4271[e]	10.97 [j]	368, 352 [l]	1.2 [n]	6.5 [q]	0 [m]	0 [m]	0 [s]	1184 [u]	1.1 [w]	7.94 [z]	0 [m]	141 [bb]	7.85 [ee]

[a] Used flow measured 6/16/15. Flow measurements taken at Otter Ck. during 2010 were of poor quality.

[b] Used gaged flow from 6/26/15. We did not measure flow at 55WBLS-03.1 or 55DRA-00.3 during 2010.

[c] Flow reported by facility

[d] Cline, 1969; page 28.

[e] Groundwater inflow volumes are based on flow balances and account for estimated surface withdrawals. See **Flow Balances** section.

[f] Based on regression between water temperatures monitored by WSU during 2004-2006, and air temperatures at Deer Park airport. Diel temperature was not monitored at this location during 2010.

[g] Mean value recorded by Spokane County, 2009-2012.

[h] Average value from Spokane CC Springs, for both July and August 2010.

[i] Average value recorded during June - September, 2009.

[j] Mean value recorded by Ecology during monitoring of Griffith Spring above the hatchery intake during 2009, as a reference site for Spokane-Rathdrum Prairie Aquifer (SVRPA) as a part of the Hangman Creek TMDL study.

[k] Values from July 2010 synoptic. 55GRI-00.0 values from August 2010 for several parameters were notably elevated. Spokane Hatchery may have been engaged in cleaning operations. However, the observed downstream values do not reflect the spike that would be expected to result from these elevated loads. The more typical July values agree with the downstream values.

[l] For the portion of this reach upstream of Waikiki Rd, we used the value from Waikiki Springs (368 uS/cm). For the portion of the reach downstream, we used the value from Griffith Springs (352 uS/cm).[m] No data. Spring water/groundwater likely contains little or no ISS, CBOD, Organic N, or detritus.

[n] Dummy input used to approximate observed instream TSS. We do not assume that this represents groundwater; more likely it represents bank erosion or other non-point source.[o] Calculated inputs based on the assumption that DO at the mouth of WBLSR tracks saturation point.

[p] Used values from Dry Ck. We did not monitor Diel DO at Bear Ck during 2010.

[q] Estimated value, chosen to match instream values downstream. Because of the overwhelming influence of the SVRPA in the lower portion of the river, it is possible to infer the DO value of the aquifer water with reasonable confidence. We assumed the same value applies to upper basin groundwater.

[r] Average value from Griffith Spring above hatchery intake, during 2009 Spokane Hatchery monitoring.

[s] Assume zero. Due to the oxygenated state of this groundwater, it is reasonable to assume that substantially all the DIN is in the form of nitrate-nitrite.

[t] Reasonable point in distribution of upper watershed well-monitoring values, which span a large range from 80 ug/L to 3730ug/L.

[u] Average value from Spokane County sampling of SVRPA wells in and north of the Hillyard trough, which is the portion of the SVRPA that leads to the Little Spokane. This included the following wells, during 2009-2012: 1.) Holy Cross, Rhoades & Washington MW (6330J01); 2.) Franklin Park, City MW (6331J01); 3.) Spokane Fish Hatchery Well (6211K01); 4.) Whitworth WD #2, Well 21 (6320D01); and 5.) N. Spokane Irrig. Dist. #4 (6328H01). We excluded one other well in this area from the average, as values from that well differed substantially from the other five.

[v] Calculated value, assumed ratio of organic P:inorganic P in upper watershed is same as for SVRPA.

[w] Average value from Spokane County sampling at Spokane Fish Hatchery Well (6211K01), 2009-2012. This value, added to the inorganic P value of 7.94, results in a TP value of 9.04, which is nearly identical to the current conditions TP value of 9 ug/L used for the SVRPA in the Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010).

[x] Average of USGS well sampling values from the Otter Ck. basin.

[y] USGS well sampling value near Bear Lake.

[z] Average value from Ecology sampling of Griffith Spring above the hatchery intake.

[aa] No data. We chose thisvalue to match instream alkalinity values in upper watershed.

[bb] Average of values from the Spokane CC springs and Griffith Spring.

[cc] Used values from Dry Ck. We did not collect diel pH at WBLSR or Bear Ck during 2010.

[dd] No data. We chose this value to improve upper watershed instream diel pH predictions. This value is typical for groundwater in grantic-rock aquifers (Ortiz, 2004; min 6.5, median 7.2, max 7.7). Use of a higher value, such as the one used for SVRPA, resulted in poor ability to predict upper watershed pH.

[ee] Average of values from Waikiki Springs, Spokane CC springs, and Griffith Springs. This also happens to be the Griffith Springs value.

[ff] We calculated CBODfast values by multiplying DOC results * (2.69 mgO_2/1 mgC). We did not use the CBODslow category, rather we set rate parameters to “pass through” all CBODslow to CBODfast. However, note that the material represented by CBODfast in this model is not actually fast-reacting (labile) material. It is actually slow-reacting (recalcitrant) material. See **Rate Parameters** section below for more information.

Table G-7. Boundary condition inputs for August 13, 2013 QUAL2Kw model run.

Boundary condition		Flow (cms)	Temperature (C)	Conductivity (uS/cm 25C)	Inorganic Solids (mgD/L)	Dissolved Oxygen (mg/L)	CBOD fast (mgO2/L) [ll]	Organic N (ugN/L)	Ammonia N (ugN/L)	Nitrate-Nitrite N (ugN/L)	Organic P (ugP/L)	Inorganic P (ugP/L)	Detritus (mgD/L)	Alkalinity (mgCaCO3/L)	pH (s.u.)
LSR @ Fridger Rd (upstream boundary)		1.076	21.18 – 25.48 [e]	212.33[p]	0.5 [j]	3.84 – 8.93 [p]	4.44 [j]	135.25 [j]	5 [j]	8.38 [j]	5.05 [j]	5.54 [j]	0.75 [j]	106.5 [p]	7.16 – 7.86 [p]
Dry Ck		0.0850	10.45 – 14.31 [f]	244.59[j]	3 [j]	9.25 – 9.91 [t]	2.76 [j]	81 [j]	5 [j]	1034 [j]	3.8 [j]	20.58 [j]	0 [j]	111.5 [j]	8.00 – 8.15 [t]
Otter Ck		0.2350	10.94 – 14.00 [g]	191.32[j]	0.75 [j]	9.37 – 10.00 [t]	1.75 [j]	25 [j]	5 [j]	1592.5 [j]	1.53 [j]	21.25 [j]	0 [j]	80.88 [j]	7.99 – 8.23 [t]
W Branch LSR		0.4531	23.06 – 27.26 [h]	100.95[j]	0.75 [j]	7.32 – 8.00 [u]	16.41 [j]	455 [j]	19.5 [j]	10.5 [j]	19.83 [j]	5.55 [j]	2.13 [j]	42.75 [j]	8.00 – 8.15 [tv]
Bear Ck		0.0425	17.95 – 23.55 [f]	318.25[j]	6.75 [j]	9.25 – 9.91 [tv]	7.36 [j]	212.25 [j]	5 [j]	858.5 [j]	20.53 [j]	22.55 [j]	0.78 [j]	152 [j]	8.00 – 8.15 [tv]
Deer Ck		0.0850[a]	14.79 – 19.29 [f]	106.55[j]	1.38 [j]	9.07 – 10.08 [tv]	6.32 [j]	95.63 [j]	8.5 [j]	403 [j]	4.94 [j]	49.14 [j]	0.66 [j]	48.51 [j]	7.17 – 7.38 [t]
Dragoon Ck		0.5380	17.40 – 20.98 [i]	329.62[j]	0.5 [j]	8.37 – 9.35 [t]	4.64 [j]	5 [j]	5 [j]	2898.75[j]	2.7 [j]	35.46 [j]	0.75 [j]	147.38 [j]	8.14 – 8.42 [t]
Colbert Landfill outfall		0.0326	11.26 [j]	523.25[j]	0.5 [j]	10.12 [p]	1.35 [j]	65 [j]	5 [j]	4732.5 [j]	0 [j]	24.85 [j]	0 [j]	231.5 [j]	8.16
Deadman Ck		0.3681	13.26 – 17.30 [k]	314.27[j]	1.25 [j]	8.07 – 9.16 [t]	4.17 [j]	101 [j]	5 [j]	712.13 [j]	25.08 [j]	40.89 [j]	0.44 [j]	135.13 [j]	8.03 – 8.28 [t]
Dartford Ck		0.1076	13.25 – 15.83 [l]	526.26[j]	5.5 [j]	9.71 – 10.42 [t]	2.42 [j]	0 [j]	7.5 [j]	8822.5 [j]	0.28 [j]	38.15 [j]	0 [j]	219 [j]	8.29 – 8.42 [t]
Waikiki Springs		0.2832[b]	10.29 [m]	368 [m]	0 [r]	9.52 [w]	0 [r]	134 [y]	0 [z]	3069 [m]	1.12 [m]	2.94 [m]	0 [r]	132 [w]	7.60 [m]
Spokane CC Springs		0.0722[c]	11.38 [j]	327.5 [j]	0.5 [j]	9.29 [p]	1.35 [j]	0 [j]	5 [j]	1497.5 [j]	0 [j]	4.95 [j]	0 [j]	132 [j]	8.02 [p]
Griffith Slough (includes spring & hatchery)		0.5239[c]	13.74 [n]	329.5 [p]	0.5 [p]	12.05 [p]	1.35 [p]	0 [p]	46.25 [p]	1690 [p]	0 [p]	17.60 [p]	0 [p]	146.25[p]	8.24 [p]
Diffuse groundwater	Frideger Rd - Milan	0.3701[d]	10.97 [o]	210	2.5 [s]	6.5 [x]	0 [r]	0 [r]	0 [z]	800 [aa]	6.4 [cc]	25 [ee]	0 [r]	100 [hh]	7.00 [jj]
	Milan – N LSR Dr	0.8336[d]	10.97 [o]	210	2.5 [s]	6.5 [x]	0 [r]	0 [r]	0 [z]	800 [aa]	2.56 [cc]	10 [ff]	0 [r]	100 [hh]	7.00 [jj]
	N LSR Dr – Mouth (SVRPA)	7.4904[d]	10.97 [o]	368, 352 [q]	2.5 [s]	6.5 [x]	0 [r]	0 [r]	0 [z]	1184 [bb]	1.1 [dd]	7.94 [gg]	0 [r]	141 [ii]	7.85 [kk]

[a] Used value of 3 cfs (0.0850 cms, same as July 28, 2010) rather than measured value of 0.13 cfs. It was discovered afterward that the location of the flow cross-section at 55DEE-00.1 was bypassed by a significant flow diversion. Comparing to 2010 and 2015 data, the measured value does not make sense given the overall flow condition of the watershed, and likely indicates that a majority of the flow bypassed the flow measurement.

[b] Cline, 1969; page 28.

[c] Used value from August 2010.

[d] Groundwater inflow volumes are based on flow balances and account for estimated surface withdrawals. See **Flow Balances** section.

[e] Used values from July 2010, which had very similar meteorological conditions. We did not monitor diel temperature at this location during 2013.

[f] Based on regression between water temperatures monitored by WSU during 2004-2006, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[g] Based on regression between water temperatures monitored by Spokane CD during 1999-2002, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[h] Based on regression between water temperatures monitored by WSU during 2004-2006 and by Spokane CD during 2010, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[i] Based on regression between water temperatures monitored by WSU during 2004-2006 and by Spokane CD during 1999-2002 and 2010, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[j] Used average value from July 2010 and August 2010 synoptics.

[k] Based on regression between water temperatures monitored by Spokane CD during 1999-2002, by WSU during 2004-2006, and by Ecology during 2010, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[l] Based on regression between water temperatures monitored by WDFW during 200 and by WSU during 2004-2006, and air temperatures at Deer Park airport. We did not monitor diel temperature at this location during 2013.

[m] Mean value recorded by Spokane County, 2009-2012.

[n] Average value recorded during June - September, 2009.

[o] Mean value recorded by Ecology during monitoring of Griffith Spring above the hatchery intake during 2009, as a reference site for Spokane-Rathdrum Prairie Aquifer (SVRPA) as a part of the Hangman Creek TMDL study.

[p] Used value from July 2010.

[q] For the portion of this reach upstream of Waikiki Rd, we used the value from Waikiki Springs (368 uS/cm). For the portion of the reach downstream, we used the value from Griffith Springs (352 uS/cm).[r] No data. Spring water/groundwater likely contains little or no ISS, CBOD, Organic N, or detritus.

[s] Dummy input used to approximate observed instream TSS. We do not assume that this represents groundwater; more likely it represents bank erosion or other non-point source.

[t] Daily average values are from July 2010, which had very similar meteorological conditions. Diel ranges are the average diel range from July 2010 and August 2010 synoptics.

[u] Calculated inputs based on the assumption that DO at the mouth of WBLSR tracks saturation point.

[v] Values from Dry Ck.

[w] Average value from Spokane CC Springs, for both July and August 2010.

[x] Estimated value, chosen to match instream values downstream. Because of the overwhelming influence of the SVRPA in the lower portion of the river, it is possible to infer the DO value of the aquifer water with reasonable confidence. We assumed the same value applies to upper basin groundwater.

[y] Average value from Griffith Spring above hatchery intake, during 2009 Spokane Hatchery monitoring.

[z] Assume zero. Due to the oxygenated state of this groundwater, it is reasonable to assume that substantially all the DIN is in the form of nitrate-nitrite.

[aa] Reasonable point in distribution of upper watershed well-monitoring values, which span a large range from 80 ug/L to 3730ug/L.

[bb] Average value from Spokane County sampling of SVRPA wells in and north of the Hillyard trough, which is the portion of the SVRPA that leads to the Little Spokane. This included the following wells, during 2009-2012: 1.) Holy Cross, Rhoades & Washington MW (6330J01); 2.) Franklin Park, City MW (6331J01); 3.) Spokane Fish Hatchery Well (6211K01); 4.) Whitworth WD #2, Well 21 (6320D01); and 5.) N. Spokane Irrig. Dist. #4 (6328H01). We excluded one other well in this area from the average, as values from that well differed substantially from the other five.

[cc] Calculated value, assumed ratio of organic P:inorganic P in upper watershed is same as for SVRPA.

[dd] Average value from Spokane County sampling at Spokane Fish Hatchery Well (6211K01), 2009-2012. This value, added to the inorganic P value of 7.94, results in a TP value of 9.04, which is nearly identical to the current conditions TP value of 9 ug/L used for the SVRPA in the Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010).

[ee] Average of USGS well sampling values from the Otter Ck. basin.

[ff] USGS well sampling value near Bear Lake.

[gg] Average value from Ecology sampling of Griffith Spring above the hatchery intake.

[hh] No data. We chose this value to match instream alkalinity values in upper watershed.

[ii] Average of values from the Spokane CC springs and Griffith Spring.

[jj] No data. We chose this value to improve upper watershed instream diel pH predictions. This value is typical for groundwater in grantic-rock aquifers (Ortiz, 2004; min 6.5, median 7.2, max 7.7). Use of a higher value, such as the one used for SVRPA, resulted in poor ability to predict upper watershed pH.

[kk] Average of values from Waikiki Springs, Spokane CC springs, and Griffith Springs. This also happens to be the Griffith Springs value.

[ll] We calculated CBODfast values by multiplying DOC results * (2.69 mgO_2/1 mgC). We did not use the CBODslow category, rather we set rate parameters to “pass through” all CBODslow to CBODfast. However, note that the material represented by CBODfast in this model is not actually fast-reacting (labile) material. It is actually slow-reacting (recalcitrant) material. See **Rate Parameters** section below for more information.

Table G-8. Boundary condition inputs for July 22, 2015 QUAL2Kw model run.

Boundary condition		Flow (cms)	Temperature (C)	Conductivity (uS/cm 25C)	Inorganic Solids (mgD/L)	Dissolved Oxygen (mg/L)	CBOD fast (mgO2/L) [ii]	Organic N (ugN/L)	Ammonia N (ugN/L)	Nitrate-Nitrite N (ugN/L)	Organic P (ugP/L)	Inorganic P (ugP/L)	Detritus (mgD/L)	Alkalinity (mgCaCO3/L)	pH (s.u.)
LSR @ Fridger Rd (upstream boundary)		0.9345	20.95 – 23.65	213.01	0.5 [f]	4.36 – 10.03	4.98 [u]	97	5	5	3	5.1	0.75 [u]	107.75 [f]	7.42 – 8.34
Dry Ck		0.0396	10.67 – 14.42 [e]	239.7 [e]	2 [f]	9.18 – 10.21 [e]	3.23 [u]	65	12	914	7.5	22.6	0 [u]	117	8.12 – 8.22
Otter Ck		0.1642	9.21 – 12.60 [e]	194.8 [e]	0.5 [f]	9.79 – 10.46 [e]	3.23 [u]	0	11	1710	3.8	15.2	0 [u]	77.5	8.00 – 8.39
W Branch LSR		0.0878	20.29 – 25.89	111.9 [e]	1 [f]	7.49 – 8.17 [q]	18.56 [u]	315	24	32	12	3.3	0 [u]	138	8.12 – 8.22 [g]
Bear Ck		0.0093	12.57 – 16.33 [e]	319 [e]	5 [f]	8.67 – 9.55 [e]	7.8 [u]	181	5	994	6.9	29.3	0.5 [u]	154	8.13 – 8.22
Deer Ck		0.0048	10.12 – 15.62 [e]	175 [e]	0.75 [f]	8.80 – 10.48 [e]	3.77 [u]	49	11	1110	0.7	25.3	0 [u]	79.7	7.95 – 8.58
Dragoon Ck		0.3681	16.58 – 21.24	338.01[e]	0.5 [f]	7.87 – 9.47 [e]	5.65 [u]	100	20	2930	7.5	20	0 [u]	145	8.12 – 8.44
Colbert Landfill outfall		0.0283[a]	11.15 [f]	541.5 [f]	0.5 [f]	10.16 [f]	1.35 [f]	0 [f]	5 [f]	4720 [f]	0 [f]	24.9 [f]	0 [f]	230 [f]	8.32 [f]
Deadman Ck		0.1812	12.16 – 16.75	384.64[ek]	0.5 [f]	8.96 – 10.21 [e]	16.29 [u k]	72.98 [k]	7.3 [k]	883.58[k]	1.93 [k]	25.76 [k]	1.28 [u k]	176.04[k]	8.00 – 8.28
Dartford Ck		0.0651	10.85 – 14.24 [g]	514 [l]	4 [f]	8.96 – 10.21[e r]	2.96 [u]	0	5	7980	0.6	34	0 [u]	212	8.33 – 8.42
Waikiki Springs		0.2832[b]	10.29 [h]	368 [h]	0 [o]	9.52 [s]	0 [o]	134 [v]	0 [w]	3069 [h]	1.12 [h]	2.94 [h]	0 [o]	132 [s]	7.60 [h]
Spokane CC Springs		0.0566[c]	11.38 [f]	335 [f]	0.5 [f]	9.71 [f]	1.35 [f]	0 [f]	5 [f]	1515 [f]	0 [f]	4.05 [f]	0 [f]	122 [f]	8.14 [f]
Griffith Slough (includes spring & hatchery)		0.5239[a]	13.74 [i]	329.5 [m]	0.5 [m]	12.05 [m]	1.35 [m]	0 [m]	46.2 [m]	1690 [m]	0 [m]	17.6 [m]	0 [m]	146.25	8.24 [m]
Diffuse groundwater	Frideger Rd - Milan	0.1464[d]	10.97 [j]	210	1.5 [p]	6.5 [t]	0 [o]	0 [o]	0 [w]	800 [x]	6.4 [z]	25 [bb]	0 [o]	100 [ee]	7.00 [gg]
	Milan – N LSR Dr	0.5530[d]	10.97 [j]	210	1.5 [p]	6.5 [t]	0 [o]	0 [o]	0 [w]	800 [x]	2.56 [z]	10 [cc]	0 [o]	100 [ee]	7.00 [gg]
	N LSR Dr – Mouth (SVRPA)	6.8926[d]	10.97 [j]	368, 352 [n]	1.5 [p]	6.5 [t]	0 [o]	0 [o]	0 [w]	1184 [y]	1.1 [aa]	7.94 [dd]	0 [o]	141 [ff]	7.85 [hh]

[a] No data. Used value from August, 2010 synoptic, which is at the low end of known values.

[b] Cline, 1969; page 28.

[c] No data. Estimate 2 cfs (0.0566 cms), which is near the low end of known values.

[d] Groundwater inflow volumes are based on flow balances and account for estimated surface withdrawals. See **Flow Balances** section.

[e] For these tributary sites, the values used are from diel Hydrolab® data collected the week following the main sampling event.

[f] Used value from August 2010.

[g] Values from Dry Ck.

[h] Mean value recorded by Spokane County, 2009-2012.

[i] Average value recorded during June - September, 2009.

[j] Mean value recorded by Ecology during monitoring of Griffith Spring above the hatchery intake during 2009, as a reference site for Spokane-Rathdrum Prairie Aquifer (SVRPA) as a part of the Hangman Creek TMDL study.

[k] During 2015, Deadman Ck. was sampled above Little Deep Ck at Shady Slope Rd, rather than below Little Deep Ck as was done in 2010. Inputs for nutrients, alkalinity, CBOD, detritus, and conductivity are a flow weighted average of values from Deadman Ck and Little Deep Ck.

[l] Value from point Hydrolab® measurements collected the week following the main sampling event.

[m] Used value from July 2010.

[n] For the portion of this reach upstream of Waikiki Rd, we used the value from Waikiki Springs (368 uS/cm). For the portion of the reach downstream, we used the value from Griffith Springs (352 uS/cm)..

[o] No data. Spring water/groundwater likely contains little or no ISS, CBOD, Organic N, or detritus.

[p] Dummy input used to approximate observed instream TSS. We do not assume that this represents groundwater; more likely it represents bank erosion or other non-point source.[q] Calculated inputs based on the assumption that DO at the mouth of WBLSR tracks saturation point.

[r] Values from Deadman Ck.

[s] Average value from Spokane CC Springs, for both July and August 2010.

[t] Estimated value, chosen to match instream values downstream. Because of the overwhelming influence of the SVRPA in the lower portion of the river, it is possible to infer the DO value of the aquifer water with reasonable confidence. We assumed the same value applies to upper basin groundwater.

[u] Used value from August 2015. DOC and TOC not collected in July 2015.

[v] Average value from Griffith Spring above hatchery intake, during 2009 Spokane Hatchery monitoring.

[w] Assume zero. Due to the oxygenated state of this groundwater, it is reasonable to assume that substantially all the DIN is in the form of nitrate-nitrite.

[x] Reasonable point in distribution of upper watershed well-monitoring values, which span a large range from 80 ug/L to 3730ug/L.

[y] Average value from Spokane County sampling of SVRPA wells in and north of the Hillyard trough, which is the portion of the SVRPA that leads to the Little Spokane. This included the following wells, during 2009-2012: 1.) Holy Cross, Rhoades & Washington MW (6330J01); 2.) Franklin Park, City MW (6331J01); 3.) Spokane Fish Hatchery Well (6211K01); 4.) Whitworth WD #2, Well 21 (6320D01); and 5.) N. Spokane Irrig. Dist. #4 (6328H01). We excluded one other well in this area from the average, as values from that well differed substantially from the other five.

[z] Calculated value, assumed ratio of organic P:inorganic P in upper watershed is same as for SVRPA.

[aa] Average value from Spokane County sampling at Spokane Fish Hatchery Well (6211K01), 2009-2012. This value, added to the inorganic P value of 7.94, results in a TP value of 9.04, which is nearly identical to the current conditions TP value of 9 ug/L used for the SVRPA in the Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010).

[bb] Average of USGS well sampling values from the Otter Ck. basin.

[cc] USGS well sampling value near Bear Lake.

[dd] Average value from Ecology sampling of Griffith Spring above the hatchery intake.

[ee] No data. We chose this value chosen to match instream alkalinity values in upper watershed.

[ff] Average of values from the Spokane CC springs and Griffith Spring.

[gg] No data. We chose this value to improve upper watershed instream diel pH predictions. This value is typical for groundwater in grantic-rock aquifers (Ortiz, 2004; min 6.5, median 7.2, max 7.7). Use of a higher value, such as the one used for SVRPA, resulted in poor ability to predict upper watershed pH.

[hh] Average of values from Waikiki Springs, Spokane CC springs, and Griffith Springs. This also happens to be the Griffith Springs value.

[ii] We calculated CBODfast values by multiplying DOC results * (2.69 mgO_2/1 mgC). We did not use the CBODslow category, rather we set rate parameters to “pass through” all CBODslow to CBODfast. However, note that the material represented by CBODfast in this model is not actually fast-reacting (labile) material. It is actually slow-reacting (recalcitrant) material. See **Rate Parameters** section below for more information.

Table G-9. Boundary condition inputs for August 19, 2015 QUAL2Kw model run.

Boundary condition		Flow (cms)	Temperature (C)	Conductivity (uS/cm 25C)	Inorganic Solids (mgD/L)	Dissolved Oxygen (mg/L)	CBOD fast (mgO2/L) [jj]	Organic N (ugN/L)	Ammonia N (ugN/L)	Nitrate-Nitrite N (ugN/L)	Organic P (ugP/L)	Inorganic P (ugP/L)	Detritus (mgD/L)	Alkalinity (mgCaCO3/L)	pH (s.u.)
LSR @ Fridger Rd (upstream boundary)		0.9061	19.05 – 22.25	226.43	0.5 [f]	4.57 – 8.78	4.98	127	12	5	2.8	4.35	0.75	107.75 [f]	7.42 – 8.06
Dry Ck		0.0425	10.94 – 14.06 [e]	240.02[e]	2 [f]	8.93 – 9.77 [e]	3.23	145	11	894	8.4	20.6	0	119	8.21 – 8.29 [e]
Otter Ck		0.1784	9.62 – 12.58 [e]	193.35[e]	0.5 [f]	9.81 – 10.47 [e]	3.23	115	5	1490	2.3	17.7	0	77.1	7.97 – 8.25 [e]
W Branch LSR		0.0311	17.62 – 25.20	145 [e]	1 [f]	8.12 – 8.98 [q]	18.56	513	26	52	8.8	4.5	0	44.6	8.21 – 8.29 [e ff]
Bear Ck		0.0085	12.05 – 15.95 [e]	313 [e]	5 [f]	8.59 – 9.58 [e]	7.8	281	5	844	6.7	22.7	0.5	154	8.15 – 8.33 [e]
Deer Ck		0.0020	10.37 – 15.26 [e]	189 [e]	0.75 [f]	8.81 – 10.14 [e]	3.77	139	11	1120	0	21.6	0	83.2	7.94 – 8.33 [e]
Dragoon Ck		0.3398	14.39 – 19.01	350 [j]	0.5 [f]	8.34 – 9.68 [e r]	5.65	595	15	2900	1.8	19.7	0	150	8.04 – 8.23 [e gg]
Colbert Landfill outfall		0.0283[a]	11.15 [f]	541.5 [f]	0.5 [f]	10.16 [f]	1.35 [f]	0 [f]	5 [f]	4720 [f]	0 [f]	24.9 [f]	0 [f]	230 [f]	8.32 [f]
Deadman Ck		0.1699	10.83 – 15.89	410.31[ek]	0.5 [f]	9.02 – 9.93 [e]	16.29 [k]	156 [k]	30 [k]	1037.31[k]	0.86 [k]	21.48 [k]	1.28 [k]	194.9 [k]	8.03 – 8.23 [e]
Dartford Ck		0.0680	10.89 – 13.78 [e]	516 [e]	4 [f]	9.23 – 10.04 [e]	2.96	915	15	7710	2.2	22.4	0	216	8.38 – 8.54 [e]
Waikiki Springs		0.2832[b]	10.29 [g]	368 [g]	0 [o]	9.52 [s]	0 [o]	134 [u]	0 [v]	3069 [g]	1.12 [g]	2.94	0 [o]	132 [s]	7.60 [g]
Spokane CC Springs		0.0566[c]	11.38 [f]	335 [f]	0.5 [f]	9.71 [f]	1.35 [f]	0 [f]	5 [f]	1515 [f]	0 [f]	4.05 [f]	0 [f]	122 [f]	8.14 [f]
Griffith Slough (includes spring & hatchery)		0.5239[a]	13.74 [h]	329.5 [m]	0.5 [m]	12.05 [m]	1.35 [m]	0 [m]	46.25 [m]	1690 [m]	0 [m]	17.6 [m]	0 [m]	146.25[m]	8.24 [m]
Diffuse groundwater	Frideger Rd - Milan	0.1719[d]	10.97 [i]	210	1.0 [p]	6.5 [t]	0 [o]	0 [o]	0 [v]	800 [w]	6.4 [y]	25 [aa]	0 [o]	100 [dd]	7.00 [hh]
	Milan – N LSR Dr	0.6408[d]	10.97 [i]	210	1.0 [p]	6.5 [t]	0 [o]	0 [o]	0 [v]	800 [w]	2.56 [y]	10 [bb]	0 [o]	100 [dd]	7.00 [hh]
	N LSR Dr – Mouth (SVRPA)	6.6349[d]	10.97 [i]	368, 352 [n]	1.0 [p]	6.5 [t]	0 [o]	0 [o]	0 [v]	1184 [x]	1.1 [z]	7.94 [cc]	0 [o]	141 [ee]	7.85 [ii]

[a] No data. Used value from August, 2010 synoptic, which is at the low end of known values.

[b] Cline, 1969; page 28.

[c] No data. Estimate 2 cfs (0.0566 cms), which is near the low end of known values.

[d] Groundwater inflow volumes are based on flow balances and account for estimated surface withdrawals. See **Flow Balances** section.

[e] For these tributary sites, the values used are from diel Hydrolab® data collected the week following the main sampling event.

[f] Used value from August 2010.

[g] Mean value recorded by Spokane County, 2009-2012.

[h] Average value recorded during June - September, 2009.

[i] Mean value recorded by Ecology during monitoring of Griffith Spring above the hatchery intake during 2009, as a reference site for Spokane-Rathdrum Prairie Aquifer (SVRPA) as a part of the Hangman Creek TMDL study.

[j] Value from point Hydrolab® measurements collected the week following the main sampling event.

[k] During 2015, Deadman Ck. was sampled above Little Deep Ck at Shady Slope Rd, rather than below Little Deep Ck as was done in 2010. Inputs for nutrients, alkalinity, CBOD, detritus, and conductivity are a flow weighted average of values from Deadman Ck and Little Deep Ck.

[m] Used value from July 2010.

[n] For the portion of this reach upstream of Waikiki Rd, we used the value from Waikiki Springs (368 uS/cm). For the portion of the reach downstream, we used the value from Griffith Springs (352 uS/cm).

[o] No data. Spring water/groundwater likely contains little or no ISS, CBOD, Organic N, or detritus.

[p] Dummy input used to approximate observed instream TSS. We do not assume that this represents groundwater; more likely it represents bank erosion or other non-point source.

[q] Calculated inputs based on the assumption that DO at the mouth of WBLSR tracks saturation point.

[r] No data. Used daily average DO value halfway between WBLSR and Deadman Ck. Used diel range of Deer Ck.

[s] Average value from Spokane CC Springs, for both July and August 2010.

[t] Estimated value, chosen to match instream values downstream. Because of the overwhelming influence of the SVRPA in the lower portion of the river, it is possible to infer the DO value of the aquifer water with reasonable confidence. We assumed the same value applies to upper basin groundwater.

[u] Average value from Griffith Spring above hatchery intake, during 2009 Spokane Hatchery monitoring.

[v] Assume zero. Due to the oxygenated state of this groundwater, it is reasonable to assume that substantially all the DIN is in the form of nitrate-nitrite.

[w] Reasonable point in distribution of upper watershed well-monitoring values, which span a large range from 80 ug/L to 3730ug/L.

[x] Average value from Spokane County sampling of SVRPA wells in and north of the Hillyard trough, which is the portion of the SVRPA that leads to the Little Spokane. This included the following wells, during 2009-2012: 1.) Holy Cross, Rhoades & Washington MW (6330J01); 2.) Franklin Park, City MW (6331J01); 3.) Spokane Fish Hatchery Well (6211K01); 4.) Whitworth WD #2, Well 21 (6320D01); and 5.) N. Spokane Irrig. Dist. #4 (6328H01). We excluded one other well in this area from the average, as values from that well differed substantially from the other five.

[y] Calculated value, assumed ratio of organic P:inorganic P in upper watershed is same as for SVRPA.

[z] Average value from Spokane County sampling at Spokane Fish Hatchery Well (6211K01), 2009-2012. This value, added to the inorganic P value of 7.94, results in a TP value of 9.04, which is nearly identical to the current conditions TP value of 9 ug/L used for the SVRPA in the Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010).

[aa] Average of USGS well sampling values from the Otter Ck. basin.

[bb] USGS well sampling value near Bear Lake.

[cc] Average value from Ecology sampling of Griffith Spring above the hatchery intake.

[dd] No data. We chose this value to match instream alkalinity values in upper watershed.

[ee] Average of values from the Spokane CC springs and Griffith Spring.

[ff] Values from Dry Ck.

[gg] No data. Used daily average pH from Deer Ck. Used diel range equal to half that of Deer Ck.

[hh] No data. We chose this value to improve upper watershed instream diel pH predictions. This value is typical for groundwater in grantic-rock aquifers (Ortiz, 2004; min 6.5, median 7.2, max 7.7). Use of a higher value, such as the one used for SVRPA, resulted in poor ability to predict upper watershed pH.

[ii] Average of values from Waikiki Springs, Spokane CC springs, and Griffith Springs. This also happens to be the Griffith Springs value.

[jj] We calculated CBODfast values by multiplying DOC results * (2.69 mgO_2/1 mgC). We did not use the CBODslow category, rather we set rate parameters to “pass through” all CBODslow to CBODfast. However, note that the material represented by CBODfast in this model is not actually fast-reacting (labile) material. It is actually slow-reacting (recalcitrant) material. See **Rate Parameters** section below for more information.

Initial Conditions

We did not specify initial conditions. Absent specified initial conditions, QUAL2Kw sets constituent values throughout the model domain to the upstream boundary condition at the first time step.

Climate and Shade Inputs

Table G-10. Data sources for climate and shade model inputs

Parameter	Data Source
Air temperature	National Weather Service/Deer Park Airport (KDEW). Hourly average for the four days prior to and including the model run date. Windspeed data modified by wind sheltering factor of 0.5.
Dew point	
Windspeed	
Cloud cover	
Solar radiation	Calculated internally using Ryan-Stolzenbach model, atmospheric transmission coefficient = 0.75
Shade	Used shade model results from *Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity TMDL* (Joy and Jones, 2012). Shade model was re-run for the model run dates used in this project. Old shade model nodes were matched and interpolated to new segmentation used in this modeling exercise, which was based on higher-resolution linework.

QUAL2Kw model settings

Table G-11. QUAL2Kw model settings

Simulation option	Setting
Calculation step	22.5 minutes
Number of days for the simulation period	30 days
Simulation mode	Repeating diel
Solution method (integration)	Euler
Solution method (pH)	Brent
Simulate hyporheic transient storage zone (HTS)	Level 2
Simulate surface transient storage zone (STS)	No
Option for conduction to deep sediments in heat budget	Lumped
State variables for simulation	All
Simulate sediment diagenesis	No
Simulate alkalinity change due to nutrient change	Yes

Model Calibration and Rate Parameters

We performed calibration of the QUAL2Kw model using the genetic auto-calibration algorithm. We based the fitness function used to evaluate the quality of various calibrations on two factors:

- Goodness of model fit to July 2010, August 2010, and August 2013 datasets
- The sensitivity of algal productivity to instream nutrient concentrations. A part of the fitness function tested how well the nutrient sensitivity curves resulting from each calibration adhered to ranges shown in research literature (Bothwell, 1985; Rier and Stevenson, 2006; see the **Assessment of Model Sensitivity to Nitrogen and Phosphorus** section later in this Appendix).

Calibration was an iterative process. We performed a total of 24 batches of auto-calibrations. Each batch consisted of between 8 and 24 individual auto-calibrations, identical except for random number seed. This provided an approximate Bayesian distribution of values for each parameter. We then used this distribution to adjust the lower and upper bounds for each parameter during subsequent batches. Other changes we made between batches included tweaks to the fitness function and the selection of which parameters to auto-calibrate.

We calibrated the model to nutrient sensitivity curves for phosphorus and nitrogen, one at a time. First, we obtained a calibration with provided a good fit to observed data and a realistic phosophorus sensitivity curve. Then, in a subsequent batch, we only auto-calibrated the rate parameters directly pertaining to nitrogen, until we obtained a calibration which also provided a realistic nitrogen sensitivity curve.

After we obtained two additional datasets during July and August of 2015, we used these to check the existing model calibration as "verification" datasets. The existing calibration largely held for the 2015 datasets, however we adjusted two parameters (Bottom algae max growth rate and photosynthetic quotient) to better match DO and pH diel ranges for all five datasets.

Table G-12 lists the final rate parameters used for all model runs.

Table G-12. QUAL2Kw rate parameters

We do not show temperature corrections; these are equal to 1.07 unless indicated otherwise.

Parameter	Value	Units	Value source or calibration basis [a]
Stoichiometry:			
Carbon	40	gC	Default values based on Redfield cellular ratio (Redfield, 1958).
Nitrogen	7.2	gN	
Phosphorus	1	gP	
Dry weight	100	gD	
Chlorophyll	0.3	gA	Avg Chl *a* : AFDW ratio from 2010 data
Inorganic suspended solids:			
Settling velocity	0	m/d	ISS conservative, 0 settling needed to match observed data
Oxygen:			
Reaeration model	User model		Calibrated reaeration model to match phase timing of diel DO fluctuations
Reaeration user model parameter A	7		
Reaeration user model parameter B	0.5		
Reaeration user model parameter C	-2		
Temp correction	1.024		Default values
Reaeration wind effect	None		
O2 for carbon oxidation	2.69	gO2/gC	Standard stoichiometric ratios
O2 for NH4 nitrification	4.57	gO2/gN	
Oxygen inhib model CBOD oxidation	Exponential		Default values
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	
Oxygen inhib model nitrification	Exponential		
Oxygen inhib parameter nitrification	0.60	L/mgO2	
Oxygen enhance model denitrification	Exponential		
Oxygen enhance parameter denitrification	0.60	L/mgO2	
Oxygen inhib model phyto resp	Exponential		
Oxygen inhib parameter phyto resp	0.60	L/mgO2	
Oxygen enhance model bot alg resp	Exponential		
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	
Slow CBOD:			
Hydrolysis rate	100	/d	Arbitrary very high rate to pass through all material to “Fast CBOD” compartment.
Oxidation rate	0	/d	
Fast CBOD:			
Oxidation rate	0.0064	/d	Autocal min = 0; max = 0.025. “CBOD fast” category was used to represent all DOC. However it’s not actually fast-reacting; it’s very recalcitrant.
Organic N:			
Hydrolysis	0.0563	/d	Autocal min = 0.01; max = 0.1
Settling velocity	0.1	m/d	Assumed low rate
Ammonium:			
Nitrification	2.76	/d	Autocal min = 0.05; max = 3
Nitrate:			
Denitrification	1.4	/d	Autocal min = 0; max = 2
Sed denitrification transfer coeff	0.5	m/d	Assumed value; midrange of default settings
Organic P:			
Hydrolysis	0.716	/d	Autocal min = 0.2; max = 0.8
Settling velocity	0.1	m/d	Assumed low rate
Inorganic P:			
Settling velocity	0.05	m/d	Assumed low rate
Sed P oxygen attenuation half sat constant	1	mgO2/L	Assumed value; midrange of default settings

Parameter	Value	Units	Value source or calibration basis [a]
Phytoplankton: (not used)			
Bottom Algae:			
Growth model	Zero-order		Standard model for periphyton
Max Growth rate	50	gD/m2/d	Hand-calibrated to match diel DO and pH
Basal respiration rate	0.44	/d	Autocal min = 0.3; max = 0.6
Photo-respiration rate parameter	0	unitless	Not using photo-respiration
Excretion rate	0.0978	/d	Autocal min = 0.02; max = 0.1
Death rate	0.0704	/d	Autocal min = 0.02; max = 0.08
Scour function	(not used)		
External nitrogen half sat constant	489	ugN/L	Autocal min = 100; max = 500
External phosphorus half sat constant	143	ugP/L	Autocal min = 50; max = 350
Inorganic carbon half sat constant	1.30E-05	moles/L	Assumed value; midrange of default settings
Bottom algae use HCO3- as substrate	Yes		Standard assumption
Light model	Half saturation		Standard model
Light constant	110	langleys/d	Upper midrange of literature values 26 - 158
Ammonia preference	10	ugN/L	Hand-calibrated
Nutrient limitation model for N and P	Minimum		Standard model
Subsistence quota for nitrogen	2.2	mgN/gD	Hand-calibrated
Subsistence quota for phosphorus	0.424	mgP/gD	Autocal as function of subsistence quota for nitrogen; implied range min = 0.05; max = 1.1
Maximum uptake rate for nitrogen	115	mgN/gD/d	Autocal min = 50; max = 700
Maximum uptake rate for phosphorus	44	mgP/gD/d	Autocal min = 30; max = 60
Internal nitrogen half sat ratio	1.056		Autocal min = 1.05; max = 5
Internal phosphorus half sat ratio	1.309		Autocal min = 1.05; max = 3
Nitrogen uptake water column fraction	1		Standard assumption for periphyton
Phosphorus uptake water column fraction	1		
Detritus (POM):			
Dissolution rate	0.893	/d	Autocal min = 0.5; max = 0.9. High value for this parameter, along with low value for CBOD fast oxidation, dictated by need to produce enough CBOD (i.e. DOC) to match data.
Settling velocity	0	m/d	Assume value would be very low; 0 value means all detritus can be passed to CBOD.
Pathogens: (not used)			
pH:			
Partial pressure of carbon dioxide	390	ppm	Atmospheric CO_2 value for 2010
Hyporheic metabolism: (not used)			
Generic constituent: (not used)			
Photosynthetic quotient and respiratory quotient for bottom algae			
Photosynthetic quotient for NO3 vs NH4 use	1.30	/d	Hand-calibrated to match diel DO and pH
Respiratory quotient	1.00		Default value
User-defined calibration parameters			
Fraction bottom coverage of algae	0.597		Autocal min = 0.55; max = 0.68
Fraction bottom coverage of SOD	0		Most of model reach rock/gravel substrate; likely little or no SOD
Hyporheic zone thickness	50	cm	Based on assumption that there is active hyporheic exchange
Hyporheic flow fraction parameter	0.0233		Autocal min = 0.015; max = 0.035
Hyporheic sediment porosity	40%		Lower end of typical range of 35% to 50%

[a] Auto-calibration min and max bounds are for the batch in which the final value for that parameter was determined. Bounds for other autocalibration batches varied.

Model Goodness-of-fit

Table G-13 summarizes the Little Spokane River QUAL2Kw model goodness of fit to observed data . The Root Mean Squared Error (RMSE) statistic expresses the magnitude of typical model error for a variable in the same units as that variable. The Root Mean Squared Error Coefficient of Variation (RMSE CV) expresses the proportion of typical model error to the typical value of the variable. The overall bias statistic expresses the tendency of the model to over- or under-predict the value of a given variable. Bias% expresses this tendency as a proportion of the typical value of the variable. We also provide the average observed values from this study for most variables for reference.

For most variables, we calculated RMSE and bias by comparing modeled daily average values to observed daily average or grab sample values. For variables that display a marked diel swing, such as temperature, dissolved oxygen, and pH, we calculated the RMSE and bias for daily maximums and minimums instead. We also calculated RMSE CV and Bias%, which express error as a proportion of typical variable values, for those variables that express a quantity or concentration of something. These "relative" statistics are not appropriate for temperature or pH, which use arbitrary (and in the case of pH, exponential) unit scales where zero does not represent the total absence of the thing being measured.

The QUAL2Kw model provides a reasonable and acceptable simulation of DO and pH in the Little Spokane River. In particular, daily minimum DO had a minimal amount of error (RMSE = 0.40 mg/L) and almost no bias (overall bias = +0.09 mg/L). Daily maximum pH also had a minimal amount of error (0.25 S.U.) and minimal bias (overall bias = +0.18 S.U.). Daily minimum DO and daily maximum pH are of particular importance because these are what we compared to the water quality standards for low DO and high pH. These model fit statistics compare well to results from models used for TMDLs by Ecology in the past (Sanderson and Pickett, 2014). The model also provides a good simulation of nutrient concentrations.

Figure G-2 presents calibration plots for all key parameters. Calibration plots are able to give a better context for understanding model performance than error statistics alone can provide.

Table G-13. Summary statistics for goodness-of-fit of the QUAL2Kw model to observed data.

Variable	RMSE Daily Max	RMSE Daily Min	RMSE Daily Avg	RMSE CV Daily Max	RMSE CV Daily Min	RMSE CV Daily Avg	Ovl. Bias Daily Max	Ovl. Bias Daily Min	Ovl. Bias Daily Avg	%Bias Daily Max	%Bias Daily Min	%Bias Daily Avg	Abg Obs Value Daily Max	Abg Obs Value Daily Min	Abg Obs Value Daily Avg
Temperature (degC)	1.01	0.85					+0.41	+0.16					20.04	16.75	
Dissolved oxygen (mgO_2/L)	0.42	0.40		4.2%	5.5%		+0.22	+0.09		+2.1%	+1.3%		10.20	7.31	
pH	0.25	0.22					+0.18	-0.08					8.50	7.91	
Conductivity (uS/cm 25C)			30.7			12.9%			-0.7			-0.3%			238.6
Total N (ugN/L)			121.6			15.0%			-31.1			-3.8%			812.1
Organic N (ugN/L)			38.9			32.0%			+10.7			+8.8%			121.4
Ammonium N (ugN/L)			4.5			59.5%			+1.0			+13.7%			7.6
Nitrate + nitrite N (ugN/L)			93.8			13.7%			-23.4			-3.4%			683.5
Total P (ugP/L)			3.6			22.8%			-0.11			-0.7%			15.7
Organic P (ugP/L)			3.2			63.6%			+0.58			+11.6%			5.0
Inorganic P (ugP/L)			1.8			16.5%			-0.69			-6.4%			10.7
Total organic C (mgC/L)			0.24			14.6%			+0.15			+8.9%			1.7
Dissolved organic C (mgC/L)			0.24			16.1%			-0.02			-1.6%			1.5
Detritus (mgD/L)			0.62			117.8%			+0.4			+73.3%			0.5
Alkalinity ($mgCaCO_3/L$)			20.6			18.3%			-6.8			-6.0%			112.4
Periphyton biomass (mg Chl a/m^2)			47.8			106.0%			+27.6			+61.2%			45.1

$$RMSE = \sqrt{\frac{\Sigma(T_{modeled} - T_{observed})^2}{n}}$$

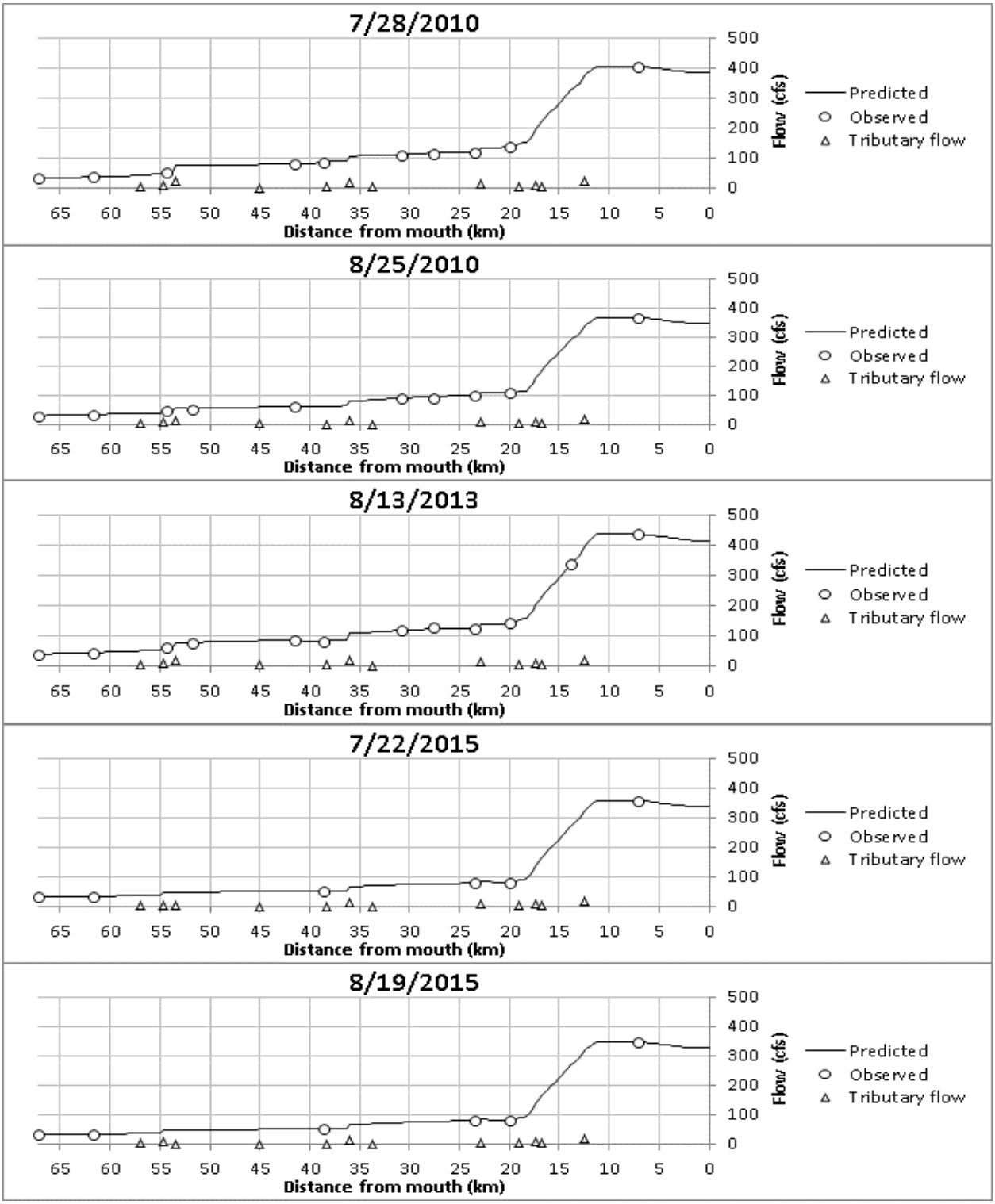
$$RMSE\ CV = \frac{RMSE}{Avg\ obs\ value}$$

$$Bias = \frac{\sum(T_{modeled} - T_{observed})}{n}$$

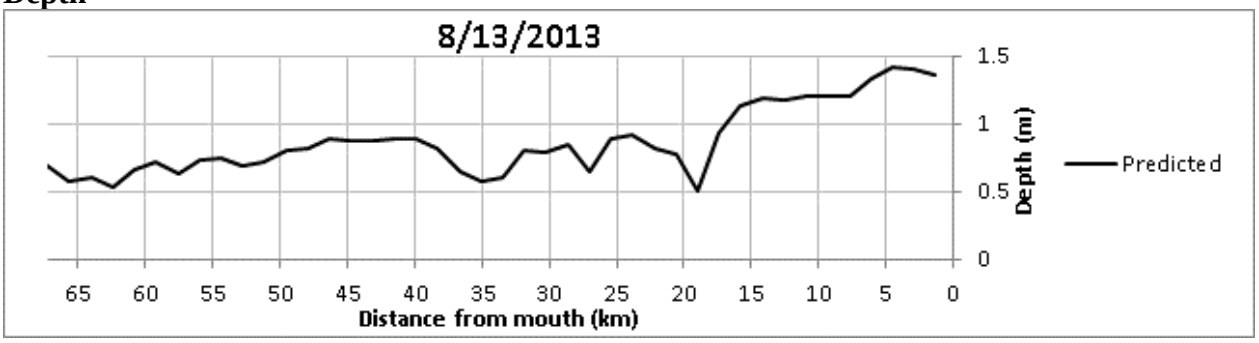
$$Bias\ \% = \frac{Bias}{Avg\ obs\ value}$$

Figure G-2. Longitudinal and (where applicable) diel plots of modeled vs. observed values for all key parameters.
(This figure includes all plots in the next 32 pages.)

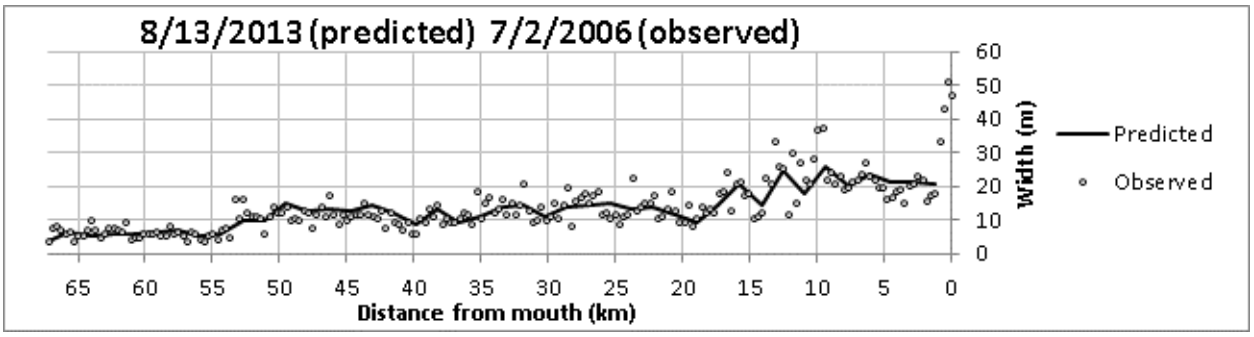
Streamflow



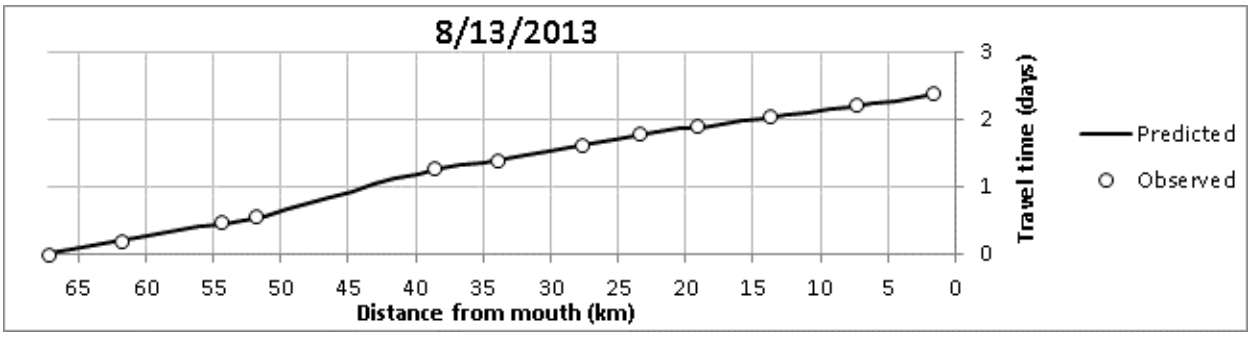
Depth



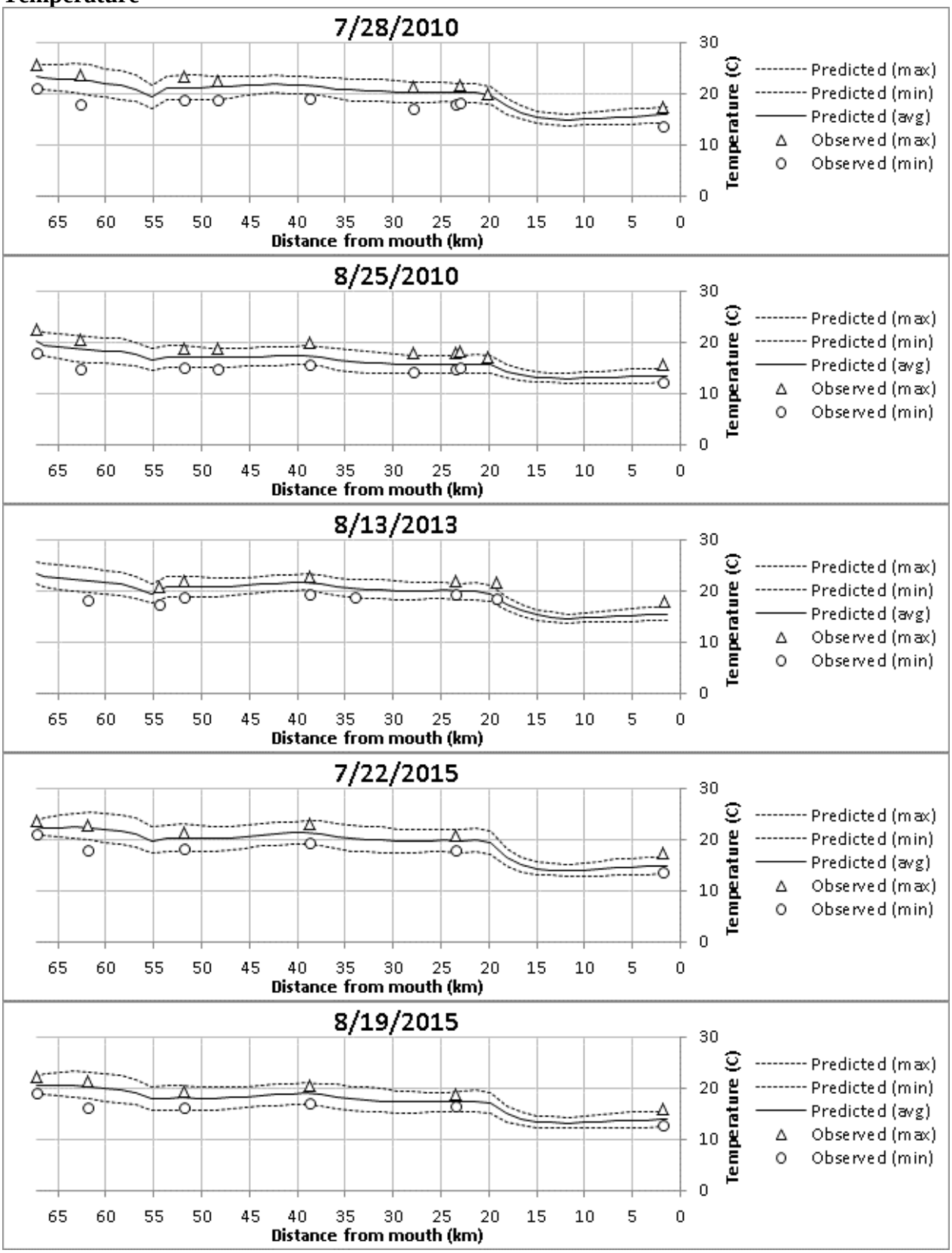
Width



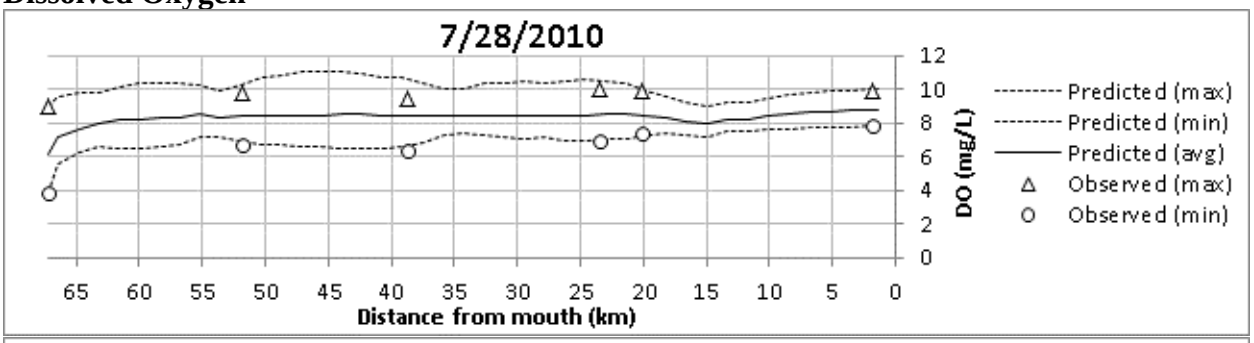
Time of Travel

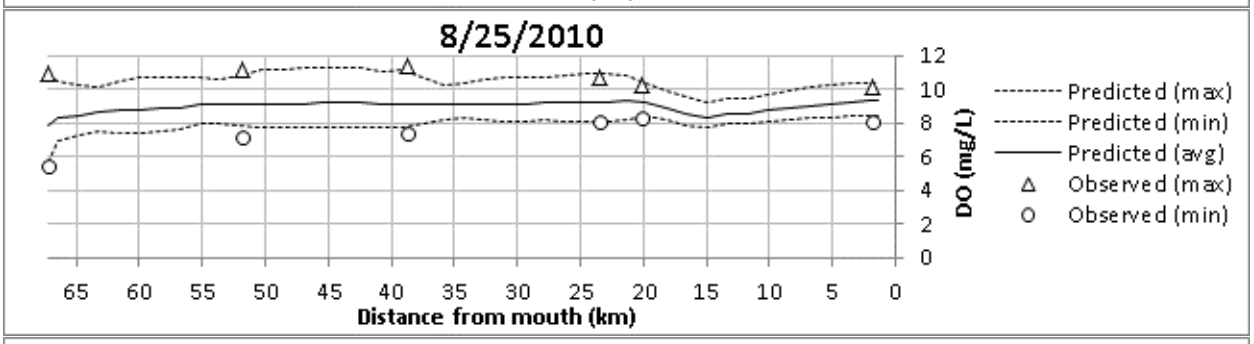


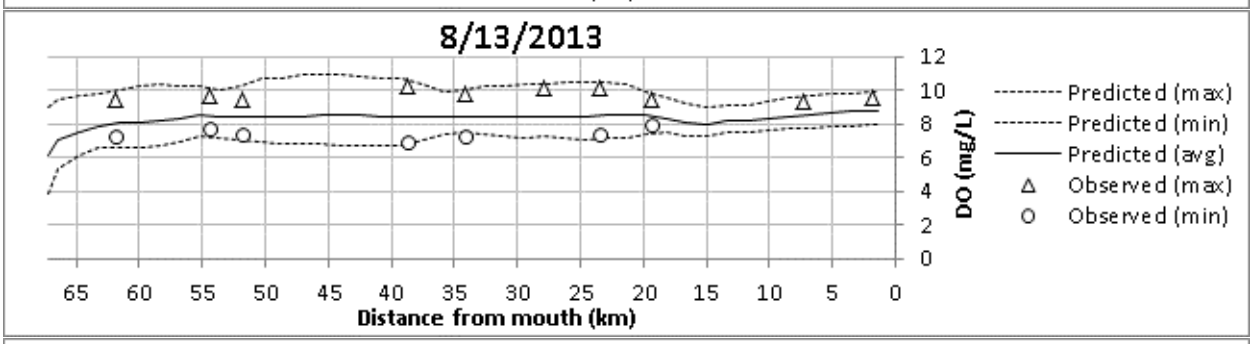
Temperature

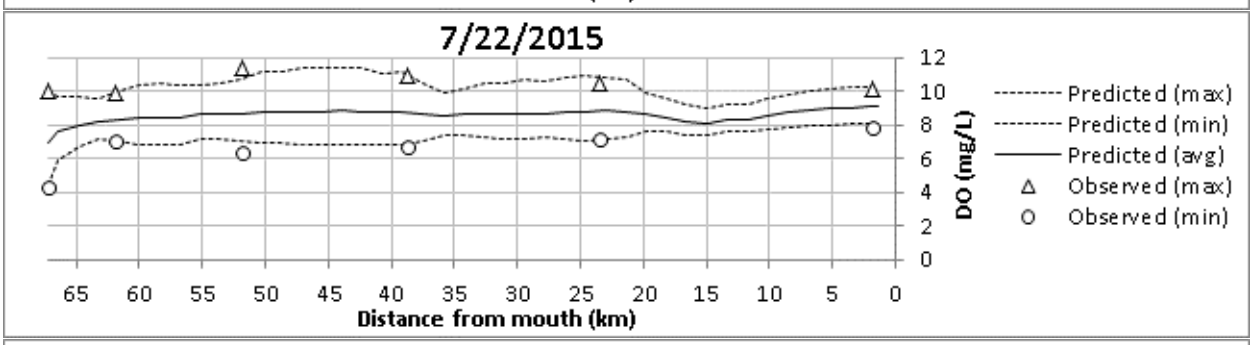


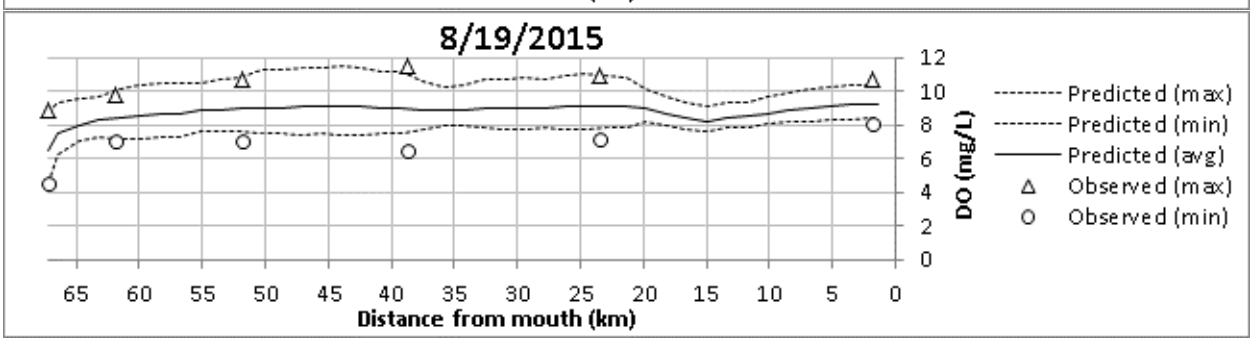
Dissolved Oxygen



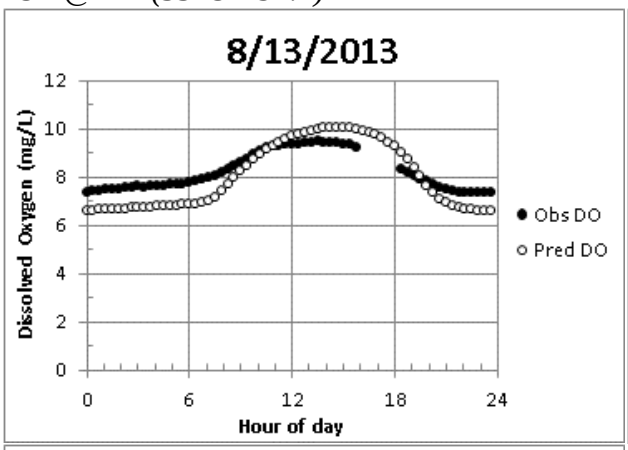


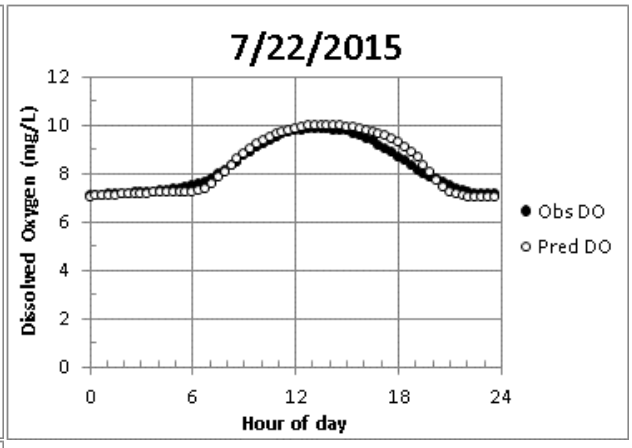


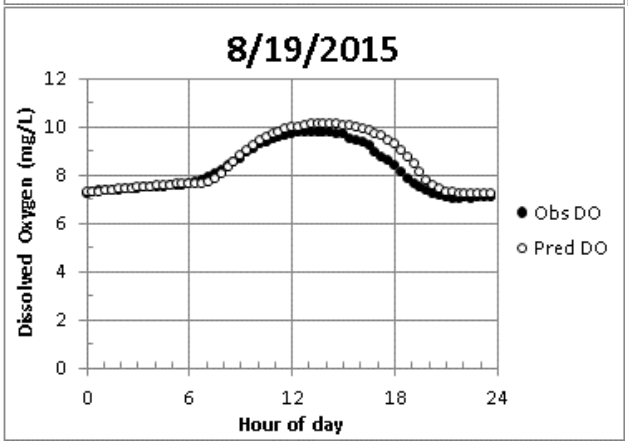




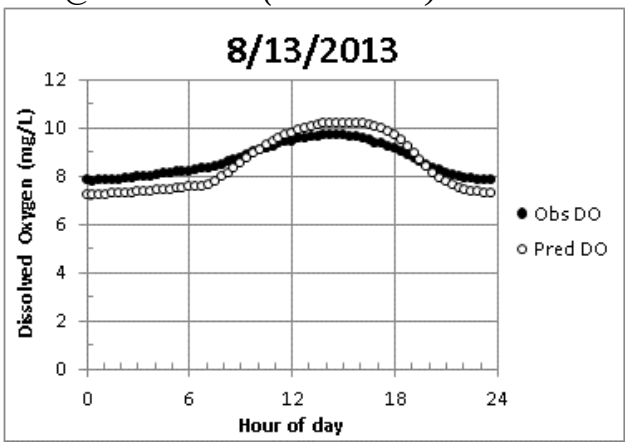
LSR @ Elk (55LSR-37.1)



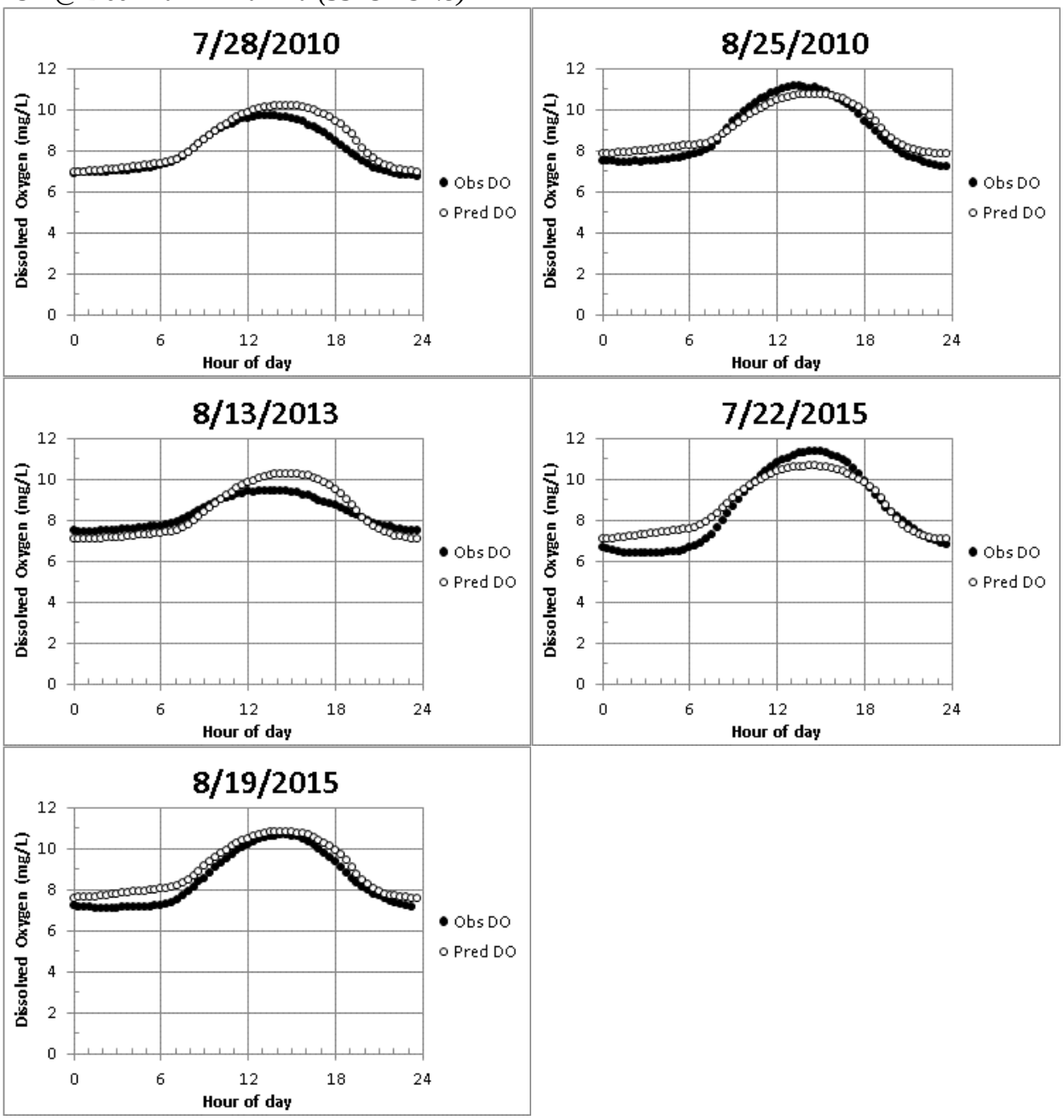




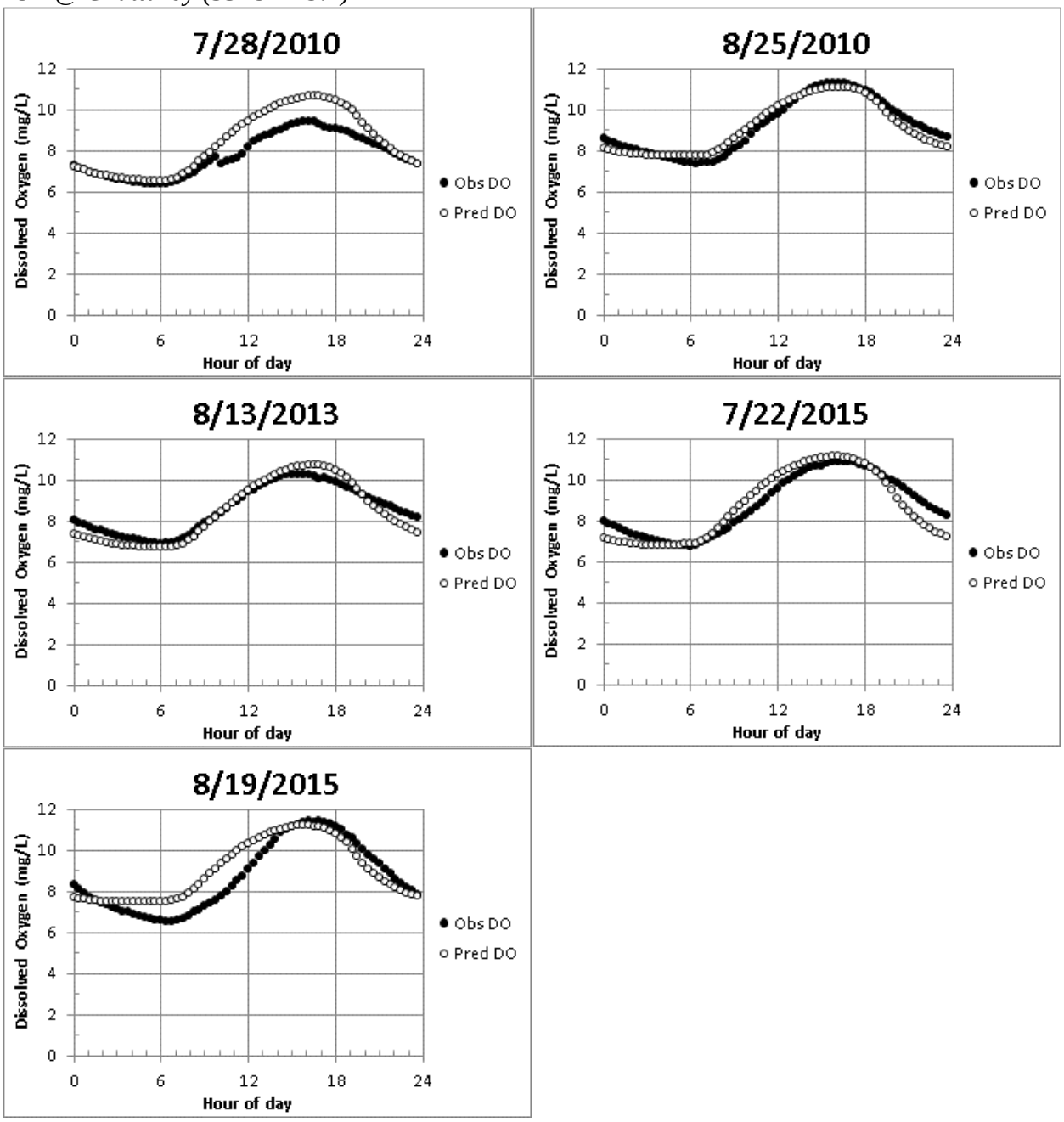
LSR @ E Eloika Rd (55LSR-33.2)



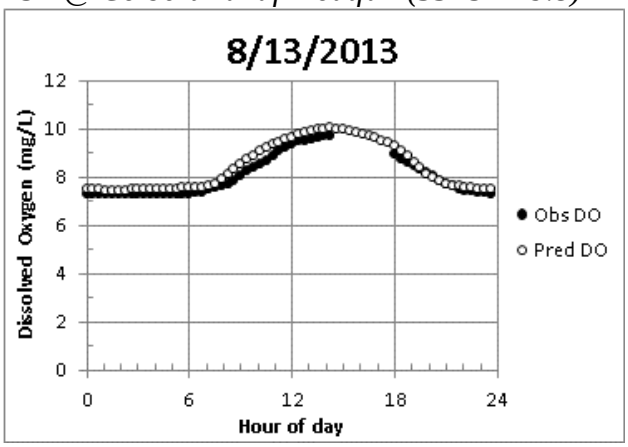
LSR @ Deer Park-Milan Rd (55LSR-31.8)



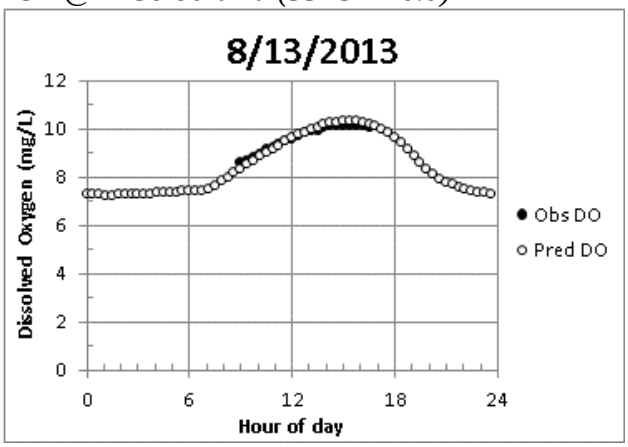
LSR @ Chattaroy (55LSR-23.4)



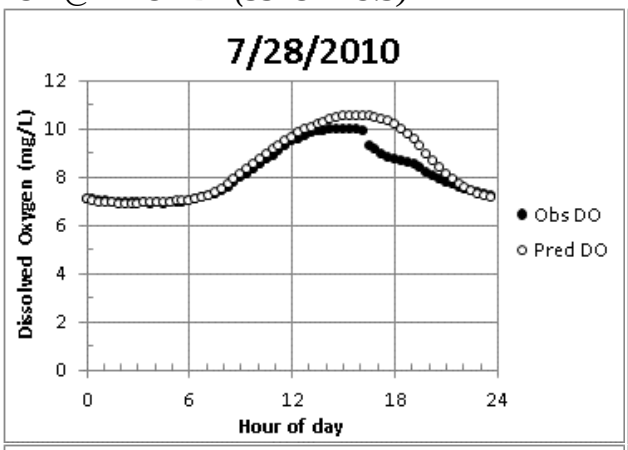
LSR @ Colbert Landfill outfall (55LSR-19.8)

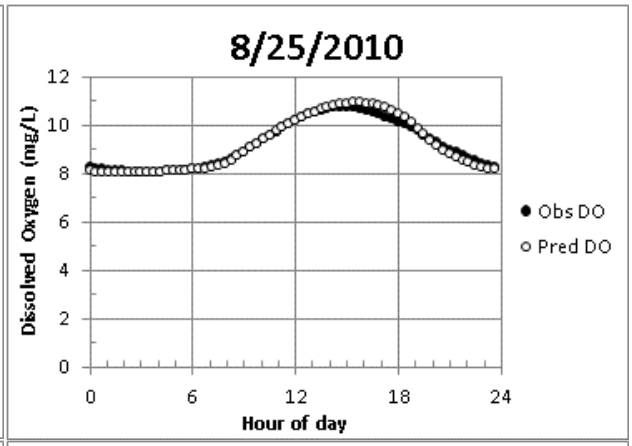


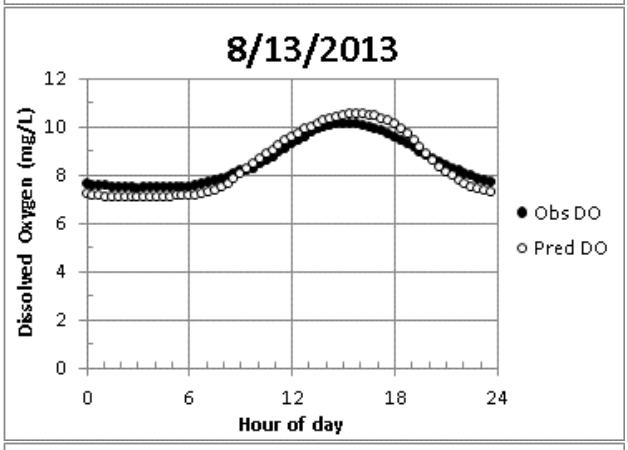
LSR @ E Colbert Rd (55LSR-16.0)

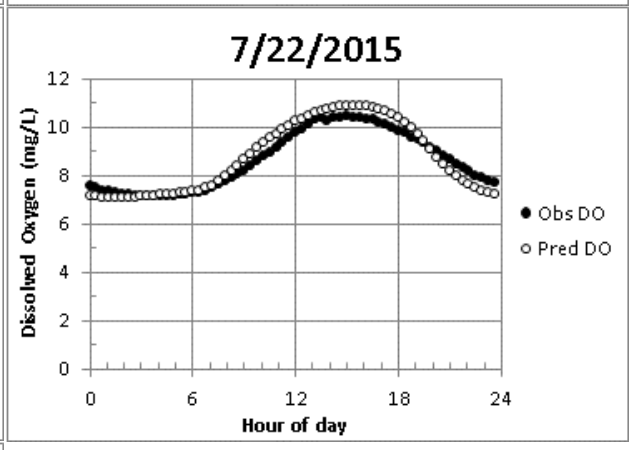


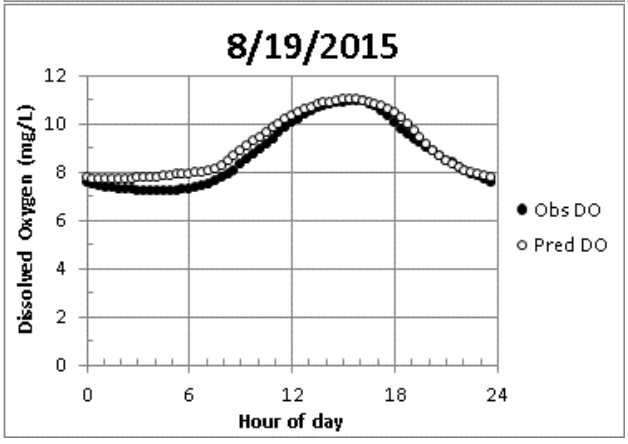
LSR @ N LSR Dr (55LSR-13.5)



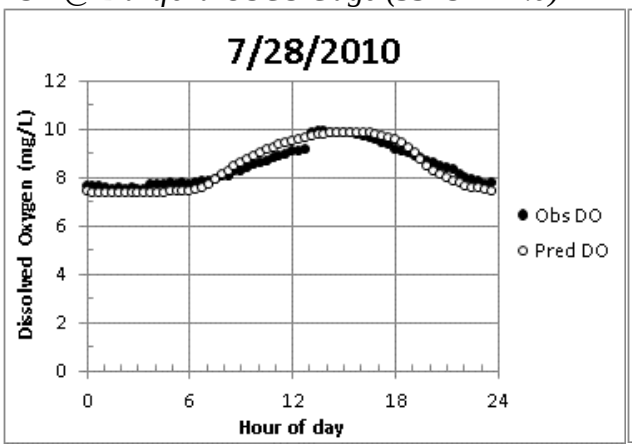


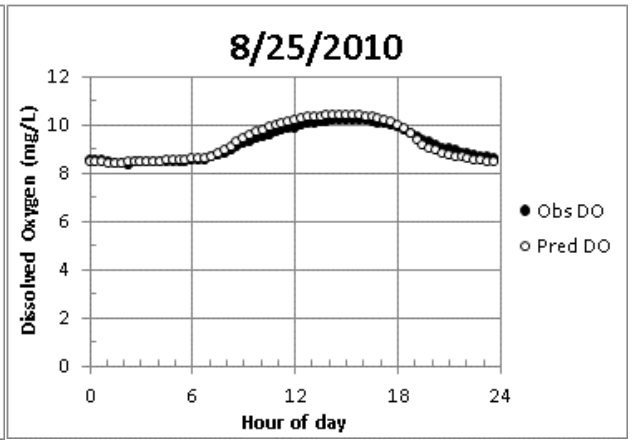




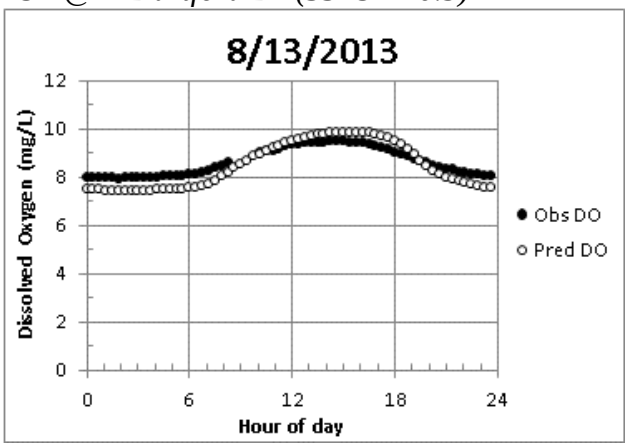


LSR @ Dartford USGS Gage (55LSR-11.0)

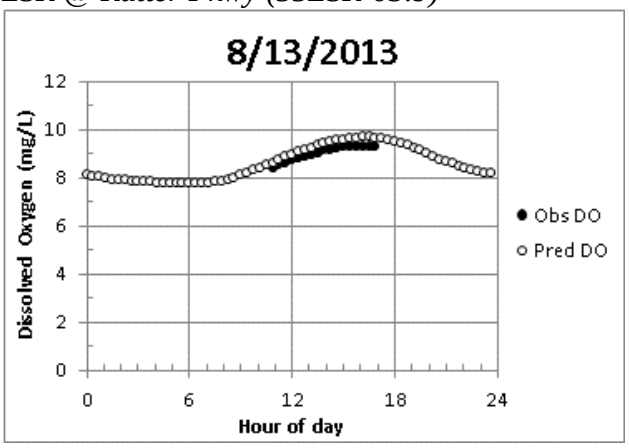




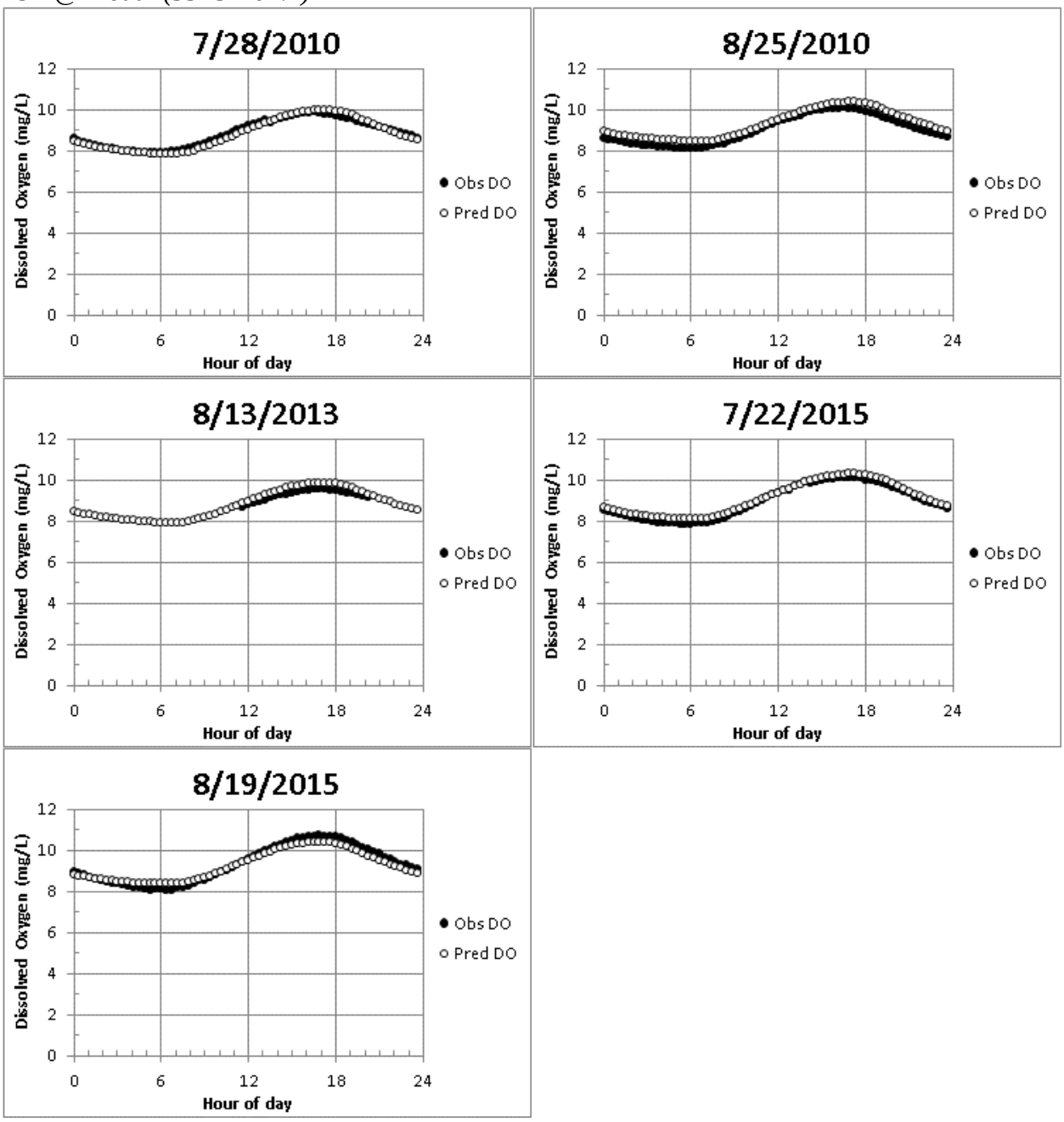
LSR @ N Dartford Dr (55LSR-10.3)



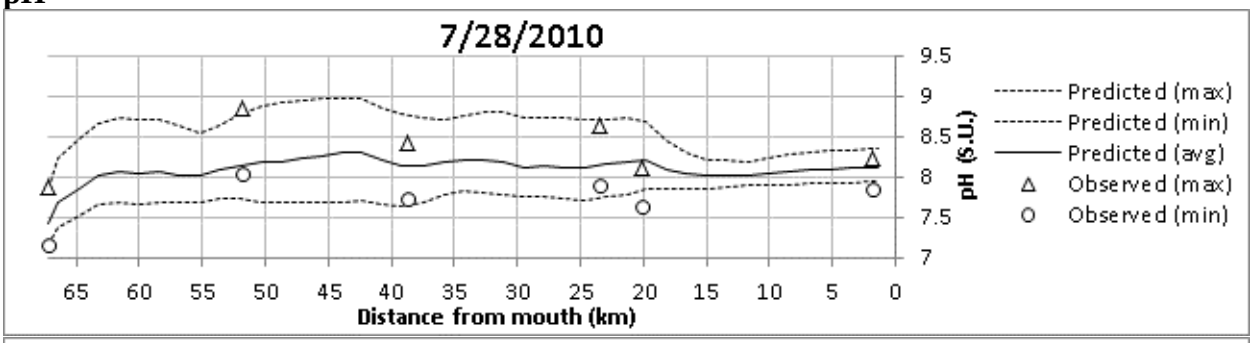
LSR @ Rutter Pkwy (55LSR-03.9)

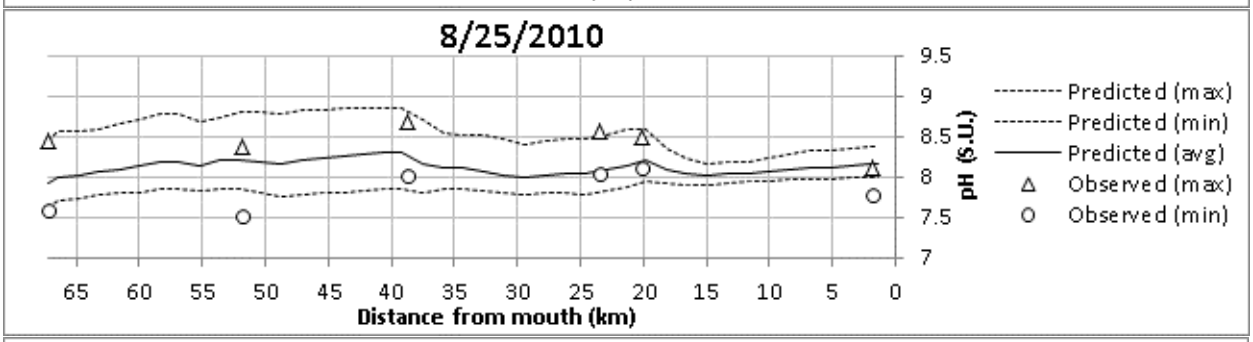


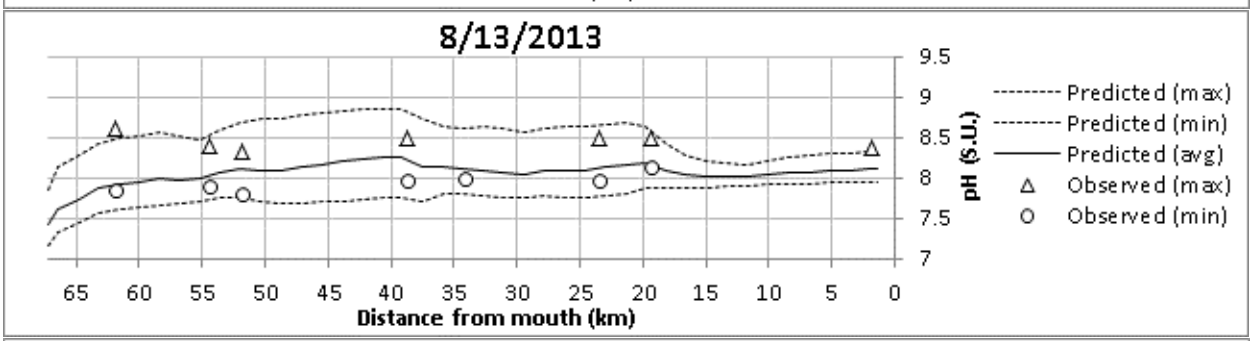
LSR @ Mouth (55LSR-01.1)

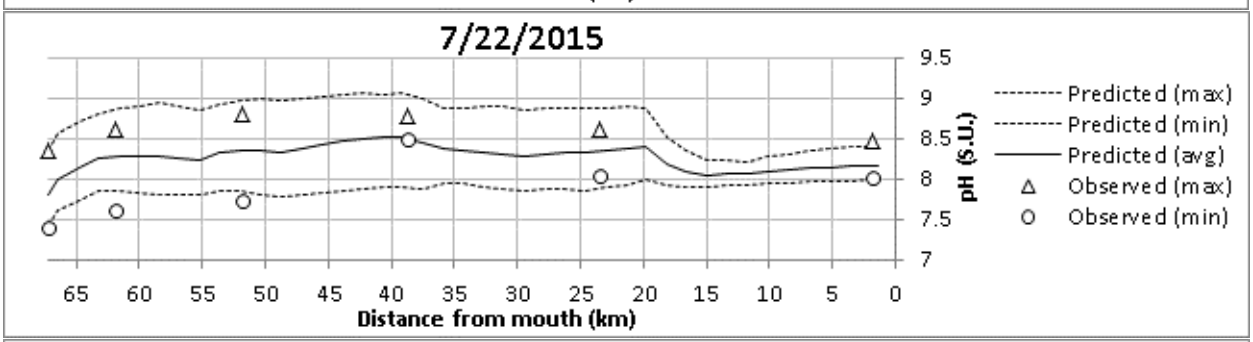


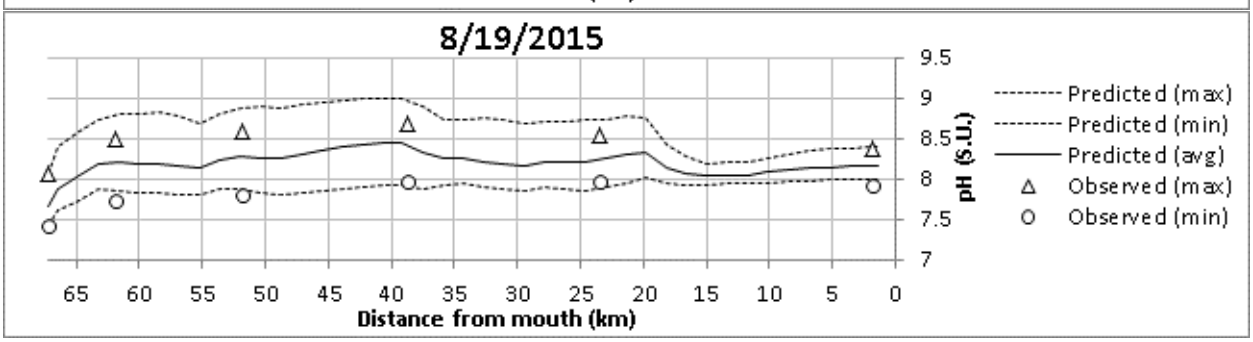
pH


7/28/2010
9.5
9
8.5
8
7.5
7
pH (S.U.)
65 60 55 50 45 40 35 30 25 20 15 10 5 0
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)

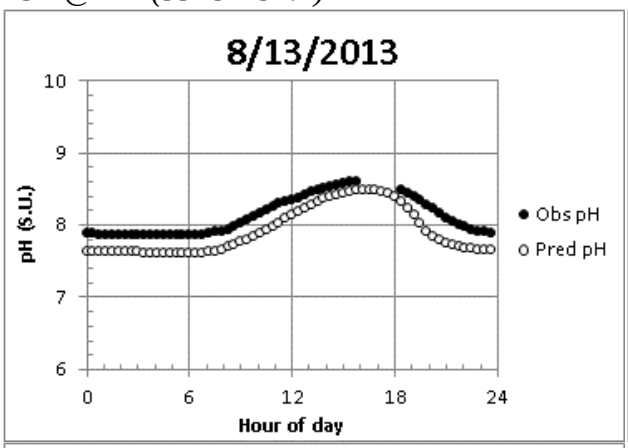

8/25/2010
9.5
9
8.5
8
7.5
7
pH (S.U.)
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Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)

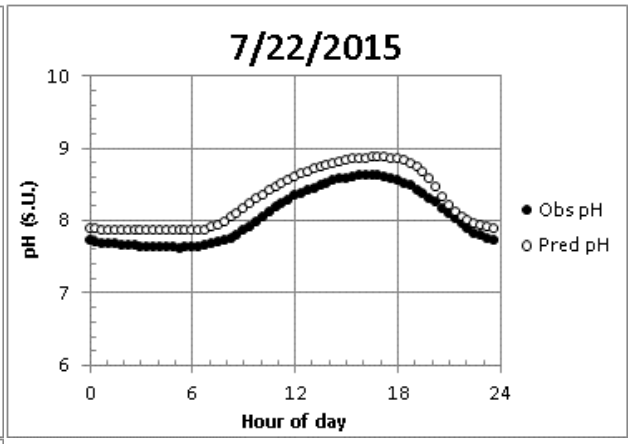

8/13/2013
9.5
9
8.5
8
7.5
7
pH (S.U.)
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Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)

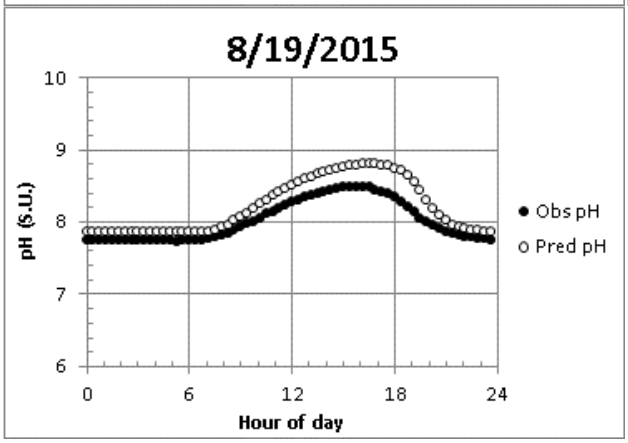

7/22/2015
9.5
9
8.5
8
7.5
7
pH (S.U.)
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Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)


8/19/2015
9.5
9
8.5
8
7.5
7
pH (S.U.)
65 60 55 50 45 40 35 30 25 20 15 10 5 0
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)

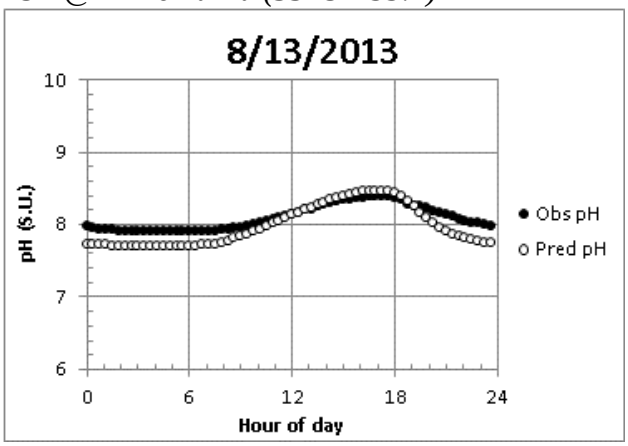
LSR @ Elk (55LSR-37.1)



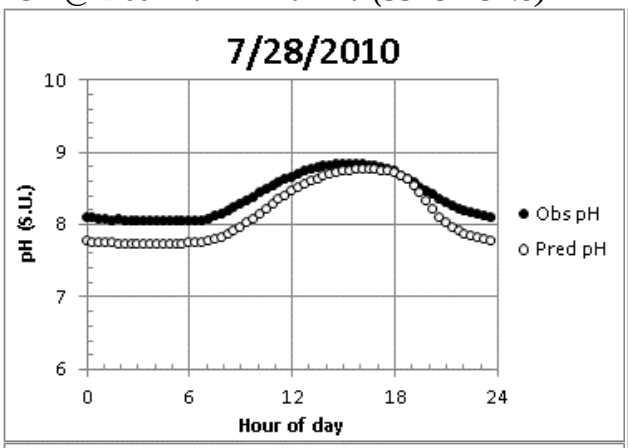


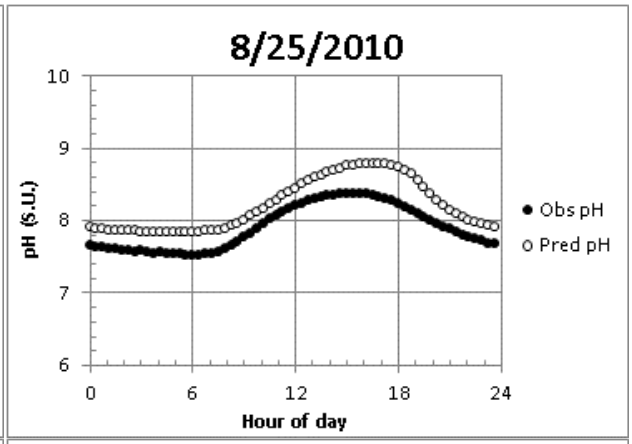


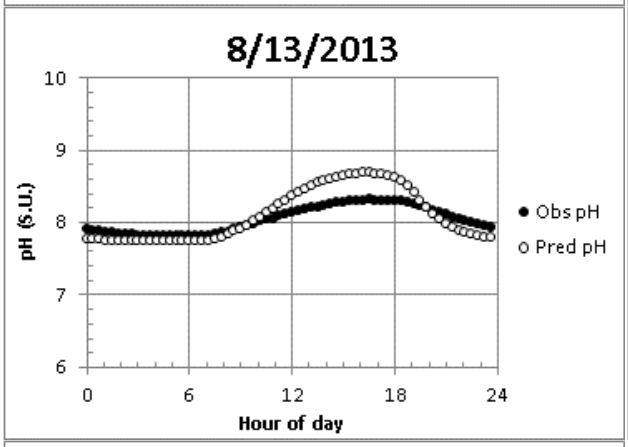
LSR @ E Eloika Rd (55LSR-33.2)

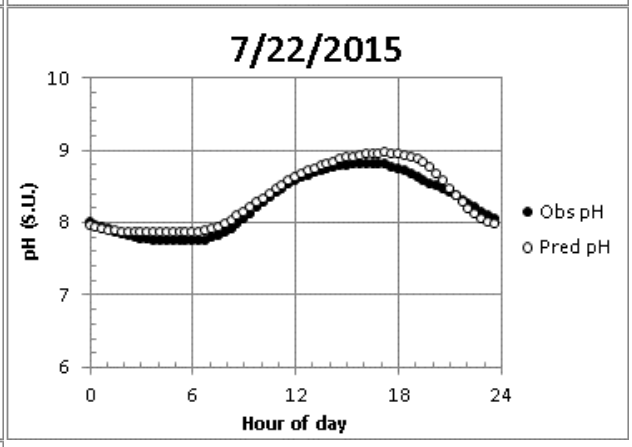


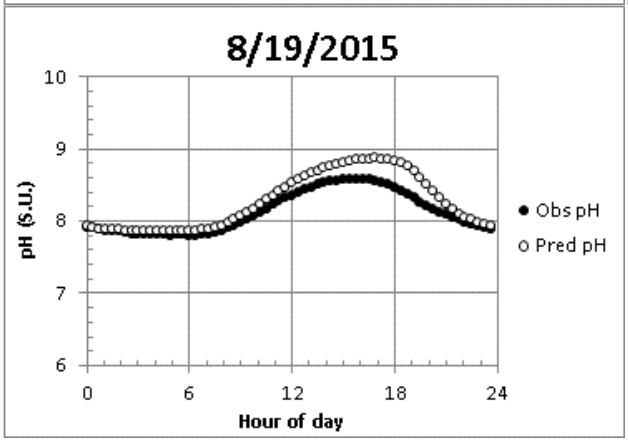
LSR @ Deer Park-Milan Rd (55LSR-31.8)



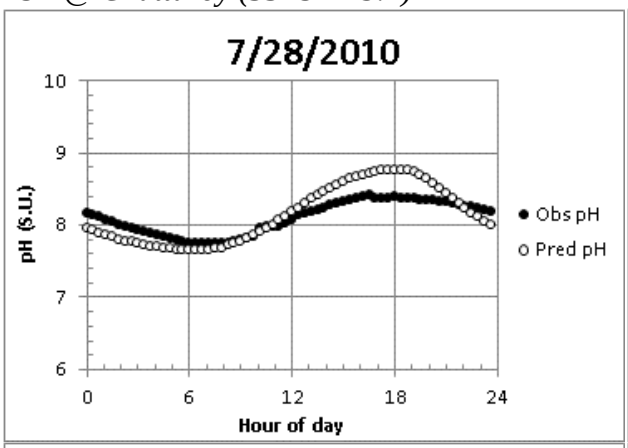


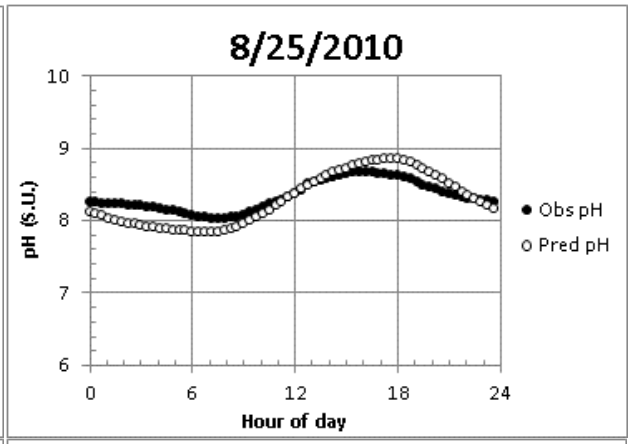


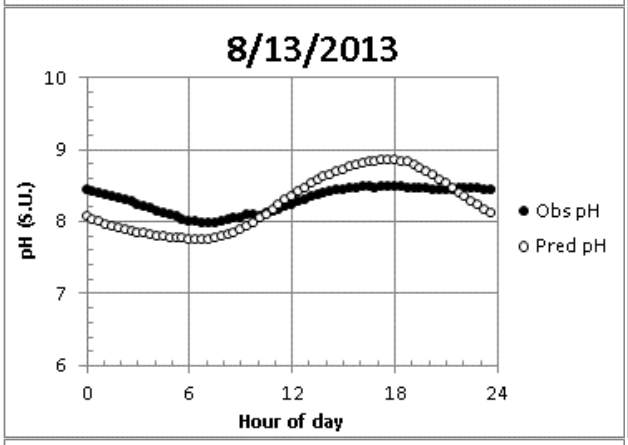


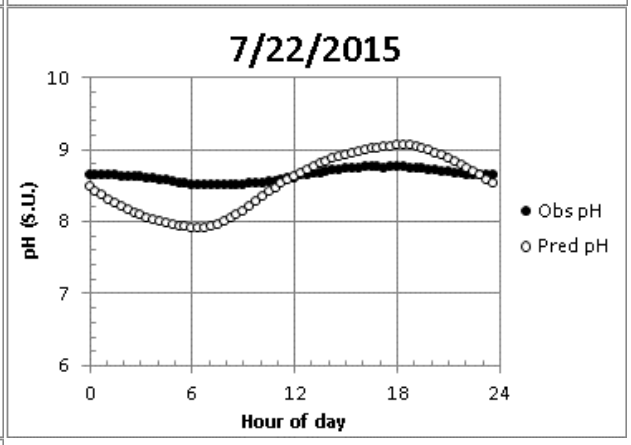


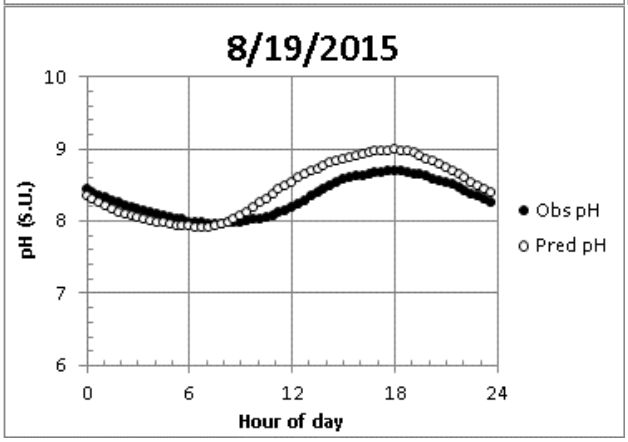
LSR @ Chattaroy (55LSR-23.4)



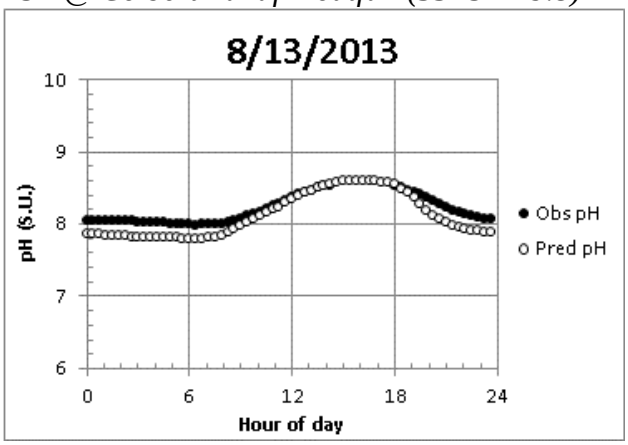




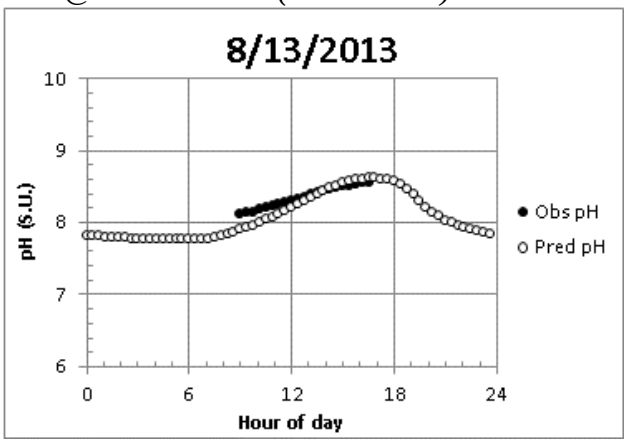




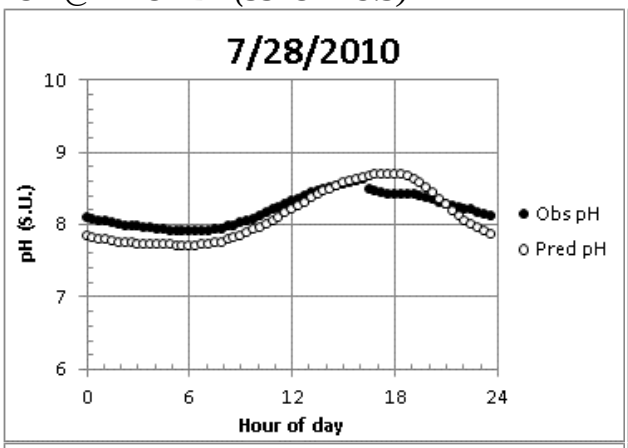
LSR @ Colbert Landfill outfall (55LSR-19.8)

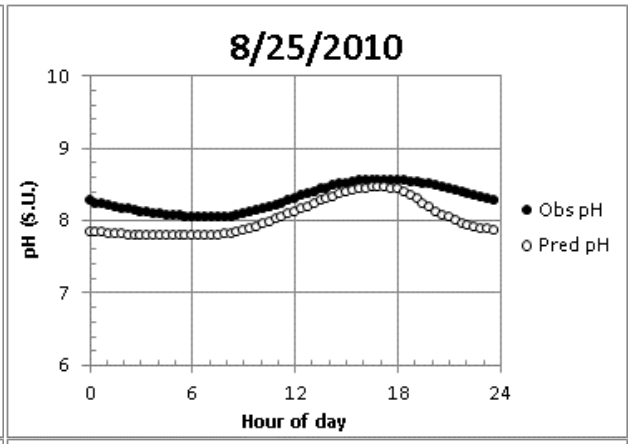


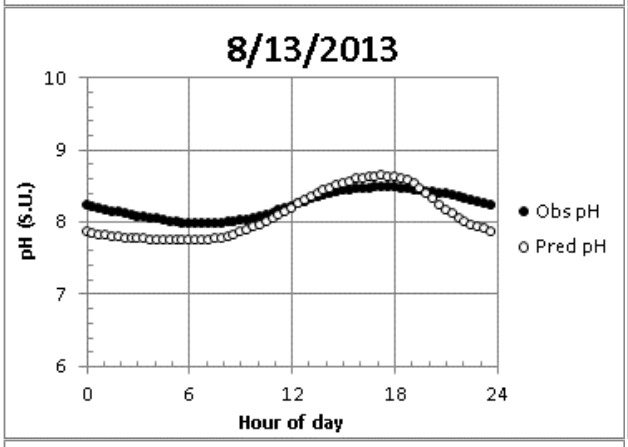
LSR @ E Colbert Rd (55LSR-16.0)

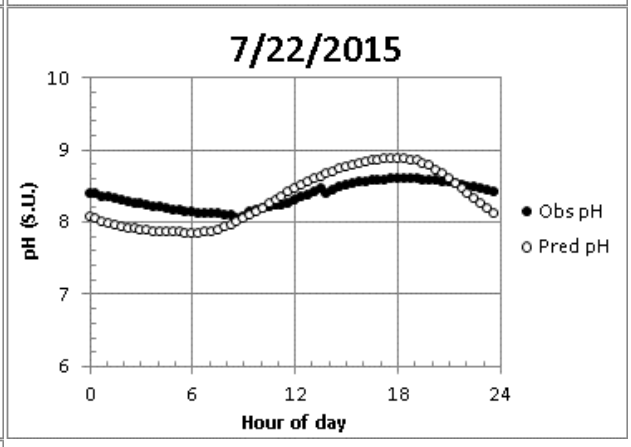


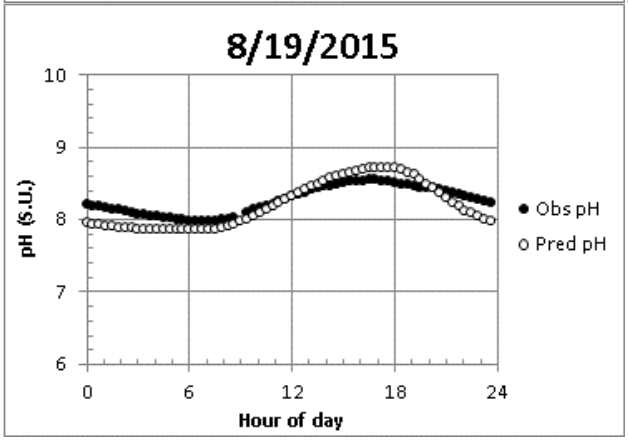
LSR @ N LSR Dr (55LSR-13.5)



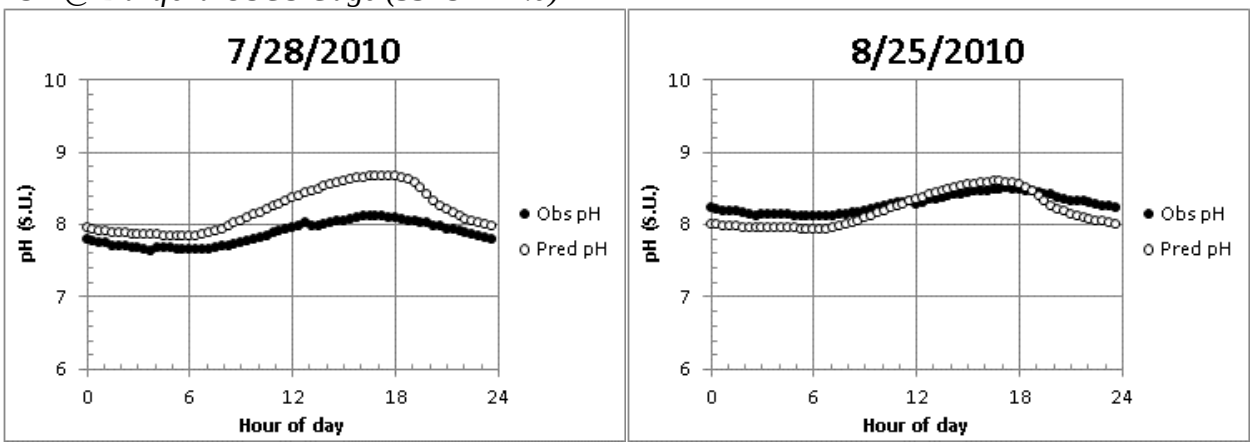




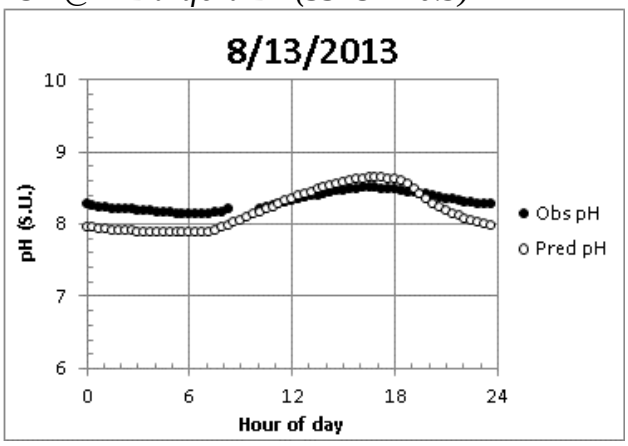




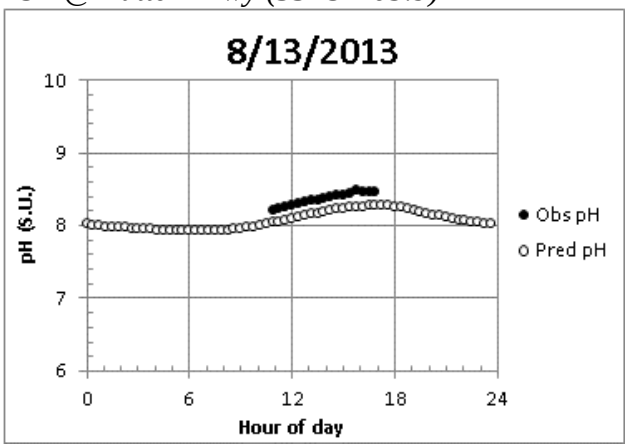
LSR @ Dartford USGS Gage (55LSR-11.0)



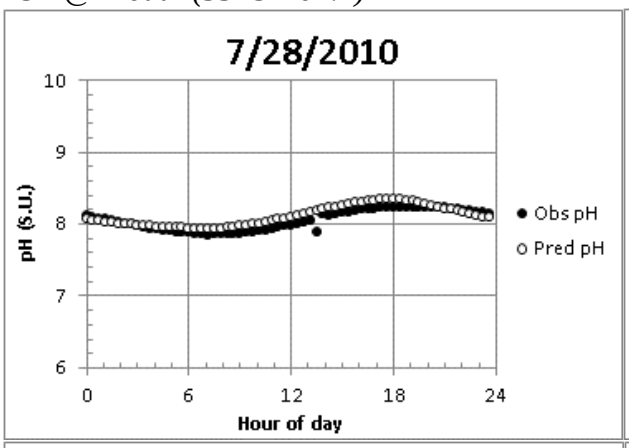
LSR @ N Dartford Dr (55LSR-10.3)

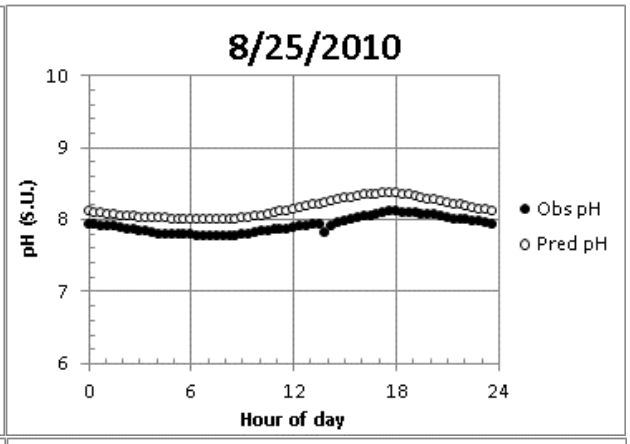


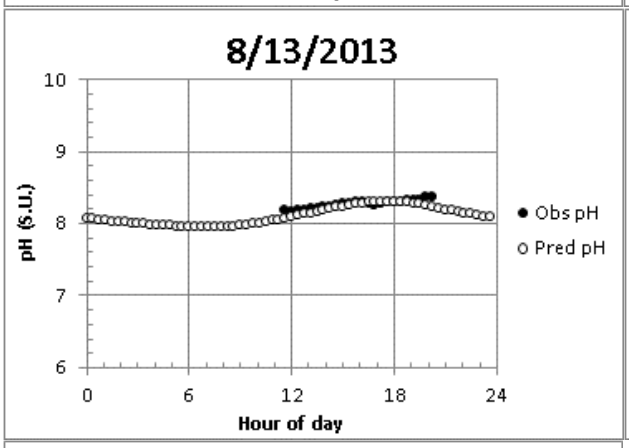
LSR @ Rutter Pkwy (55LSR-03.9)

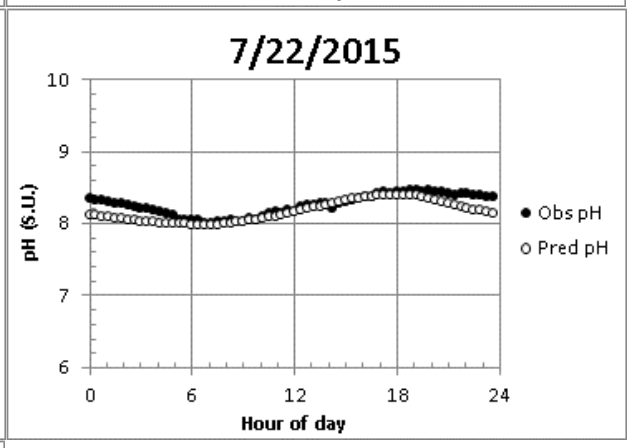


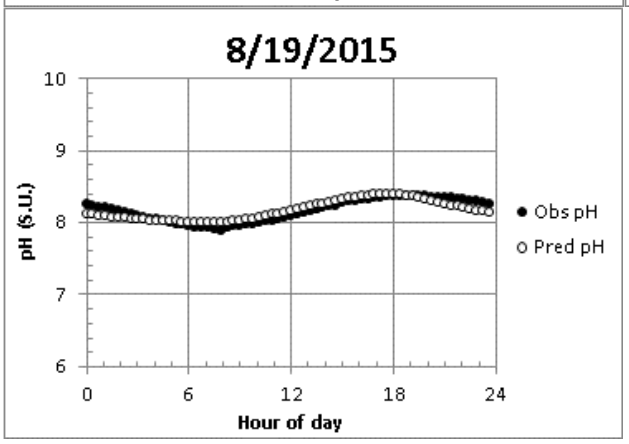
LSR @ Mouth (55LSR-01.1)



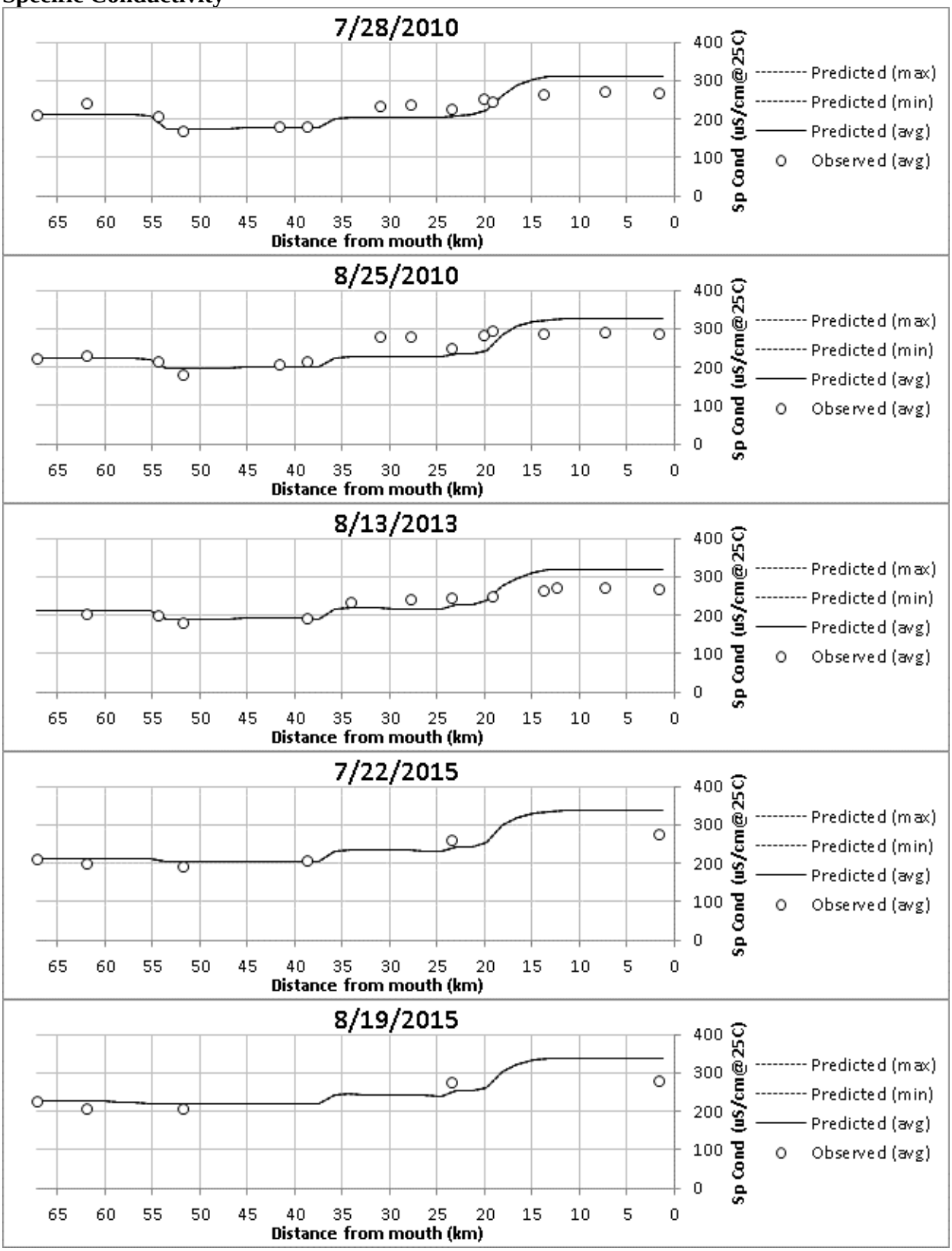




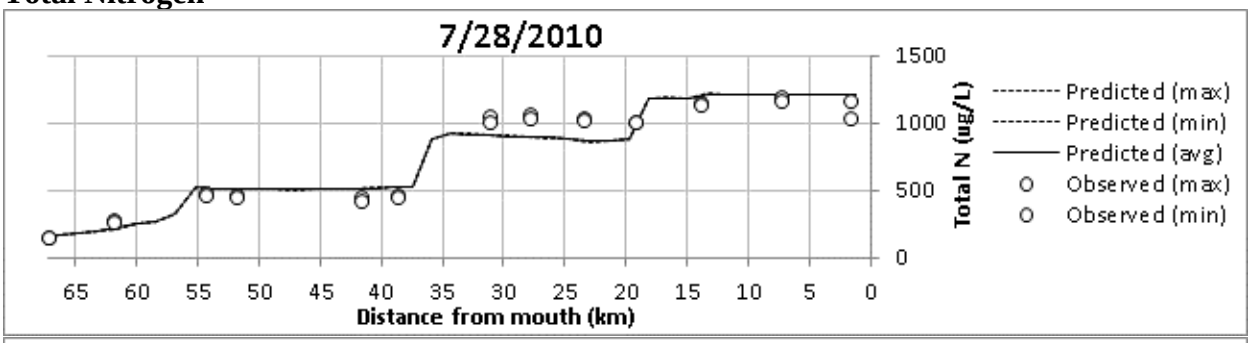


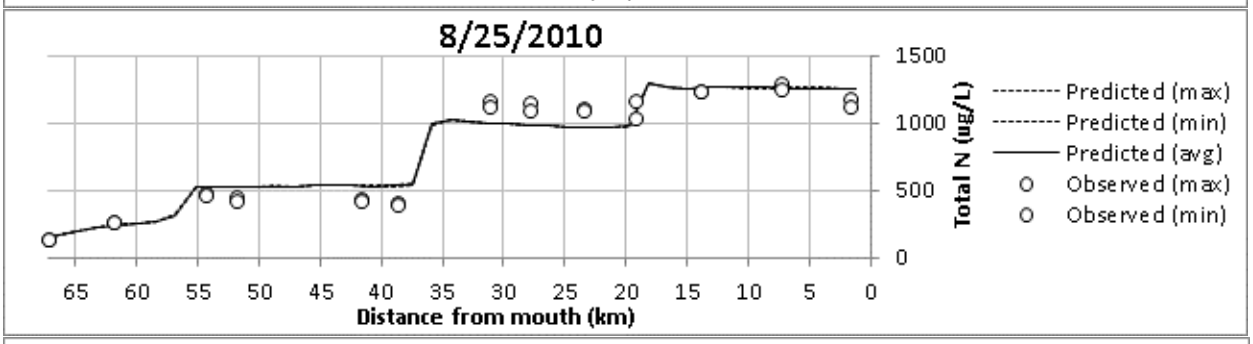


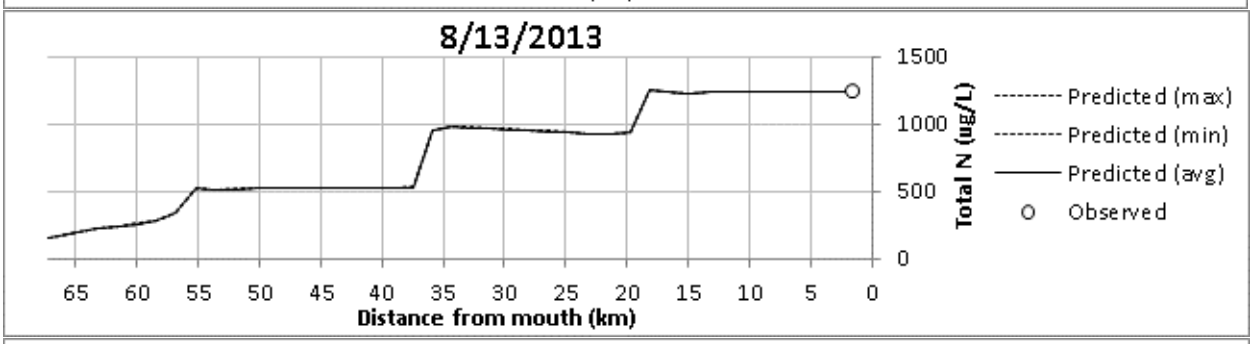
Specific Conductivity

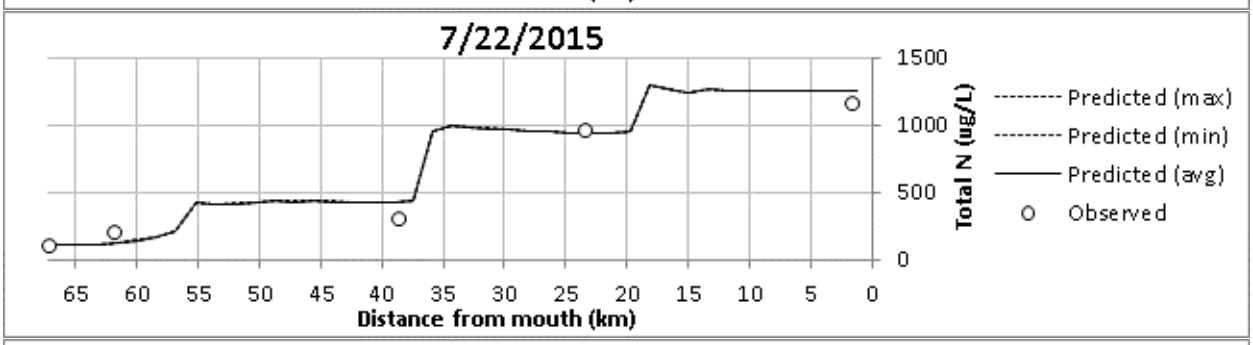


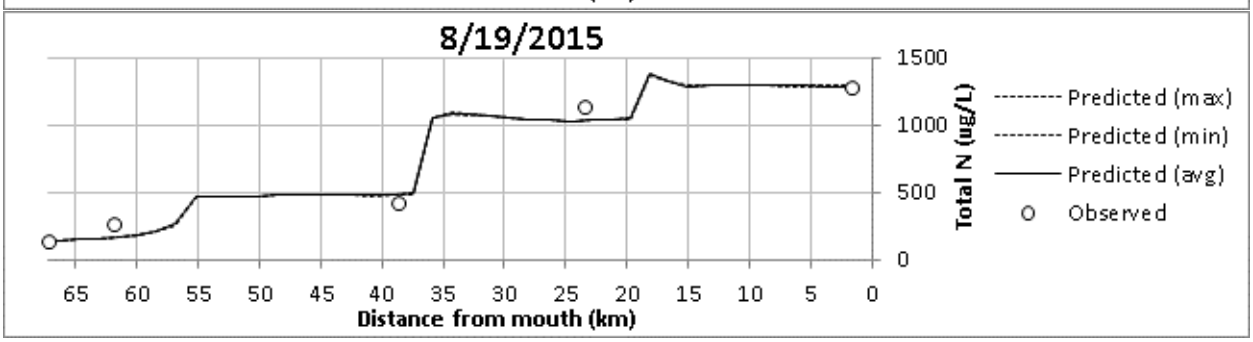
Total Nitrogen



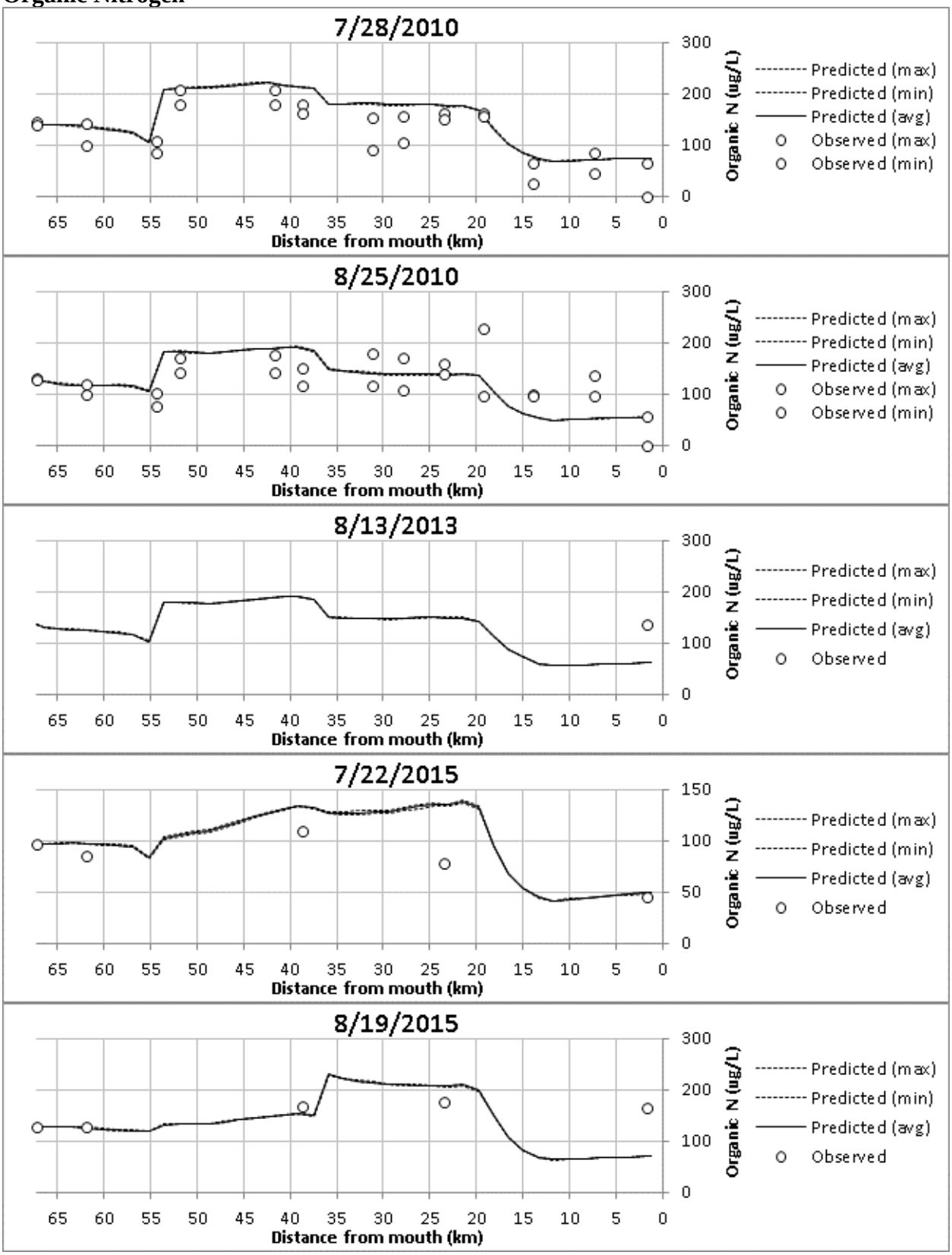




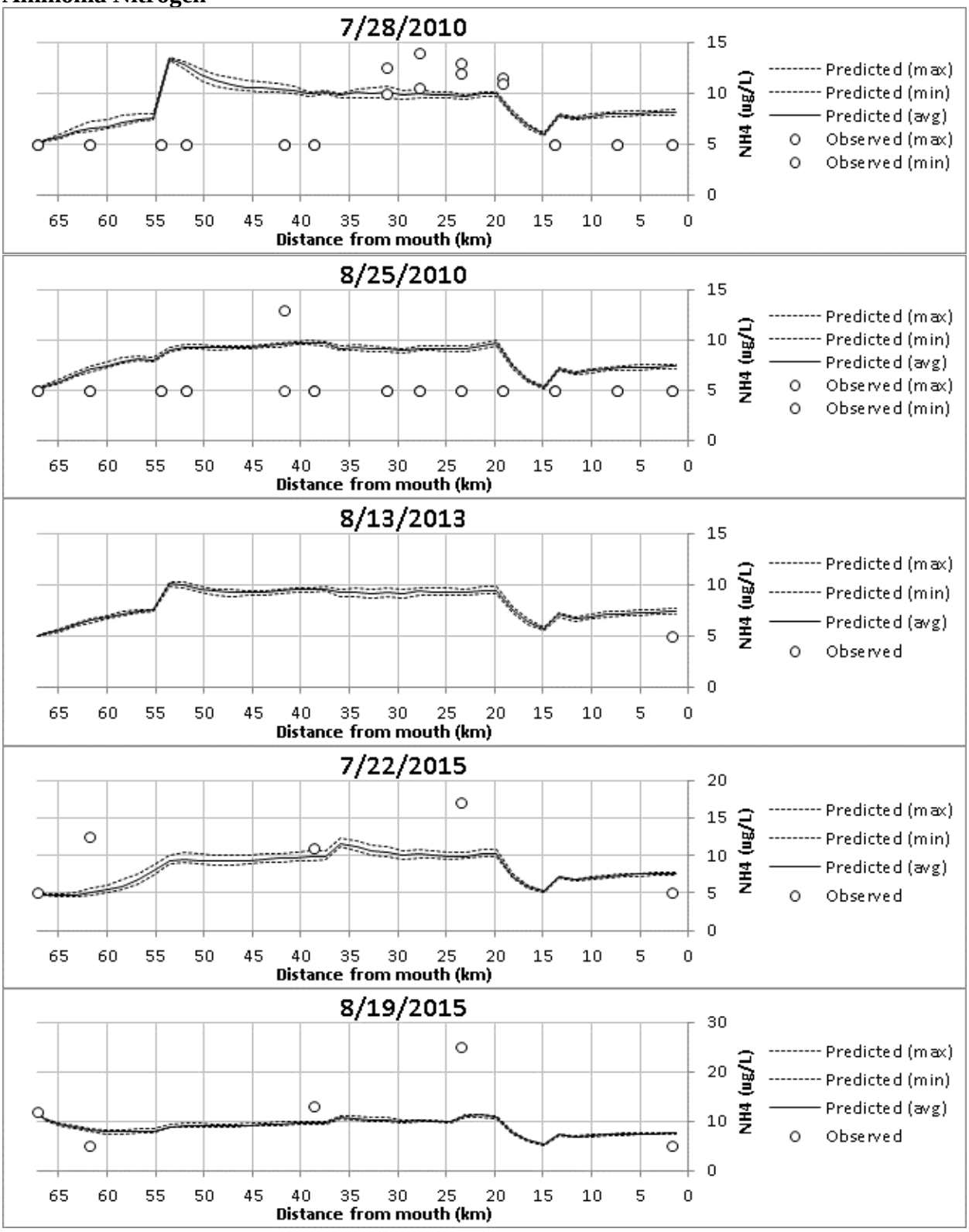




Organic Nitrogen

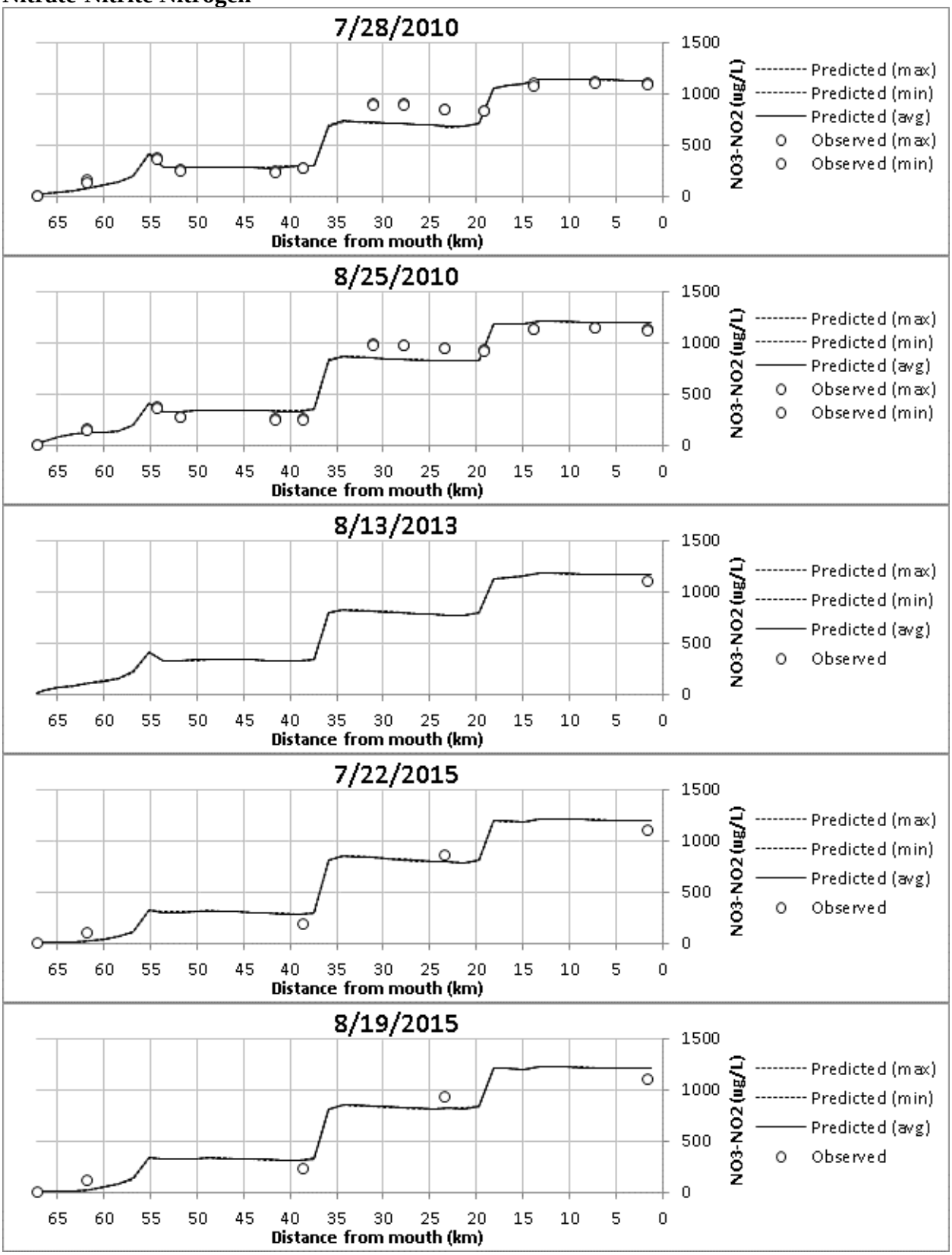


Ammonia Nitrogen[6]

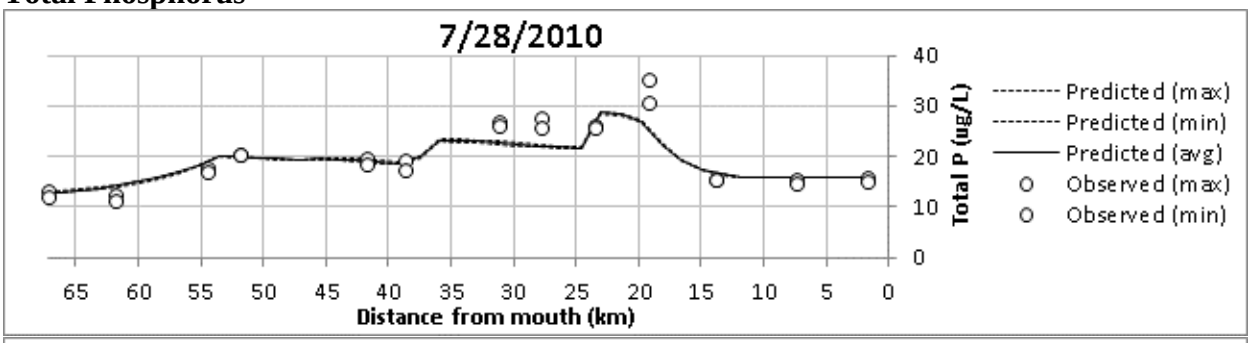


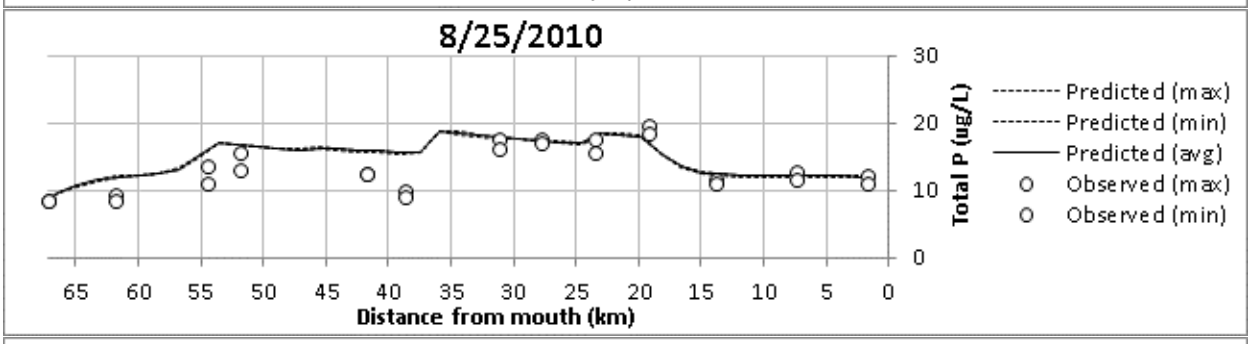
[6] The detection limit for Ammonia is 10 ug/L. On the plots, observed values of 5 ug/L represent non-detects. The actual value could be anything less than 10 ug/L.

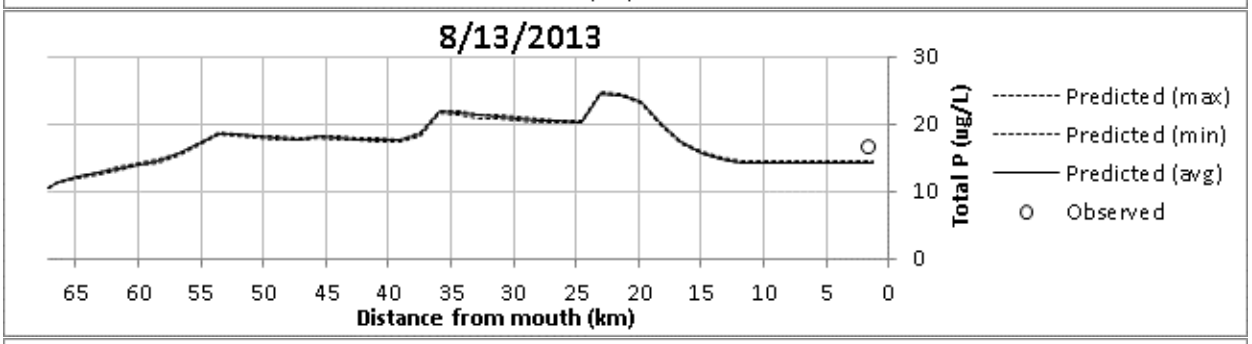
Nitrate-Nitrite Nitrogen

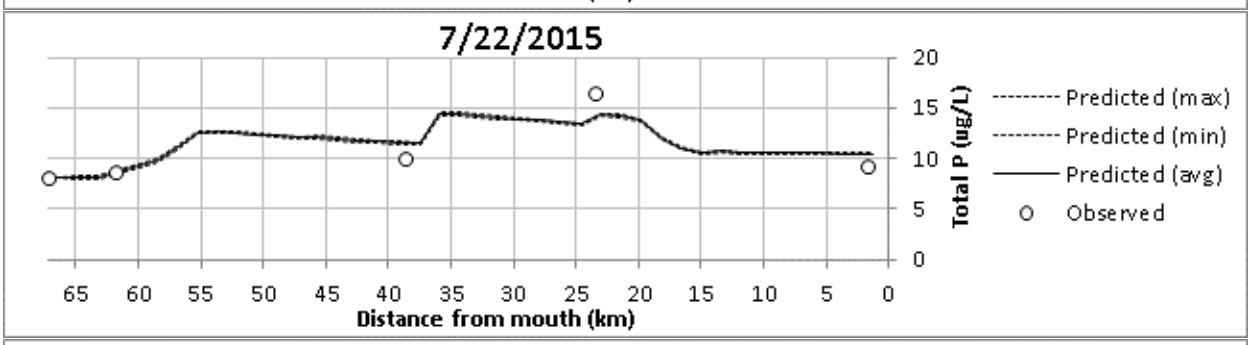


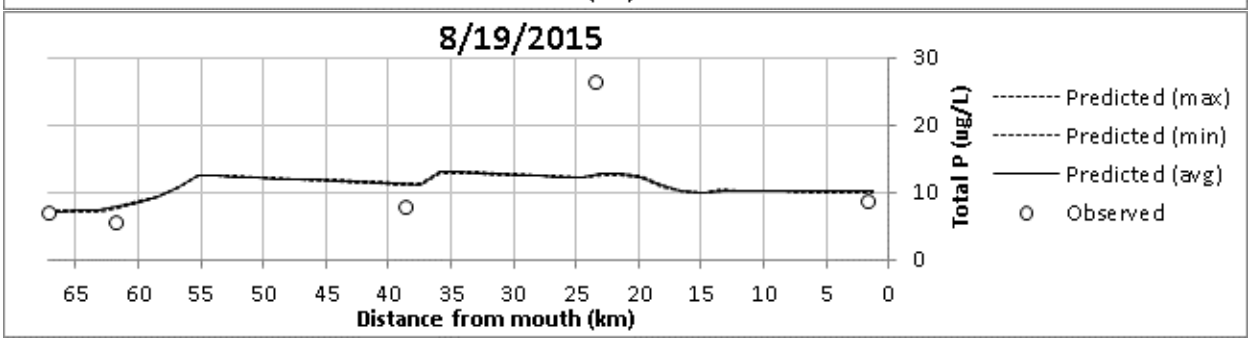
Total Phosphorus



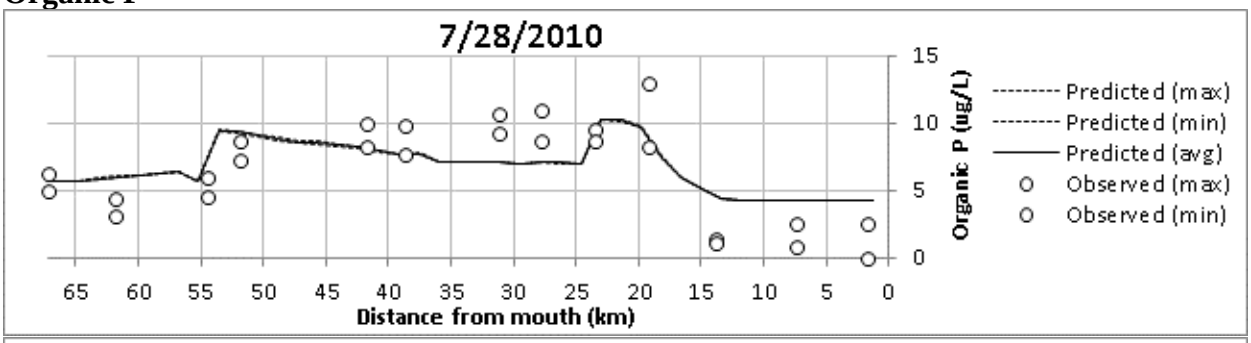


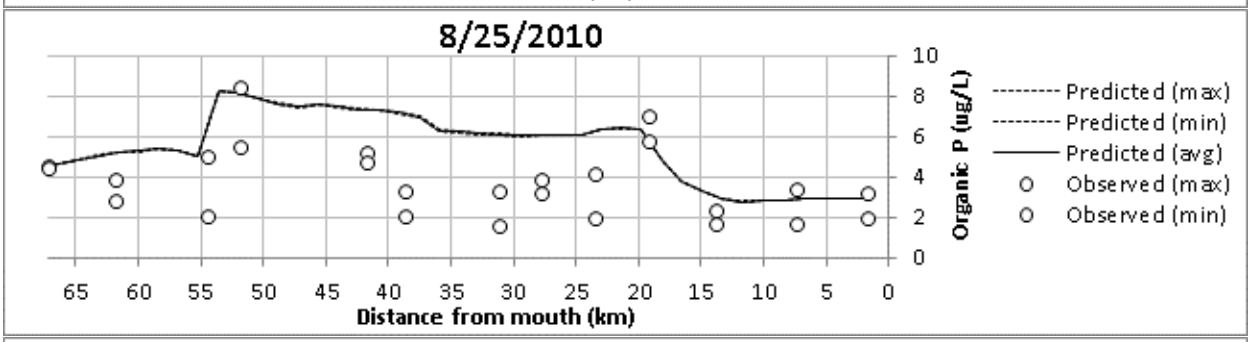


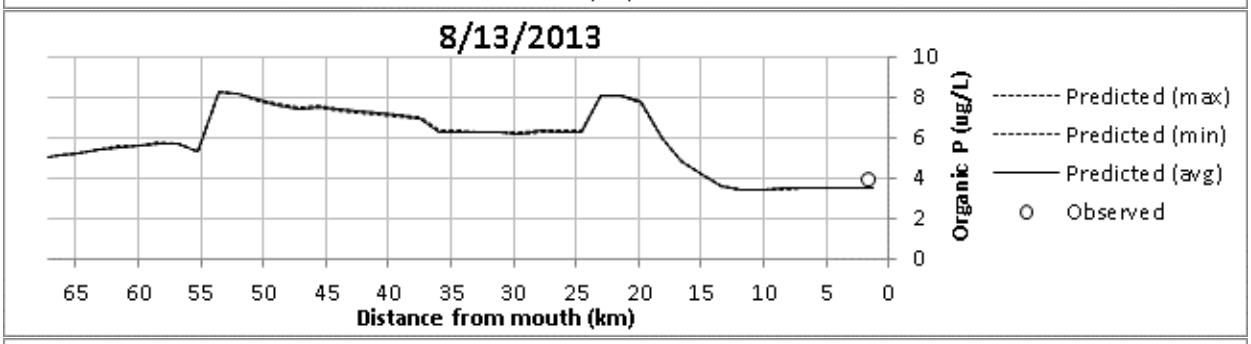


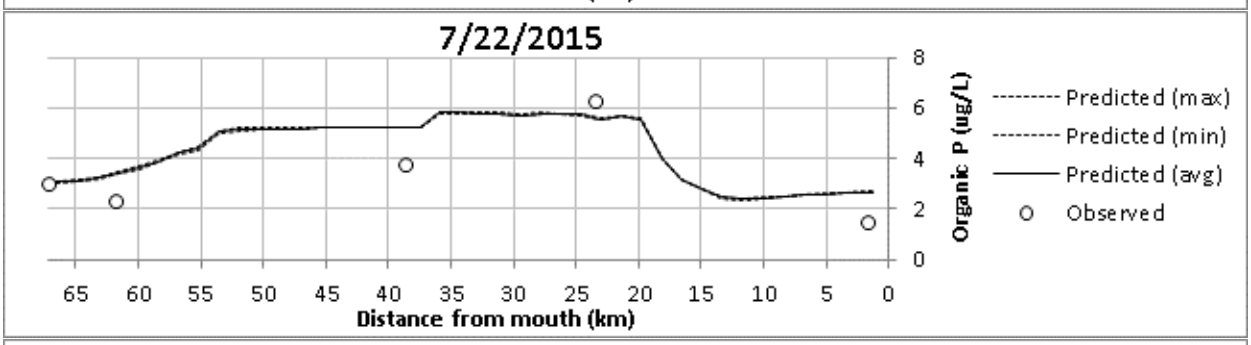


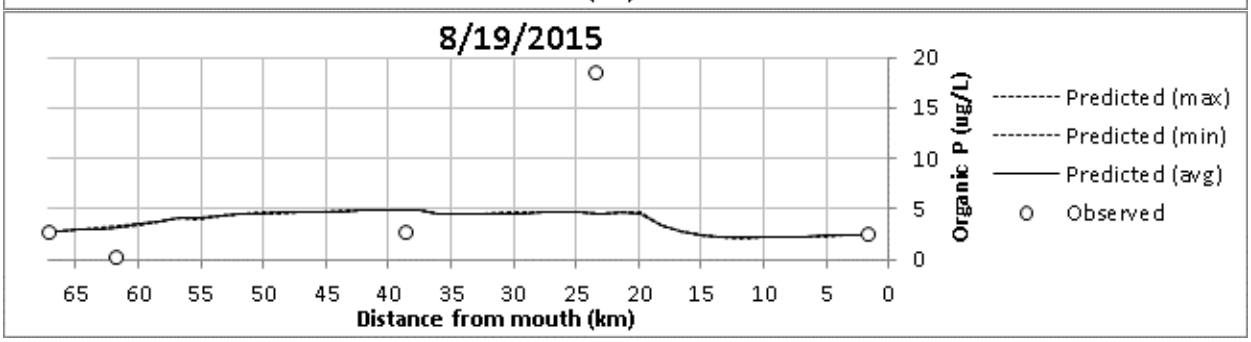
Organic P


7/28/2010
Organic P (ug/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)

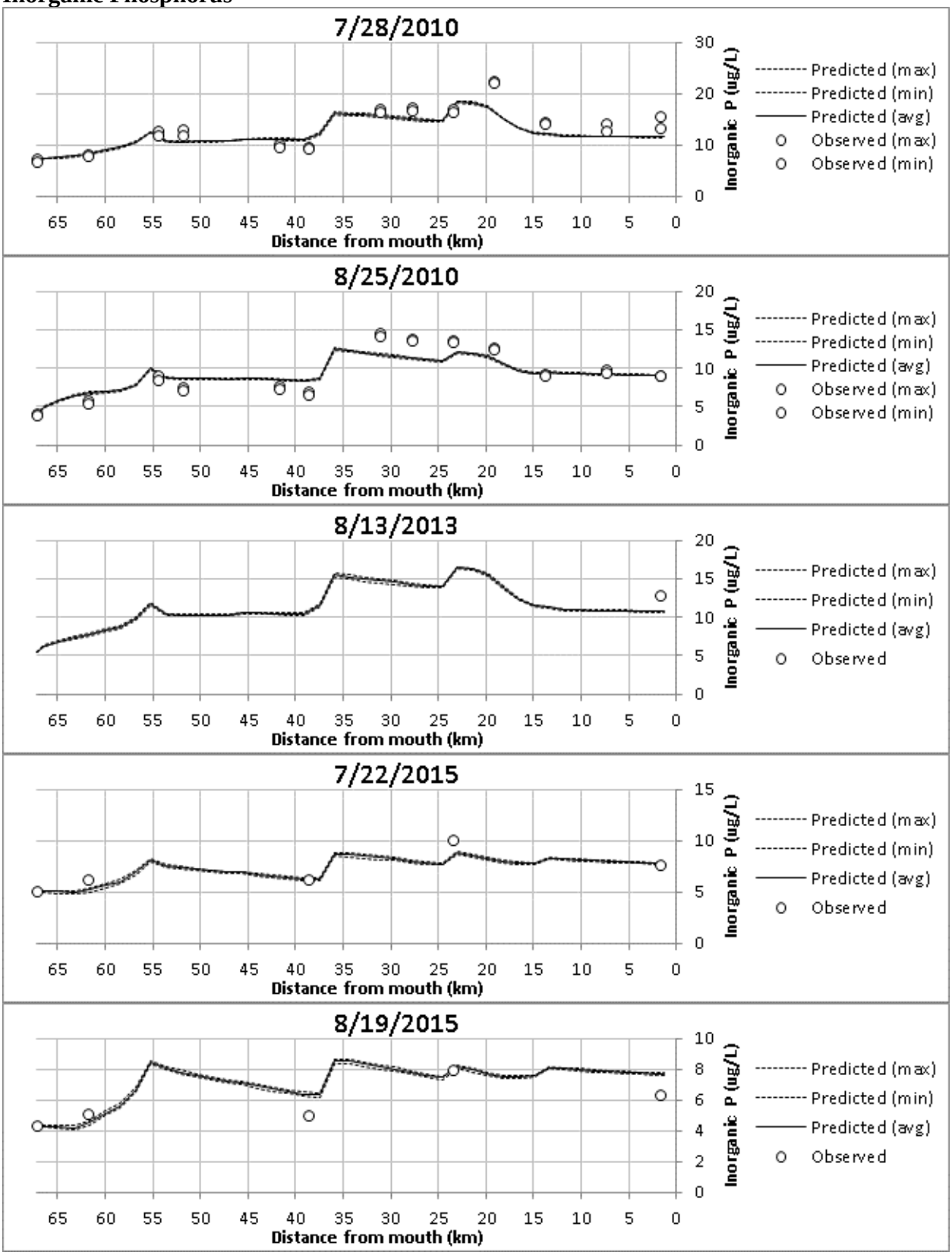

8/25/2010
Organic P (ug/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)


8/13/2013
Organic P (ug/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed

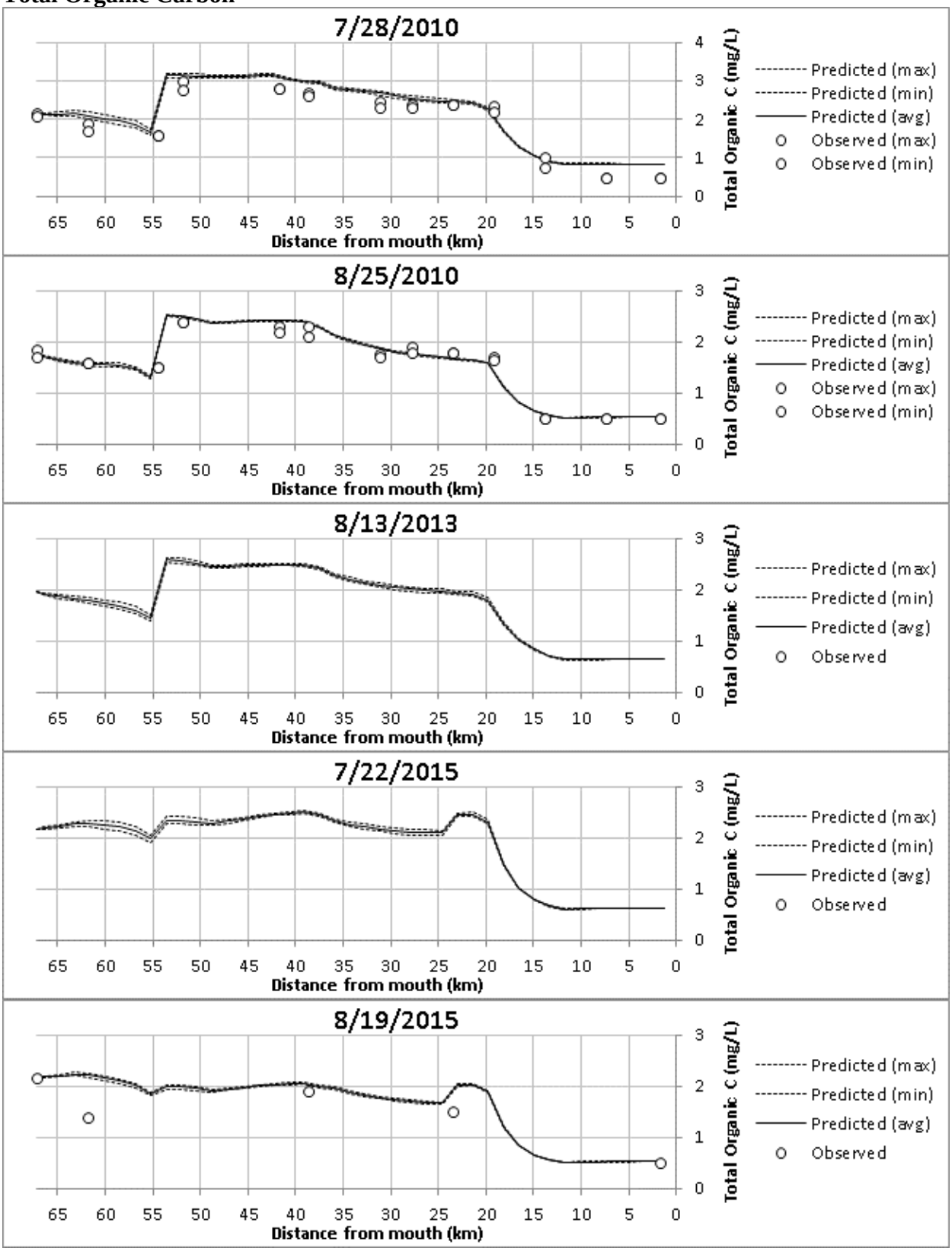

7/22/2015
Organic P (ug/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed


8/19/2015
Organic P (ug/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed

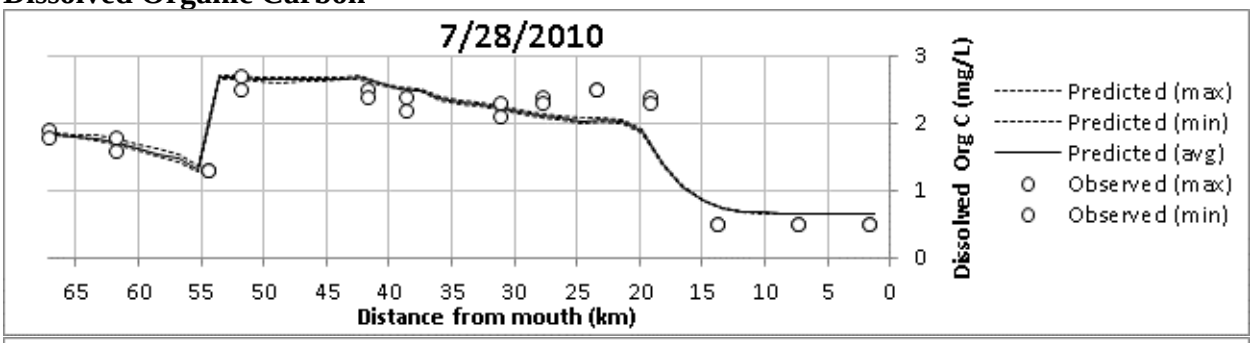
Inorganic Phosphorus

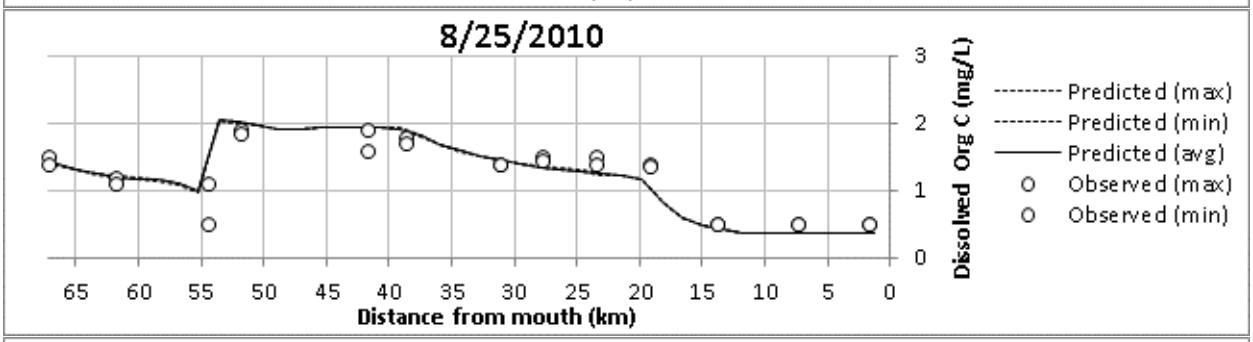


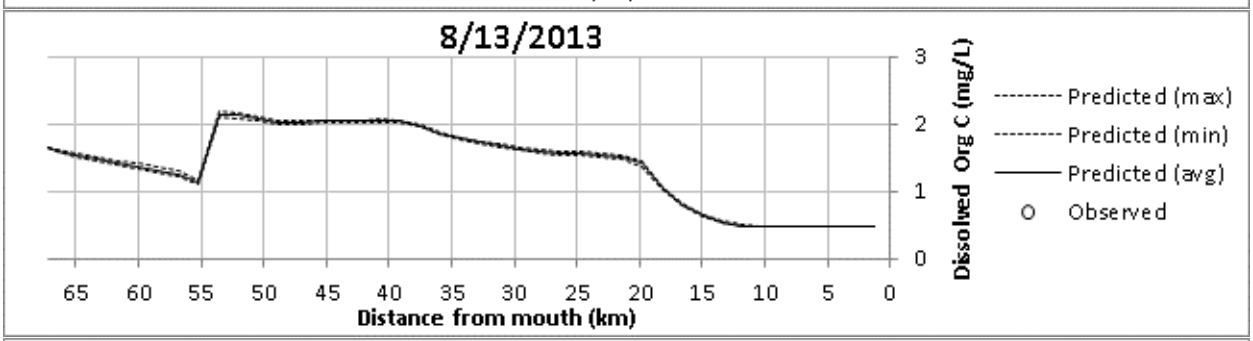
Total Organic Carbon

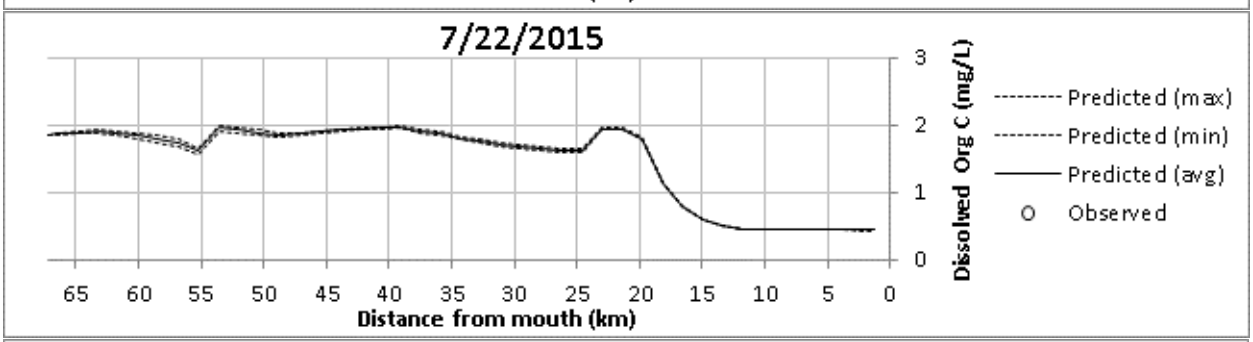


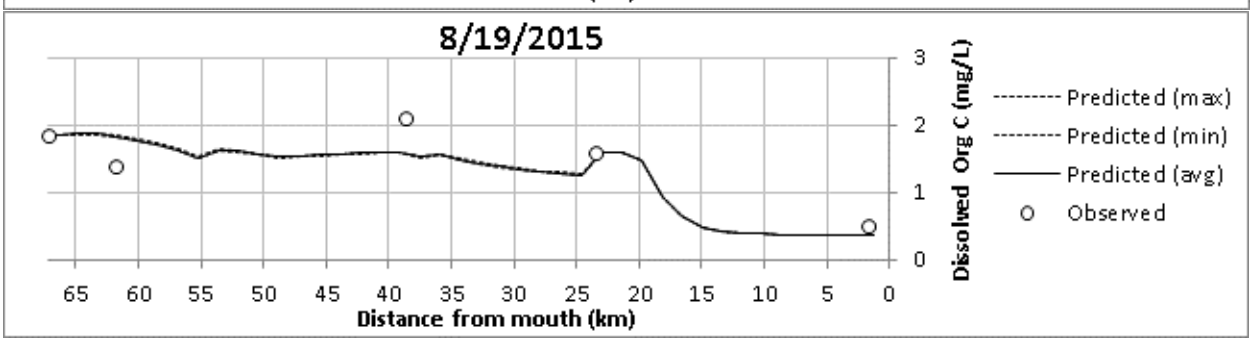
Dissolved Organic Carbon



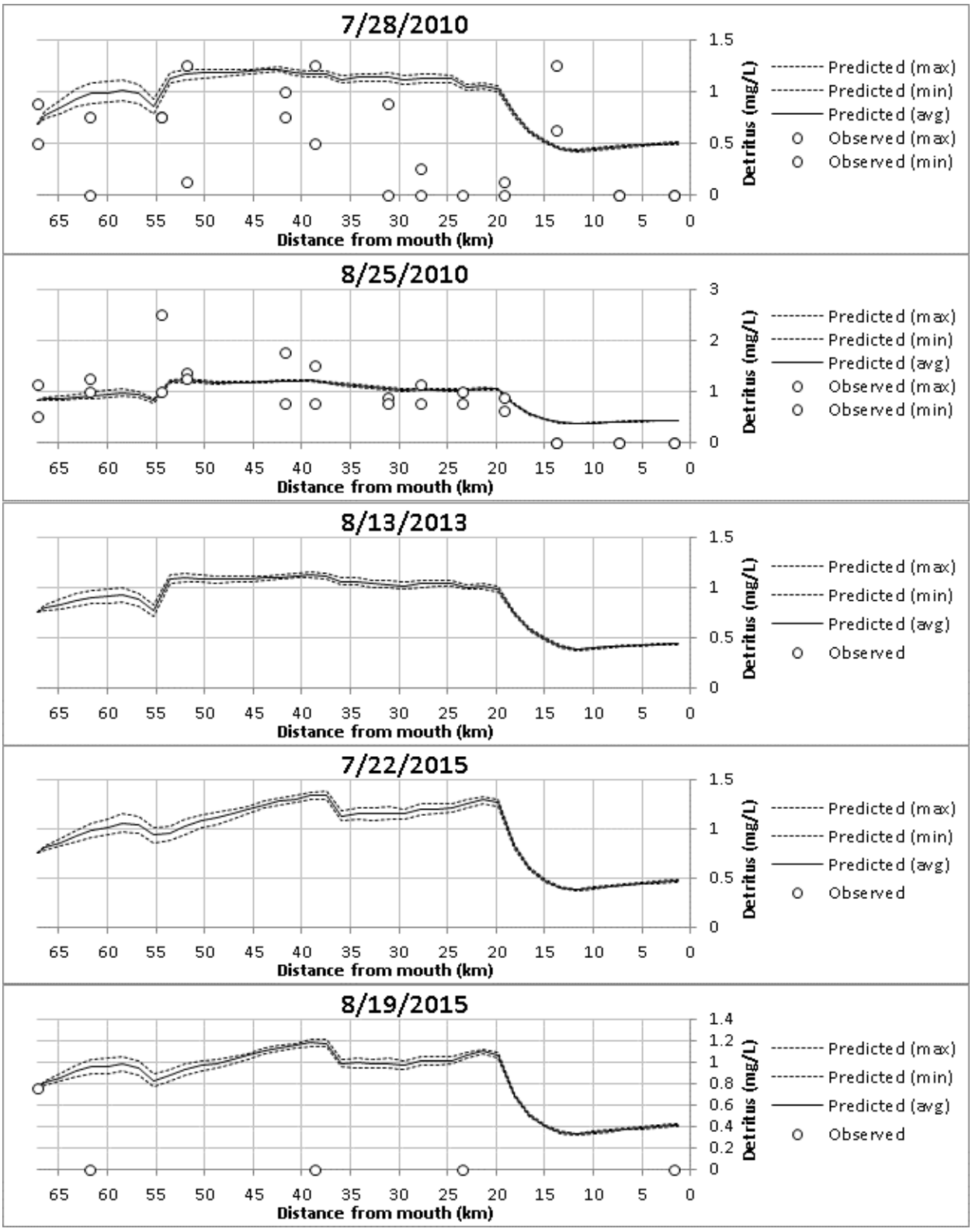






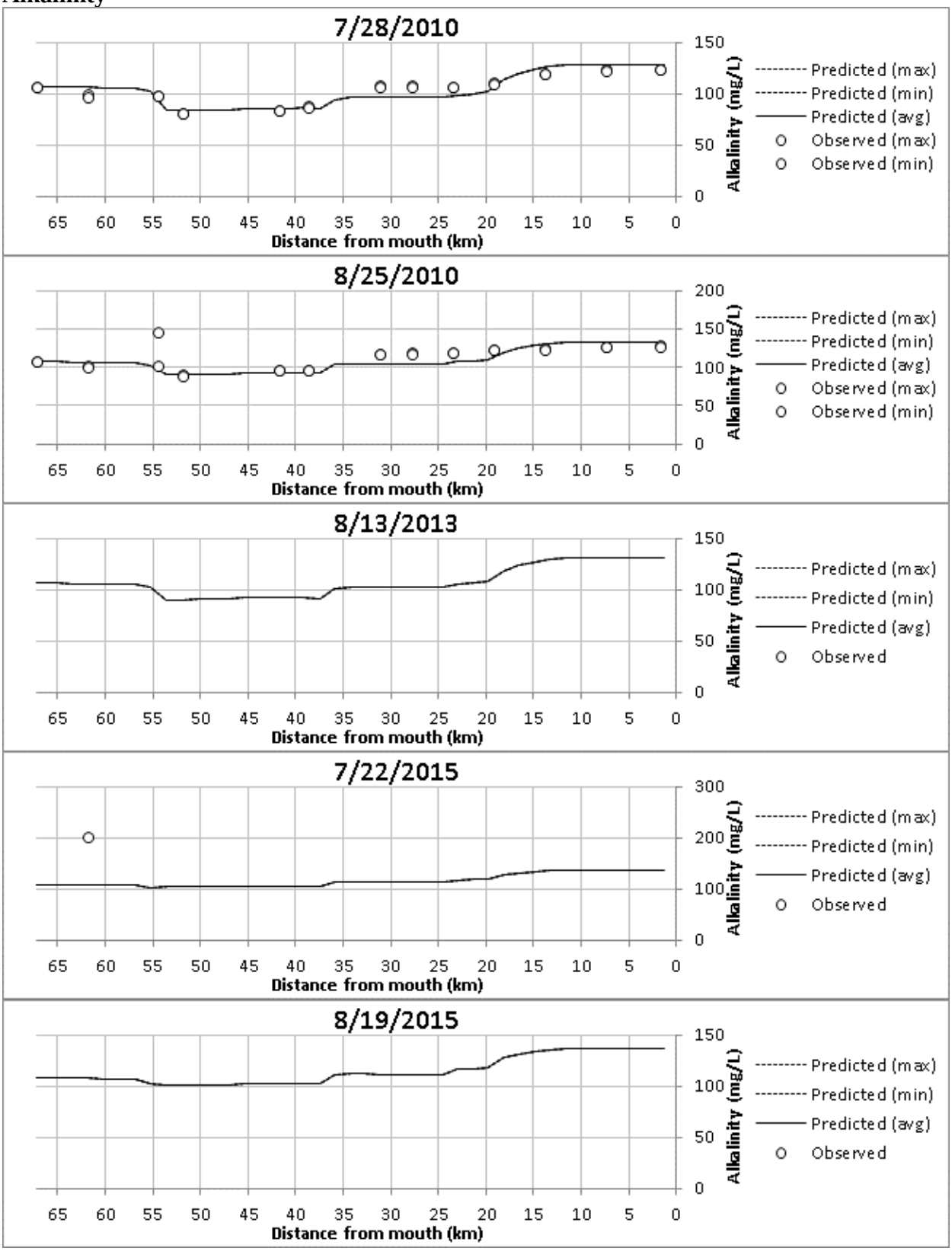


Detritus[7]

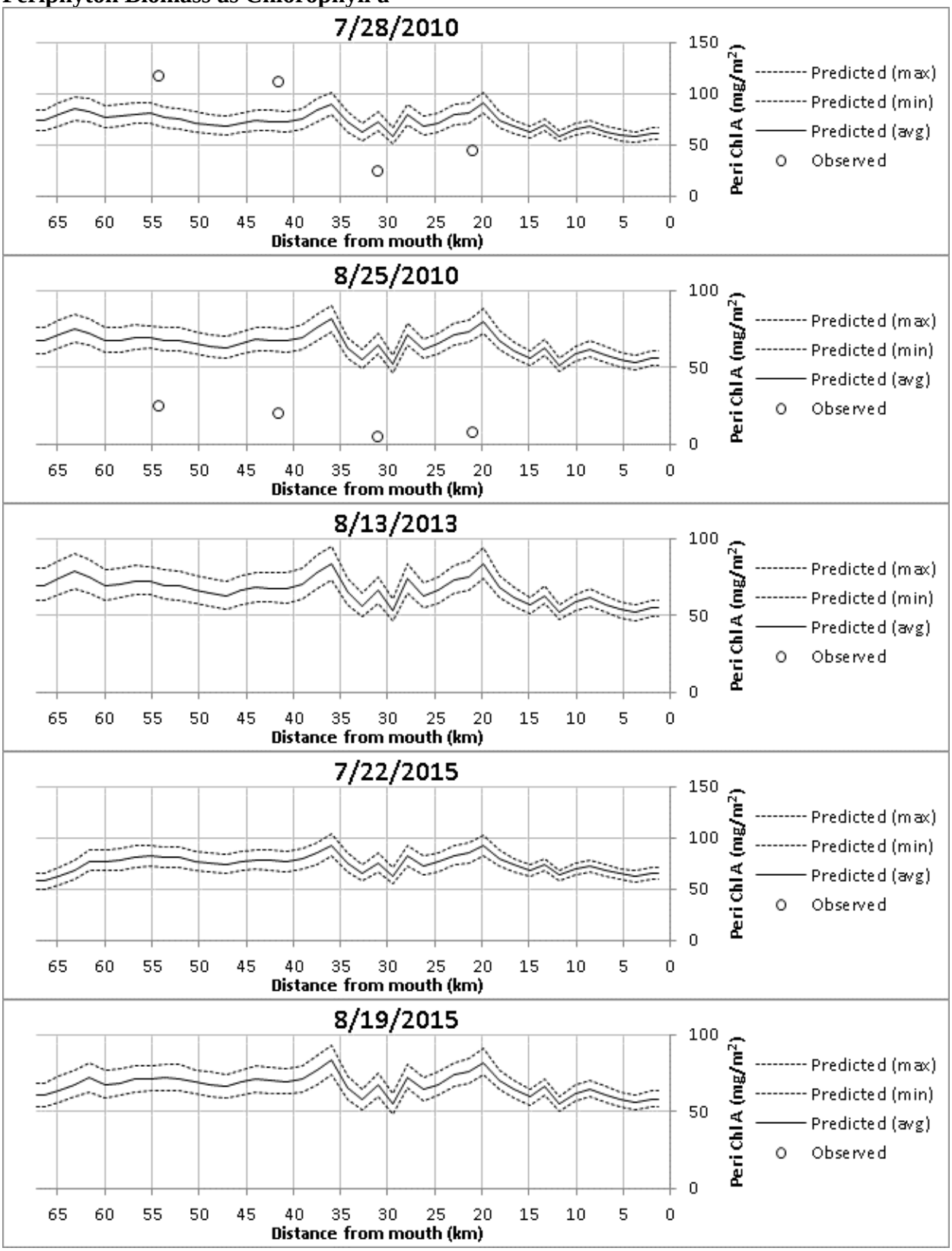


[7] We calculated "Observed" data values for detritus from laboratory data as (TOC-DOC)*2.5, where TOC-DOC represents particulate organic carbon (POC) and 2.5 is the assumed stoichiometric ratio of dry weight to carbon.

Alkalinity


7/28/2010
8/25/2010
8/13/2013
7/22/2015
8/19/2015
Alkalinity (mg/L)
Distance from mouth (km)
Predicted (max)
Predicted (min)
Predicted (avg)
Observed (max)
Observed (min)
Observed

Periphyton Biomass as Chlorophyll a



Assessment of Model Sensitivity to Nitrogen and Phosphorus

The sensitivity curve that describes the model's prediction of the relationship between nutrient concentrations and periphtyon productivity is very important. It determines how the model predictions of DO and pH will respond under scenario conditions where nutrients are reduced relative to current conditions.

The sensitivity of periphyton to the presence of a limiting nutrient can be conceptualized as a relationship between primary productivity and the concentration of the limiting nutrient, using algorithms such as the Monod equation (Figure G-3). This relationship is not linear. Rather, at low concentrations of the limiting nutrient, a small increase in limiting nutrient concentration will have a large impact on productivity. At higher concentrations, additional increases in concentration will have a smaller impact on productivity.

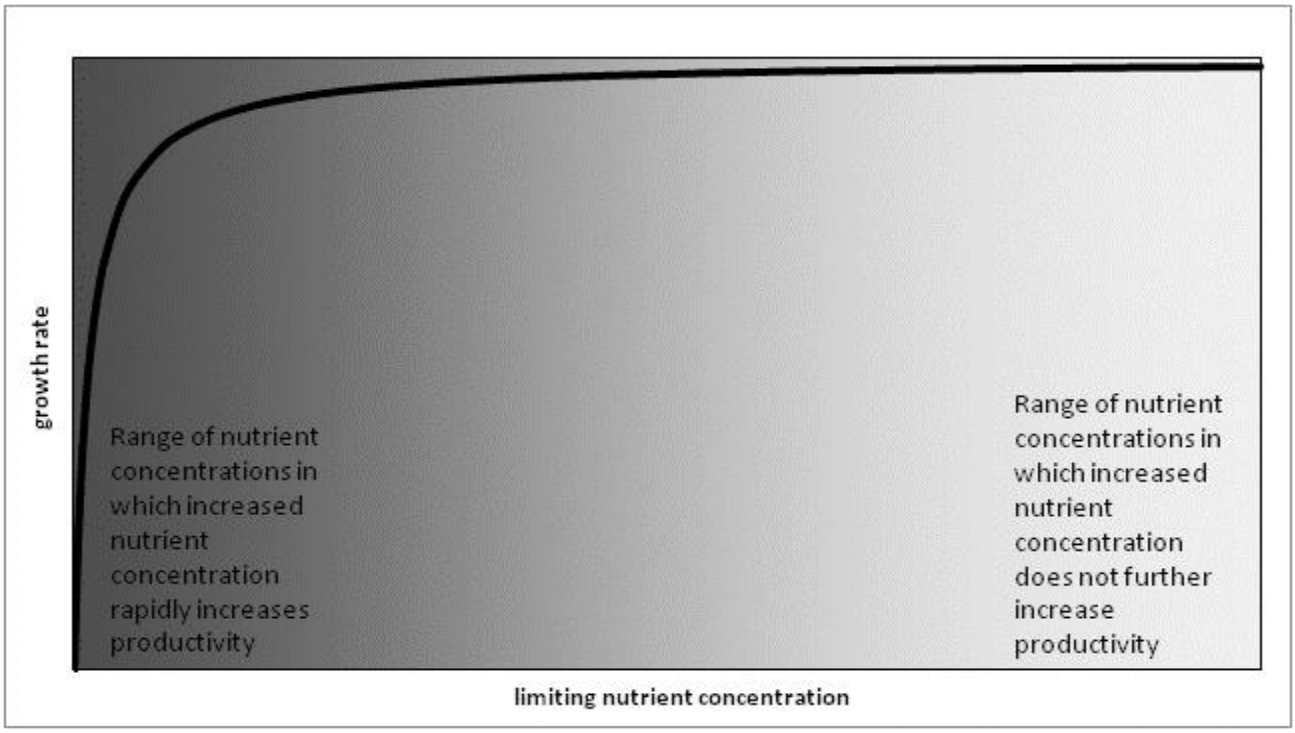


Figure G-3. Conceptual diagram of the relationship between limiting nutrient concentration and algal growth rate, using Monod equation (Monod, 1950; see Borchardt, 1996).

Under current observed conditions, neither nitrogen or phosphorus concentrations are low enough to significantly limit algal productivity in the Little Spokane River. Therefore the available data does not lend itself to being able to directly assess the nutrient sensitivity of algae in this system. Research literature, along with other TMDL studies, provides a guide. All studies on this topic have concluded that the productivity of periphyton communities dominated by diatom algae is saturated by extraordinarily low concentrations of nutrients. This is likely because these organisms have evolved to be extremely efficient at extracting nutrients from very dilute water.

Bothwell (1985) observed approximately half-saturated growth at soluble reactive phosphorus (SRP) concentrations of 1.1 ug/L, and approximately 90% saturated growth at SRP concentrations of 3-4 ug/L. Rier and Stevenson (2006) found 90% saturated growth at 16 ug/L SRP, which is higher than the Bothwell value, but still extremely low. Data collected by Ecology from the Palouse River, which is a nitrogen-limited system, suggest approximately 90% saturated growth at dissolved inorganic nitrogen (DIN) concentrations of about 16 ug/L (Snouwaert and Stuart, 2015; Ecology, unpublished data). Rier and Stevenson (2006) found 90% saturated growth at 86 ug/L DIN.

Periphyton taxonomy data also provides a guide. Appendix K provides an analysis of Periphyton taxonomy results. These data confirm that periphyton in the Little Spokane watershed mostly consist of diatom algae, and show that low-nutrient indicator species of diatoms dominate the periphyton communities in the Little Spokane River as well as most tributary locations. This suggests that the saturation ranges outlined by the literature and studies referenced above are reasonable for the Little Spokane, and that there is no reason to suspect that saturating nutrient concentrations would be any higher.

To assess the sensitivity of the final calibrated QUAL2Kw model to phosphorus, we ran multiple model scenarios. We reduced all phosphorus inputs by various fractions, resulting in various instream phosphorus concentrations ranging from approximately zero to well above the likely range of growth saturation. Then, for all scenarios, for each model segment, we plotted the simulated inorganic phosphorus against the bottom algae growth limitation factor for phosphorus. We repeated this procedure for nitrogen, this time comparing dissolved inorganic nitrogen (calculated as the sum of nitrate-nitrite and ammonia) to the bottom algae growth limitation factor for nitrogen.

Figure G-4 presents the results of this nutrient sensitivity assessment. Along with each scatter plot, we show a line which represents a Monod curve that closely approximates the QUAL2Kw model sensitivity. For nitrogen, the Monod curve half-saturation constant is 7.2 ug/L; 90% saturation occurs at 65 ug/L. For phosphorus, the half-saturation constant is 1 ug/L; 90% saturation occurs at 9 ug/L. These curves fit inside the “envelope” outlined by the literature values referenced above. The nitrogen and phosphorus half-saturation constants are in a 7.2:1 ratio, which is equal to the Redfield ratio for nitrogen:phosphorus. We also used the half-saturation constants curves in the RMA tributary models (Appendix H), insuring that model sensitivity to nutrients will be effectively the same between the QUAL2Kw mainstem and the RMA tributary models.

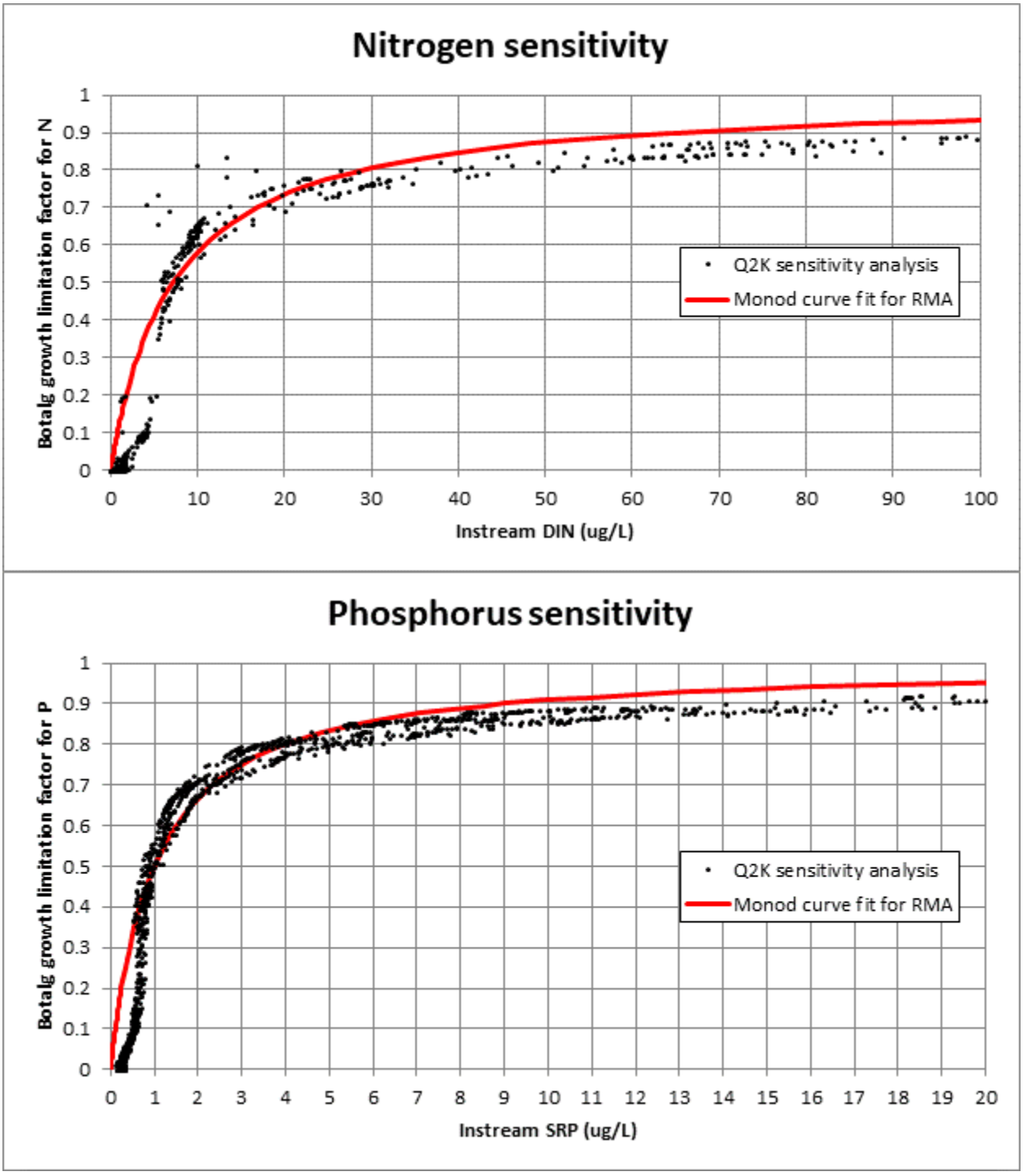


Figure G-4. Nutrient sensitivity assessment results for the Little Spokane River QUAL2Kw model.

Sensitivity analysis for rate parameters

We assessed the sensitivity of key model outputs to changes in the rate parameters by using the YASAIw Excel plug-in (Pelletier, 2009) to perform a parameter perturbation analysis. We performed this analysis by running the July 22, 2015 model simulation 1000 times. Each time the model ran, YASAIw replaced the rate parameters with a set of random numbers, generated for each parameter from a normal distribution with the mean equal to the original parameter value, and a standard deviation equal to 5% of the original parameter value. YASAIw then performed a sensitivity analysis wherein it assessed the sensitivity of each defined model output to changes in each rate parameter. This sort of analysis is useful for showing which parameters are very important for accurately predicting instream conditions, and which parameters are less important. Tables G-14 and G-15 present the results of this sensitivity analysis for DO/pH and nutrients, respectively. We analyzed a total of 55 parameters. However, we only show the most important parameters, which together make up 90% of the contribution to variance.

Table G-14. YASAIw parameter perturbation sensitivity analysis results for dissolved oxygen and pH.

Model output	Rate Parameter	Spearman's Rho	Contribution to variance
Output: Upper Watershed (Rchs 1-30) Max pH	Input: Periphyton Max Growth rate	0.8080	63.93%
	Input: User Fraction bottom coverage of algae	0.4734	21.95%
	Input: Partial pressure of carbon dioxide	-0.1807	3.20%
	Input: Periphyton Light constant	-0.1786	3.12%
Output: Upper Watershed (Rchs 1-30) Min DO	Input: Periphyton Max Growth rate	-0.6013	36.28%
	Input: Reaeration user model parameter A	0.5231	27.46%
	Input: User Fraction bottom coverage of algae	-0.4151	17.29%
	Input: Periphyton Light constant	0.2127	4.54%
	Input: Periphyton Basal respiration rate	-0.1720	2.97%
	Input: Periphyton Death rate	0.1711	2.94%
Output: Lower Watershed (Rchs 33-41) Max pH	Input: Periphyton Max Growth rate	0.6496	41.35%
	Input: User Fraction bottom coverage of algae	0.6414	40.32%
	Input: Reaeration user model parameter A	0.2333	5.34%
	Input: Periphyton Light constant	-0.1906	3.56%
Output: Lower Watershed (Rchs 33-41) Min DO	Input: Reaeration user model parameter A	0.7070	49.97%
	Input: User Fraction bottom coverage of algae	-0.4346	18.88%
	Input: Periphyton Max Growth rate	-0.4332	18.76%
	Input: Periphyton Light constant	0.1955	3.82%

Table G-15. YASAIw parameter perturbation sensitivity analysis results for nutrients.

Model output	Rate Parameter	Spearman's Rho	Contribution to variance
Output: Dartford gage (Rch 30) avg TN	Input: Oxygen enhance parameter denitrification	0.5931	36.45%
	Input: User Hyporheic sediment porosity	-0.3494	12.65%
	Input: User Hyporheic zone thickness	-0.3257	10.99%
	Input: HTS Respiration rate	-0.3198	10.60%
	Input: Denitrification	-0.3108	10.01%
	Input: HTS Death rate	0.1674	2.90%
	Input: HTS Oxygen inhib parameter	-0.1604	2.67%
	Input: OrgP Hydrolysis	-0.1481	2.27%
	Input: Periphyton Maximum uptake rate for phosphorus	0.1170	1.42%
	Input: User Hyporheic flow fraction parameter	0.1093	1.24%
Output: Dartford gage (Rch 30) avg TP	Input: HTS Death rate	0.4215	18.93%
	Input: OrgP Hydrolysis	-0.3435	12.58%
	Input: Periphyton Basal respiration rate	0.3283	11.49%
	Input: Periphyton Death rate	0.3084	10.14%
	Input: Periphyton Max Growth rate	-0.2556	6.96%
	Input: User Hyporheic flow fraction parameter	-0.2401	6.15%
	Input: User Hyporheic sediment porosity	-0.2298	5.63%
	Input: Periphyton Subsistence quota for phosphorus	-0.2269	5.49%
	Input: User Fraction bottom coverage of algae	-0.2238	5.34%
	Input: User Hyporheic zone thickness	-0.2130	4.83%
	Input: HTS Max biofilm growth rate	-0.1673	2.98%
Output: Mouth (Rch 41) avg TN	Input: Oxygen enhance parameter denitrification	0.8080	64.47%
	Input: Denitrification	-0.3024	9.03%
	Input: User Hyporheic sediment porosity	-0.2642	6.89%
	Input: User Hyporheic zone thickness	-0.2335	5.39%
	Input: HTS Respiration rate	-0.1865	3.44%
	Input: HTS Death rate	0.1076	1.14%
Output: Mouth (Rch 41) avg TP	Input: Periphyton Basal respiration rate	0.4716	22.96%
	Input: Periphyton Max Growth rate	-0.3810	14.98%
	Input: User Fraction bottom coverage of algae	-0.3351	11.59%
	Input: Periphyton Subsistence quota for phosphorus	-0.2958	9.03%
	Input: HTS Death rate	0.2668	7.35%
	Input: Periphyton Death rate	0.2443	6.16%
	Input: Periphyton Excretion rate	0.1929	3.84%
	Input: HTS Respiration rate	0.1904	3.74%
	Input: OrgP Hydrolysis	-0.1864	3.59%
	Input: User Hyporheic sediment porosity	-0.1684	2.93%
	Input: Periphyton Internal phosphorus half sat ratio	-0.1578	2.57%
	Input: Periphyton Light constant	0.1470	2.23%

These results indicate that the most important rate parameters for predicting dissolved oxygen and pH are those directly relating to algae growth, namely the periphyton max growth rate and the fraction bottom coverage of algae. These two parameters have a similar effect. In other words, an increase in algae growth rate has a similar effect to an increase in the amount of the streambed that is available for algae growth. For dissolved oxygen, the reaeration user model parameter A was also very important. This parameter is the proportional scalar for reaeration, and it is not surprising that dissolved oxygen, which is strongly affected by reaeration, is sensitive to this, while pH, which is not as strongly affected by reaeration, is less so.

The rate parameters that are most important for predicting nutrients depend upon the nutrient. For nitrogen, the important rate parameters are those that concern denitrification and hyporheic processes. This indicates that instream and/or hyporheic transformations play a larger role in determining nitrogen concentration than do nutrient cycling involving periphyton. This is probably because the nitrogen availability in the Little Spokane River is greatly in excess of algal demand. For phosphorus, the important rate parameters are a mix of those concerning algal growth, uptake, and cycling, and those concerning hyporheic processes. The emphasis seems to be more on the algal rather than the hyporheic processes. This is likely because phosphorus availability in the Little Spokane River, although probably somewhat in excess of algal demand, is not greatly so. Therefore, algal process have a greater relative impact on phosphorus than they do on nitrogen. This is consistent with the observation that the Little Spokane River mainstem is more phosphorus-limited than nitrogen-limited.

Critical conditions scenarios

We used the calibrated QUAL2Kw model to simulate critical weather conditions based on the historical record. We simulated two sets of critical conditions, moderate critical conditions with 7-day average, 2 year low flow (7Q2) and 50th percentile air temperatures, and extreme critical conditions with 7-day average, 10 year low flow (7Q10) and 90th percentile air temperatures. Table G-16 presents the model inputs used for these scenarios.

Table G-16. Model inputs for critical climatic conditions scenarios.

Model input	Moderate critical conditions	Extreme critical conditions
Flow balance	from 7/28/2010 model run (approx. 7Q2)	from 7/22/2015 model run (approx. 7Q10)
Climate inputs	Four day period ending 8/13/2003 – historically average air temperature (Joy and Jones, 2012)	Four day period ending 7/31/2003 – 90th percentile air temperature (Joy and Jones, 2012)
Shade	Shade model outputs for 8/13/2003	Shade model outputs for 7/31/2003
Boundary condition temperature inputs	Reduce 7/28/2010 inputs by 0.5°C, to approximately align with modeled equilibrium conditions downstream	Increase 7/22/2015 inputs by 3°C, approximately align with modeled equilibrium conditions downstream
All other boundary conditions	Same as 7/28/2010 model run	Same as 7/22/2015 model run

Natural conditions scenarios

To simulate natural conditions, we adjusted a number of model inputs to reflect Ecology's best estimate of conditions that did not include post-settlement human modifications. We made these inputs to both the moderate critical and the extreme critical conditions scenarios described above, in order to represent natural conditions across range of low-flow summer conditions.

Streamflow

We turned off the surface water withdrawals simulated in the current conditions model (as described in the **Flow Balances** section above). This resulted in an added 8.2 cfs of water in the system.

Additionally, we made an assumption that without pumping from numerous wells in the basin, additional groundwater would contribute to summer baseflows. Golder Associates Inc. estimated the flow depletion at the USGS Dartford gage to be 6 cfs during the summer using the MIKE SHE groundwater model framework (Golder Associates, Inc., 2004; Spokane County, 2006). We distributed this estimate proportionally throughout the watershed based on the permitted water volumes for wells within 500 ft of waterbodies in each mainstem reach or tributary (Table G-17, see the **Watershed Loading TMDL Analysis** > **Separation of human and natural background loading** section in main report for more details).

A cursory trends analysis of the difference between flows at the the two LSR USGS gage stations - at Dartford and Near Dartford (Painted Rocks) – did not suggest any impact from pumping on Spokane Valley Rathdrum Prairie Aquifer flows to the Little Spokane River.

Table G-17. Estimated additional groundwater contribution to baseflow absent well pumping.

Mainstem Reach	River Mile	Total withdrawals (cfs)
Upstream of Frideger Rd	51.1[a] – 39.5	0
Frideger Rd - Elk	39.5 – 37.1	0
Elk – Eloika Rd	37.1 – 33.2	0.169
Eloika Rd – Milan	33.2 – 31.8	0.059
Milan – Abv Bear Ck	31.8 – 29.5	0.088
Abv Bear Ck – Riverway Rd	29.5 – 25.4	0.147
Riverway Rd – Chattaroy	25.4 – 23.4	0.066
Chattaroy – Buckeye	23.4 – 18.0	0.107
Buckeye – Colbert Rd	18.0 – 16.0	0.045
Colbert Rd – N LSR Dr	16.0 – 13.5	0.058
N LSR Dr – Pine R Park	13.5 – 11.7	1.258
Pine R Park – Dartford gage	11.7 – 11.0	0.472
Dartford gage – Topo gap	11.0 – 9.9	0
Topo gap – Waikiki Rd	9.9 – 7.5	0
Waikiki Rd – St George's	7.5 – 6.1	0
St George's – Painted Rocks	6.1 – 3.9	0
Painted Rocks – Hwy 291	3.9 – 1.1	0

[a] RM 51.1 represents the Little Spokane River headwaters near Penrith.

Tributary	Mainstem River Mile	Total withdrawals (cfs)
Tribs US of Frideger Rd	Various, 39.5+	0
Dry Ck	34.5	0
Otter Ck	33.5	0.4
WB Little Spokane R	32.7	1.65
Bear Ck	27.8	0.18
Deer Ck	23.0	0
Dragoon Ck	21.3	1.12
Deadman Ck	13.1	0.18
Dartford Ck	10.3	0

Total (mainstem & tributaries): 6.0 cfs

Nutrients

Table G-18 presents natural condition nutrient inputs. We selected natural conditions phosphorus inputs by taking either 1) the lowest observed value from July-September 2015; or 2) the average of predicted natural conditions estimates for July-September as determined by the watershed analysis (Appendix F); whichever was lower. For groundwater and tributaries not associated with the Spokane Valley-Rathdrum Prairie Aquifer (SVRPA), phosphorus levels during dry low-flow conditions are mostly driven by groundwater and we consider are considered to be similar to natural condition levels.

For the SVRPA, we used a value of 0.004 mg/L total phosphorus, which is significantly less than the current conditions value of 0.009 mg/L but consistent with the Spokane River and Lake Spokane DO TMDL. This is based on deep and/or up-gradient well monitoring data collected by Spokane County, and represents a reasonable assumption, noting that the SVRPA is comprised of unconsolidated glacial deposits and lies beneath metropolitan and agricultural areas, that the upper portion of the aquifer that feeds the Little Spokane River has experienced an increase in phosphorus due to human activities.

We used a value of 0.1 mg/L total nitrogen in the uppermost reach of the LSR, upstream of Elk. This was based on the observation that groundwater nitrate appears to be lower in wells in the extreme upper portion of the watershed, including two wells near Penrith and one near Elk, than in the rest of the watershed. For groundwater and tributaries downstream of Elk, we used a value of 0.2 mg/L total nitrogen. This compares well to the median of relatively unaffected wells in the upper watershed (0.215 mg/L), as well as the median of wells in the relatively undeveloped Hidden Valley, Idaho hillside drainage to the SVRPA (0.242 mg/L; Clarkson and Buchanan, 1998). These values are significantly lower than current conditions levels, and represent an assumption that the vast majority of nitrate found in groundwater in the Little Spokane watershed is anthropogenic.

For all nutrient parameters in tributaries, we determined the division of total nutrients into their relative fractions according to the average proportion observed during July – September 2015.

Table G-18. Natural conditions nutrient inputs for the Little Spokane River QUAL2Kw model.

Tributary or Mainstem Reach	Organic P (ug/L)	Inorganic P (ug/L)	Organic N (ug/L)	Ammonia N (ug/L)	Nitrate-Nitrite N (ug/L)
Tributaries					
Dry Ck	4.88	12.56	17.71	0	182.29
Otter Ck	3.01	15.99	17.71	0	182.29
WBLSR	9.46	3.84	158.59	15.94	25.46
Bear Ck	4.1	11.4	17.71	0	182.29
Deer Ck	0	20	17.71	0	182.29
Dragoon Ck	3.25	12.35	17.71	0	182.29
Deadman Ck	2.11	17.26	17.71	0	182.29
Dartford Ck	1.45	23.15	17.71	0	182.29
All SVRPA springs	0.49	3.51	0	0	200
Diffuse Groundwater					
Frideger – Elk	6.4	25	0	0	100
Elk – Milan	6.4	25	0	0	200
Milan – LSR Dr	2.56	10	0	0	200
LSR Dr - Mouth	0.49	3.51	0	0	200

Shade

The shade model developed for the *Little Spokane River Fecal Coliform Bacteria, Temperature, and Turbidity TMDL* (Joy and Jones, 2012) assumed system potential shade would be defined by a strip of mature conifer forest at the edge of the stream, 25 m tall, with 70% canopy density, and 3.3 m branches overhanging the stream. This type of riparian composition may be appropriate for the smaller forested headwater streams in this watershed but overestimates shade for mainstem streams and larger tributaries.

While this overestimate would not affect the nonpoint source implementation efforts needed for the temperature TMDL, the natural conditions analysis for this DO/pH/TP TMDL includes multiple factors such as nutrients, flow, and channel geometry. Each of these factors has its own uncertainty. The final natural conditions estimate reflects the compound uncertainty from all these factors. (See the **uncertainty analysis for natural conditions predictions** section below.) Using a biased estimate for a key factor like shade would be detrimental to such an analysis. Therefore, it was important to adjust the system potential shade model for this TMDL to achieve the most accurate estimate possible.

At reference locations with undisturbed riparian vegetation along the Little Spokane River, conifer forest only occasionally reaches the edge of the water. Ecology staff observed, both in the field and by looking at orthophotos, that natural conifer forest gives way to a riparian zone consisting of deciduous shrubs and small trees such as black hawthorn (*Crataegus douglasii*) and willow (*Salix sp.*). It is this deciduous band which, by virtue of being directly proximate to the stream bank, primarily provides shade to the stream.

We re-ran the system potential shade model with values reflecting a band of hawthorn 10 m tall, with 75% canopy density, and 1 m overhang. We used the resulting system potential shade predictions (Figure G-5) as inputs to the QUAL2Kw natural conditions scenario. These predictions also form the basis of the shade and heat allocations for the mainstem Little Spokane River in this TMDL. (See Appendix I for the basis of shade and heat allocations for tributaries and the upper LSR.)

It is important to point out that although the system potential shade analysis and resulting shade and heat allocation numeric values differ somewhat between the 2012 TMDL and this TMDL, for practical purposes, the implementation of both TMDLs is the same. Both TMDLs require system potential shade, which means restoring native riprian vegetation conditions along streams throughout the Little Spokane River watershed.

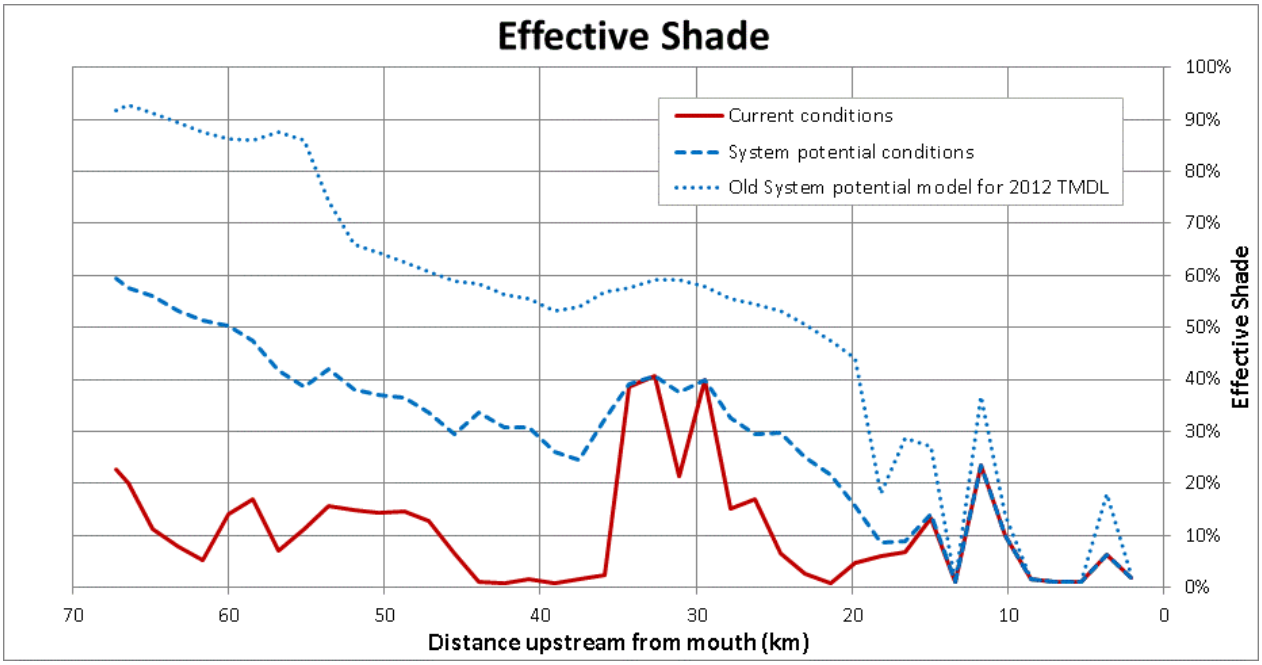


Figure G-5. Effective shade under current conditions, system potential conditions, and the old system potential prediction from the 2012 TMDL.

Microclimate

To simulate the changes to riparian microclimate that might occur under with system potential riparian vegetation, we reduced air temperature inputs by 1°C and increased dew point inputs by 0.5°C. These are small inputs, which reflect that the differences between current and system potential vegetation are moderate, and the channel wide enough that large microclimate changes are unlikely.

Channel Geometry

To simulate natural channel geometry, we increased depth inputs by 5%, and reduced width inputs by 5%. This results in a 10% reduction in the overall ratio of width:depth. The channel morphology of the Little Spokane River is largely intact, without much incidence of the out-and-out mechanical straightening and widening that is seen in many other river systems. However, these small model input changes represent an assumption that present-day channel geometry may have deteriorated from natural conditions, through riparian vegetation removal and resulting bank erosion.

Uncertainty analysis for natural conditions predictions

We estimated model inputs for natural conditions through a combination of weight-of-evidence and statistical exercises; modeling; and reference to other modeling exercises and studies. Each of these inputs has uncertainty associated with it. Because the natural conditions model contains multiple input assumptions each with its own sometimes significant uncertainty, there is at least the potential for these uncertainties to compound one another.

We used YASAIw (Pelletier, 2009) to test the impact of multiple input uncertainty on output uncertainty. YASAIw is an add-in for Microsoft Excel that provides the ability to perform Monte Carlo simulations. For each of 10 different natural condition input assumptions, we assigned the range of uncertainty as a probability distribution centered on the input value (Table G-19). We ran the moderate critical and extreme critical system potential model simulations 1000 times each. Each time the model was run, YASAIw replaced the natural conditions input assumptions with a set of random numbers, generated from these defined probability distributions. The distribution of resulting model outputs defines the range of confidence in the natural conditions prediction (Table G-20). YASAIw then performed a sensitivity analysis by assessing the sensitivity of selected model outputs to changes in each of these input assumptions (Tables G-14 and G-15).

Table G-19. Probability distributions for natural condition input values for YASAIw uncertainty analysis.

The range from the 5th percentile to the 95th percentile represents a 90% confidence envelope.

Assumptions	Original value	Units	Distribution type	5th percentile	95th percentile	Commentary
System potential shade model output multiplier	1	dimensionless	Normal, upper bound shade values = 100%	0.666667	1.333333	Highest modeled system potential shade of 60% can therefore range from ~40% - 80%
Surface withdrawals assumption multiplier	1	dimensionless	Normal, lower bound zero	0	2	NC model assumed 8.2 cfs total of surface withdrawals throughout basin (20% of certificate paper). This represents additional flow that would be in the system under NC. This assumes it could range from about 0 – 16.4 cfs
Groundwater inflow change due to well pumping	6	cfs	Lognormal	2	18	Heavily skewed lognormal distribution. It seems widely accepted that this effect is occurring, and little or no probability that this would be zero. 6 cfs was predicted by MIKE SHE model as part of watershed management plan (Golder Associates, Inc., 2004; Spokane County, 2006). Low flow trend declines shown in emails between WR staff and P. Pickett suggest there is at least a possibility it could be significantly more (Covert, 2016).
Air temperature adjustment for microclimate	-1	deg C	Normal, upper bound zero	-2	0	
Dew point adjustment for microclimate	0.5	deg C	Normal, lower bound zero	0	1	
Depth fraction increase	0.05	dimensionless	Lognormal	0.025	0.1	[Depth multiplier = 1 + Depth fraction increase] This means that depth multiplier can range from ~1.025 – 1.1 (original was 1.05)
Width fraction decrease	0.05	dimensionless	Lognormal	0.025	0.1	[Width multiplier = 1/(1 + Width fraction decrease)] This means that width multiplier can range from ~0.9091 – 0.976 (original was 0.95)
Nitrogen concentration multiplier	1	dimensionless	Lognormal	0.4	2.5	NC model total N value typically 200 ug/L, so this means ~ 80 – 500 ug/L
Non-SVRP phosphorus concentration multiplier	1	dimensionless	Lower 25% of normal, upper bound 1	0.75	1.65 (defines dist.) 1.0 (actual 95th %ile)	For the most part we assumed that Non-SVRPA P current = natural. Distribution mean of 1.2, but upper bound 1. This essentially says that we think there's a 75% chance that our current = natural assumption is correct, but there's a 25% chance P could be lower, as defined by the bottom 25%ile of a normal dist.
SVRP total phosphorus concentration:	4	ug/L	Lognormal, upper bound 9	2.666667	6	Upper bound of 9 = current conditions; this upper bound will hardly ever come into play since 95%ile is 6.

NC = natural conditions
WR = Ecology Water Resources Program

Table G-20. Range of confidence in natural conditions predictions

Selected Model Output	units	Distribution of NC model predictions (percentiles)			90% confidence range (95%ile – 5%ile)	
		5%	50%	95%	as units	as % of median
Moderate critical conditions (7Q2 flow and 50th percentile meteorology)						
Output: 7Q2 Dartford gage (Rch 30) avg TN	ug/L	93.071	178.150	400.599	307.528	172.62%
Output: 7Q2 Dartford gage (Rch 30) avg TP	ug/L	10.772	13.755	14.272	3.500	25.44%
Output: 7Q2 Lower Watershed (Rchs 33-41) Max pH	S.U.	8.151	8.179	8.198	0.048	
Output: 7Q2 Lower Watershed (Rchs 33-41) Min DO	mg/L	7.838	7.907	7.977	0.138	1.75%
Output: 7Q2 Mouth (Rch 41) avg TN	ug/L	83.606	184.930	450.432	366.825	198.36%
Output: 7Q2 Mouth (Rch 41) avg TP	ug/L	6.216	7.446	8.942	2.726	36.61%
Output: 7Q2 Upper Watershed (Rchs 1-30) Max pH	S.U.	8.410	8.483	8.540	0.131	
Output: 7Q2 Upper Watershed (Rchs 1-30) Min DO	mg/L	7.373	7.559	7.774	0.401	5.30%
Extreme critical conditions (7Q10 flow and 90th percentile meteorology)						
Output: 7Q10 Dartford gage (Rch 30) avg TN	ug/L	87.283	159.027	347.609	260.326	163.70%
Output: 7Q10 Dartford gage (Rch 30) avg TP	ug/L	9.305	11.726	12.403	3.098	26.42%
Output: 7Q10 Lower Watershed (Rchs 33-41) Max pH	S.U.	8.228	8.253	8.270	0.042	
Output: 7Q10 Lower Watershed (Rchs 33-41) Min DO	mg/L	7.665	7.740	7.816	0.151	1.95%
Output: 7Q10 Mouth (Rch 41) avg TN	ug/L	81.970	183.033	445.739	363.769	198.74%
Output: 7Q10 Mouth (Rch 41) avg TP	ug/L	4.715	5.904	7.574	2.859	48.43%
Output: 7Q10 Upper Watershed (Rchs 1-30) Max pH	S.U.	8.729	8.788	8.838	0.109	
Output: 7Q10 Upper Watershed (Rchs 1-30) Min DO	mg/L	6.941	7.152	7.392	0.451	6.31%

Table G-21. Sources of uncertainty for moderate critical conditions natural conditions run

Forecast	Assumption	Spearman's Rho [a]	Contribution to variance
Output: 7Q2 Dartford gage (Rch 30) avg TN	Input: Nitrogen concentration multiplier	0.9999	99.29%
Output: 7Q2 Mouth (Rch 41) avg TN	Input: Nitrogen concentration multiplier	1.0000	99.31%
Output: 7Q2 Dartford gage (Rch 30) avg TP	Input: Nitrogen concentration multiplier	-0.5950	48.45%
	Input: Non-SVRP phosphorus concentration multiplier	0.5213	37.20%
	Input: SVRP total phosphorus concentration:	0.2516	8.66%
	Input: Groundwater inflow change due to well pumping	-0.1486	3.02%
	Input: Surface withdrawals assumption multiplier	0.1201	1.97%
Output: 7Q2 Mouth (Rch 41) avg TP	Input: SVRP total phosphorus concentration:	0.8476	82.95%
	Input: Non-SVRP phosphorus concentration multiplier	0.3224	12.00%
	Input: Nitrogen concentration multiplier	-0.1513	2.64%
	Input: Surface withdrawals assumption multiplier	0.1374	2.18%
Output: 7Q2 Upper Watershed (Rchs 1-30) Min DO	Input: System potential shade model output multiplier	0.7813	67.94%
	Input: Nitrogen concentration multiplier	-0.5211	30.22%
	Input: Air temperature adjustment for microclimate	-0.0957	1.02%
Output: 7Q2 Lower Watershed (Rchs 33-41) Min DO	Input: System potential shade model output multiplier	0.6481	56.01%
	Input: Depth fraction increase	-0.3260	14.17%
	Input: SVRP total phosphorus concentration:	-0.2968	11.75%
	Input: Air temperature adjustment for microclimate	-0.2198	6.44%
	Input: Non-SVRP phosphorus concentration multiplier	-0.2105	5.91%
	Input: Surface withdrawals assumption multiplier	-0.1237	2.04%
	Input: Nitrogen concentration multiplier	-0.1107	1.63%
	Input: Groundwater inflow change due to well pumping	-0.0884	1.04%
Output: 7Q2 Upper Watershed (Rchs 1-30) Max pH	Input: System potential shade model output multiplier	-0.6251	41.02%
	Input: Depth fraction increase	-0.5389	30.49%
	Input: Surface withdrawals assumption multiplier	-0.4305	19.45%
	Input: Groundwater inflow change due to well pumping	-0.2671	7.49%
Output: 7Q2 Lower Watershed (Rchs 33-41) Max pH	Input: Depth fraction increase	-0.7933	67.64%
	Input: System potential shade model output multiplier	-0.3604	13.96%
	Input: Surface withdrawals assumption multiplier	-0.2909	9.10%
	Input: Groundwater inflow change due to well pumping	-0.2192	5.16%
	Input: Width fraction decrease	-0.1384	2.06%
	Input: Nitrogen concentration multiplier	-0.1020	1.12%

[a] Spearman's Rho is a non-parametric statistical test used to measure the association between two variables. A Rho value of 1 means the two variables have a perfect positive correlation, -1 means they have a perfect inverse correlation, and 0 means they are not correlated.

Table G-22. Sources of uncertainty for extreme critical conditions natural conditions run

Forecast	Assumption	Spearman's Rho	Contribution to variance
Output: 7Q10 Dartford gage (Rch 30) avg TN	Input: Nitrogen concentration multiplier	0.9997	99.35%
Output: 7Q10 Mouth (Rch 41) avg TN	Input: Nitrogen concentration multiplier	1.0000	99.39%
Output: 7Q10 Dartford gage (Rch 30) avg TP	Input: Nitrogen concentration multiplier	-0.6495	55.80%
	Input: Non-SVRP phosphorus concentration multiplier	0.4827	30.81%
	Input: Surface withdrawals assumption multiplier	0.2510	8.33%
	Input: Groundwater inflow change due to well pumping	0.1196	1.89%
	Input: SVRP total phosphorus concentration:	0.1128	1.68%
Output: 7Q10 Mouth (Rch 41) avg TP	Input: SVRP total phosphorus concentration:	0.9295	92.21%
	Input: Non-SVRP phosphorus concentration multiplier	0.1679	3.01%
	Input: Surface withdrawals assumption multiplier	0.1436	2.20%
	Input: Nitrogen concentration multiplier	-0.1059	1.20%
Output: 7Q10 Upper Watershed (Rchs 1-30) Min DO	Input: System potential shade model output multiplier	0.8769	83.55%
	Input: Nitrogen concentration multiplier	-0.3780	15.53%
Output: 7Q10 Lower Watershed (Rchs 33-41) Min DO	Input: System potential shade model output multiplier	0.5760	40.99%
	Input: SVRP total phosphorus concentration:	-0.4456	24.54%
	Input: Depth fraction increase	-0.3002	11.13%
	Input: Groundwater inflow change due to well pumping	-0.2685	8.91%
	Input: Surface withdrawals assumption multiplier	-0.2592	8.30%
	Input: Air temperature adjustment for microclimate	-0.1790	3.96%
	Input: Non-SVRP phosphorus concentration multiplier	-0.1167	1.68%
Output: 7Q10 Upper Watershed (Rchs 1-30) Max pH	Input: System potential shade model output multiplier	-0.5343	32.26%
	Input: Surface withdrawals assumption multiplier	-0.4784	25.87%
	Input: Depth fraction increase	-0.4238	20.29%
	Input: Groundwater inflow change due to well pumping	-0.3163	11.31%
	Input: Nitrogen concentration multiplier	0.2409	6.56%
	Input: Width fraction decrease	-0.1623	2.98%
Output: 7Q10 Lower Watershed (Rchs 33-41) Max pH	Input: Depth fraction increase	-0.8258	69.66%
	Input: System potential shade model output multiplier	-0.3777	14.57%
	Input: Width fraction decrease	-0.2743	7.69%
	Input: Surface withdrawals assumption multiplier	-0.2061	4.34%
	Input: Groundwater inflow change due to well pumping	-0.1436	2.11%
	Input: Air temperature adjustment for microclimate	0.1120	1.28%

Table G-20 shows that while uncertainty around natural conditions nutrient predictions is high, the uncertainty around natural conditions dissolved oxygen and pH predictions is reasonably low. Under extreme critical conditions for nutrients, the 90 percent confidence envelope for predictions at the mouth of the Little Spokane River is about 82 – 446 ug/L for total N and 4.7 – 7.6 ug/L for total P. These wider confidence bands directly reflect the higher levels of assumed uncertainty about natural levels of groundwater nitrogen throughout the system, and natural levels of phosphorus in the Spokane Valley-Rathdrum Prairie Aquifer (Table G-19)

The fact that these wide confidence bands do not translate into correspondingly wide confidence bands for dissolved oxygen and pH predictions reflects the overall lack of algal sensitivity to nutrients in this system. The **Assessment of Model Sensitivity to Nitrogen and Phosphorus** section earlier in this appendix explains the non-linear relationship between nutrients and algal productivity, and the range of nutrient concentrations where algae growth would be expected to become sensitive. Even the low end nutrient predictions in this uncertainty analysis are not low enough to trigger meaningful algal nutrient sensitivity. (Though, the low-end predictions for phosphorus do approach this point.)

The 90 percent confidence envelope under extreme critical conditions for daily minimum dissolved oxygen in the upper watershed (from Camden to Dartford) is about 6.9 – 7.4 mg/L, about a 0.5 mg/L spread. The 90 percent confidence envelope for pH in the upper watershed is about 8.7 – 8.8 S.U., about a 0.1 S.U. spread. This is a very modest level of model output uncertainty considering the amount of input uncertainty. The dissolved oxygen and pH confidence envelopes for the lower watershed (from Waikiki Rd. to the mouth) are even tighter.

Tables G-21 and G-22 shows that the primary driver of uncertainty around natural conditions DO predictions is shade. This makes sense, because the capacity of water to hold dissolved oxygen (and other gasses) depends on temperature. Cold water tends to have higher dissolved oxygen than warmer water. Also, shade regulates photosynthetically active radiation (PAR) reaching the stream, which affects light limitation of algae growth.

For pH, shade was also a primary driver of uncertainty, but channel geometry and stream flow also played an important role. Nutrients played only a secondary role in determining uncertainty for both dissolved oxygen and pH, consistent with the lack of nutrient sensitivity discussed above.

To conclude, although lack of certainty around natural conditions nutrient inputs led to corresponding lack of certainty in model nutrient predictions, the lack of algal sensitivity to nutrients in the model (and presumably in the real world as well) meant that uncertainty around nutrients did not translate to uncertainty around dissolved oxygen and pH predictions. The 90% confidence envelope covered about a 0.5 mg/L spread for dissolved oxygen, and a 0.1 S.U. spread for pH in the upper watershed. This small amount of model prediction uncertainty was mainly driven, not by nutrient input uncertainty, but rather by uncertainty around system potential shade and other non-nutrient related inputs.

Appendix H. RMA model inputs and calibration

RMA Tool Description

We used the River Metabolism Analyzer (RMA) tool (Pelletier, 2013) to simulate the effects of nutrients as well as other factors on DO and pH in tributary streams, as well as the portion of the Little Spokane River upstream of the outlet of Chain Lake. The RMA tool is available at http://www.ecy.wa.gov/programs/eap/models.html.

RMA is an Excel workbook that contains four methods for analyzing stream metabolism, using diel DO, pH, and temperature data. We used two of these methods, inverse modeling and predictive modeling. We did not use the other two methods, the delta method and night-time regression, as those are simpler methods that don't meet the needs of this study.

The inverse and predictive modeling tools in RMA predict diel DO and pH patterns using a simple equation/model with the following characteristics:

- Zero dimensional. The channel is simulated as a single "box" of water of defined depth. Width is not defined, nor are hydraulic characteristics such as flow, velocity, or transport.
- Temperature is specified, not simulated.
- Gross Primary Productivity (GPP) and Ecosystem Respiration (ER), once calibrated, are kept in proportion to one another and are attenuated by limiting nutrient concentration. Attenuation follows a Monod curve, with specified half-saturation constant.

In order to adequately simulate small tributary streams, which are largely groundwater-fed during the low-flow season, we modified the version of RMA used for this project to include bulk mixing of groundwater, with specified inputs for groundwater inflow rate, DO, and pH.

The model has the following four main rate parameters:

- Gross Primary Productivity (GPP)
- Ecosystem Respiration (ER)
- Reaeration (Ka)
- Photosynthetic Quotient (PQ; optional, but used for this project)

The inverse modeling method uses the PIKAIA genetic algorithm (Charbonneau and Knapp, 1995) to determine the optimum values for the rate parameters to match observed DO and pH. The approximate Bayesian computation method extends this capability by running PIKAIA multiple times with different random number seeds. This allows for analysis of the distribution of PIKAIA results, or simply for choosing the best results. The predictive modeling method then uses these rate parameter values to predict the effect of nutrient changes on DO and pH.

Model Inputs

We built a separate RMA model for each diel Hydrolab® monitoring location (with a few exceptions), and for each deployment date. Table H-1 lists the inputs used for each model. The basis for these inputs, unless otherwise noted are:

- Partial pressure of CO2 – annual atmospheric averages obtained from ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt
- Alkalinity, conductivity, limiting nutrient, limiting nutrient concentration – Ecology sample and measurement data
- Depth – Ecology channel survey data
- Cloud cover – Average cloud cover at Deer Park airport (KDEW) for all days of Hydrolab® deployment that the model run was based on
- Nutrient half-sat constant – Set to match RMA model sensitivity to nutrients to that of QUAL2Kw model. See the **Assessment of Model Sensitivity to Nitrogen and Phosphorus** section in Appendix G.

Table H-1. RMA model inputs for current/calibration conditions.

Location ID	Survey Date	Latitude	Longitude	Elevation (m)	Partial Presure of CO2	Alkalinity (mg/L)	Cond (uS/cm)	Depth (m)	Cloud Cover [h]	Limiting nutrient	Limiting nutrient conc. (ug/L) [g]	Nutrient half-sat. constant
55LSR-46.7	Jul 2015	48.1059	-117.1528	633	400.83	117	236	0.67	5.5%	P	7.9	1
	Aug 2015	48.1059	-117.1528	633	400.83	118	237	0.67	30.3%	P	6	1
55DRY-00.4	Jul 2010	47.9865	-117.2951	560	389.85	109.5	227	0.26	4.9%	P	22.7	1
	Aug 2010	47.9865	-117.2951	560	389.85	113.5	262 [f]	0.26	0.7%	P	18.45	1
	Jul 2015	47.9865	-117.2951	560	400.83	117	239	0.25	7.7%	P	22.6	1
	Aug 2015	47.9865	-117.2951	560	400.83	119	240	0.25	31.3%	P	20.6	1
55OTT-01.4	Jul 2015	48.0041	-117.3173	597	400.83	77.5 [a]	263	0.24	7.7%	P	15.2 [a]	1
	Aug 2015	48.0041	-117.3173	597	400.83	77.1 [a]	235	0.24	31.3%	P	17.7 [a]	1
55OTT-00.3	Jul 2010	47.9903	-117.3212	579	389.85	82.55	189	0.19	4.9%	P	21.9	1
	Aug 2010	47.9903	-117.3212	579	389.85	79.2	193	0.19	0.7%	P	20.6	1
	Jul 2015	47.9903	-117.3212	579	400.83	77.5	194	0.17	7.7%	P	15.2	1
	Aug 2015	47.9903	-117.3212	579	400.83	77.1	193	0.17	31.3%	P	17.7	1
55MOO-02.9	Jul 2015	48.1180	-117.2737	707	400.83	39.1	145	0.25	7.7%	P	10.5	1
	Aug 2015	48.1180	-117.2737	707	400.83	38.4	148	0.25	31.3%	P	10	1
55BUC-00.3	Jul 2015	48.1192	-117.4181	611	400.83	2.5 [b]	73	0.21	0.5%	N	40	7.2
	Aug 2015	48.1192	-117.4181	611	400.83	34.2	84	0.2	38.3%	N	15 [h]	7.2
55WBLS-07.7	Jul 2015	48.0607	-117.3994	589	400.83	2.5 [b]	160	1.65	0.5%	N	17 [h]	7.2
	Aug 2015	48.0607	-117.3994	589	400.83	82.4	172	1.65	30.3%	N	32 [h]	7.2
55BEAR-00.4	Jul 2015	47.9297	-117.3416	554	400.83	154	319	0.21	7.7%	P	29.3	1
	Aug 2015	47.9297	-117.3416	554	400.83	154	313	0.21	31.3%	P	22.7	1
55DEE-05.9	Jul 2015	47.9139	-117.2653	605	400.83	190	147	0.17	19.9%	P	42	1
	Aug 2015	47.9139	-117.2653	605	400.83	74.8	171	0.16	32.1%	P	29	1
55DEE-01.4	Jul 2015	47.8908	-117.3366	571	400.83	70.52 [c]	127	0.13	7.7%	N	272.5	7.2
55DEE-00.1	Aug 2010	47.8883	-117.3536	521	389.85	57.35	124	0.13	0.7%	P	44.95	1
	Jul 2015	47.8883	-117.3536	521	400.83	79.7	175	0.11	7.7%	P	25.3	1
	Aug 2015	47.8883	-117.3536	521	400.83	83.2	124	0.1	31.3%	P	21.6	1
55DRA-19.6	Aug 2015	47.9894	-117.4947	653	400.83	153 [d]	231	0.22	29.0%	N	91 [d]	7.2
55SPR-00.4	Jul 2015	47.9622	-117.4831	644	400.83	265.5	273	0.2	0.3%	P	9.2	1
	Aug 2015	47.9622	-117.4831	644	400.83	117	272	0.2	29.0%	P	7.7	1

Location ID	Survey Date	Latitude	Longitude	Elevation (m)	Partial Presure of CO2	Alkalinity (mg/L)	Cond (uS/cm)	Depth (m)	Cloud Cover [h]	Limiting nutrient	Limiting nutrient conc. (ug/L) [g]	Nutrient half-sat. constant
55DRA-16.4	Jul 2015	47.9537	-117.4878	641	400.83	239	273	0.3	0.3%	P	21.6	1
	Aug 2015	47.9537	-117.4878	641	400.83	124	278	0.23	29.0%	P	15.7	1
55DRA-13.2	Jul 2015	47.9320	-117.4985	626	400.83	404	296	0.32	0.3%	P	33.4	1
	Aug 2015	47.9320	-117.4985	626	400.83	138	302	0.3	29.0%	P	19.7	1
55WBDR-00.1	Jul 2015	47.9157	-117.4983	617	400.83	377	260	0.48	0.3%	P	52.1	1
	Aug 2015	47.9157	-117.4983	617	400.83	125	261	0.48	29.0%	P	38.7	1
55DRA-04.3	Jul 2015	47.8879	-117.4232	578	400.83	146	339	0.46	0.3%	P	17.3	1
	Aug 2015	47.8879	-117.4232	578	400.83	153	354	0.46	29.0%	P	21.5	1
55DRA-00.3	Jul 2010	47.8751	-117.3728	517	389.85	144	339	0.42	9.4%	P	38.55	1
	Aug 2010	47.8751	-117.3728	517	389.85	150.25	339	0.41	8.9%	P	32.35	1
	Jul 2015	47.8751	-117.3728	517	400.83	145	338	0.4	0.3%	P	20	1
55SFLD-01.1	Jul 2015	47.8708	-117.2378	610	400.83	2.5 [b]	48	0.06	7.7%	N	107	7.2
	Aug 2015	47.8708	-117.2378	610	400.83	22.1	54	0.04	24.2%	N	32	7.2
55LDP-00.1	Jul 2015	47.7972	-117.3783	498	400.83	218	454	0.24	7.7%	P	30.9	1
	Aug 2015	47.7972	-117.3783	498	400.83	223	458	0.24	31.3%	P	27.1	1
55LDP-00.0	Jul 2010	47.7960	-117.3797	495	389.85	151.5	314	0.25	14.1%	P	55.55	1
	Aug 2010	47.7960	-117.3797	495	389.85	217.5	487	0.25	6.6%	P	25.55	1
55DEA-20.2	Aug 2015	47.8819	-117.1350	931	400.83	11.4	37	0.12	24.4%	N	23 [h]	7.2
55DEA-13.8	Jul 2015	47.8298	-117.2077	586	400.83	2.5 [b]	42	0.15	0.5%	N	68	7.2
	Aug 2015	47.8298	-117.2077	586	400.83	16.1	49	0.14	24.4%	N	10 [h]	7.2
55DEA-09.2	Jul 2015	47.7875	-117.2489	561	400.83	2.5 [b]	120	0.29	0.5%	N	60.5 [e]	7.2
	Aug 2015	47.7875	-117.2489	561	400.83	37.225 [e]	76	0.22	24.4%	N	29.5 [e]	7.2
55DEA-00.6	Jul 2015	47.7937	-117.3771	497	400.83	169	373	0.31	0.5%	P	24.9	1
	Aug 2015	47.7937	-117.3771	497	400.83	190	402	0.3	24.4%	P	20.5	1
55DEA-00.2	Jul 2010	47.7956	-117.3808	495	389.85	116	257	0.33	9.4%	P	53.1	1
	Aug 2010	47.7956	-117.3808	495	389.85	154.25	372 [f]	0.31	6.6%	P	28.65	1
55DAR-00.2	Aug 2010	47.7847	-117.4173	491	389.85	220	529	0.24	8.9%	P	36.2	1
	Aug 2015	47.7847	-117.4173	491	400.83	216	516	0.23	31.3%	P	22.4	1

[a] Used values from 55OTT-00.3

[b] Lab result for alkalinity was a non-detect at 5 mg/L.

[c] Not sampled in 2015. Based on average values from 2010, corrected based on ratio of 2015 to 2010 values at Deer mouth.

[d] Used value from 55DRA-17.0

[e] Used average of values from 55DEA-13.8 and 55DEA-05.9.

[f] Used point conductivity measurement because we had qualified diel conductivity data from this deployment as an estimate.

[g] Expressed as inorganic nutrient fraction; i.e. soluble reactive phosphorus (orthophosphate) or dissolved inorganic nitrogen.

[h] Dissolved inorganic nitrogen results based on nitrate-nitrite and ammonia results near or at the detection limit. In these instances we calculated DIN using uncensored laboratory data, which means that the laboratory reported data down to the method detection limit (MDL) rather than the usual reporting limit (RL). These calculations should be considered estimates.

We estimated photosynthetically active radiation (PAR) using the SolRad calculation tool (Pelletier, 2012b) as follows:

- We calculated total solar radiation above the canopy using the Ryan-Stolzenbach radiation model. We used an atmospheric transmission coefficient value of 0.75, the same value that was used for QUAL2Kw modeling. We used the cloud cover values shown in Table H-1 to attenuate total radiation at this step.
- We estimated PAR above the canopy as 47% of total radiation.
- We then further attenuated PAR reaching the stream according to the current conditions estimate of effective shade (see Appendix I).

Calibration procedure and rate parameters

Table H-2 lists the rate parameters that we used identically for each RMA model. Except for the source of PAR data, the values are all generally suggested defaults.

Table H-2. Uniform rate parameters used in all RMA models.

Rate Parameter	Value
Source of photosynthetically active radiation (PAR) data	Input data (from SolRad)
Light extinction coefficient (m^-1)	0.3
Dominant primary producers	bottom algae
Light limitation model	half saturation
Light limitation parameter 'Kpar' (langleys/day)	75.00
Diel data to optimize for the inverse modeling method	dissolved oxygen and pH
Temperature parameter 'thetaGPP' for adjustment of gross primary production	1.070
Temperature parameter 'thetaER' for adjustment of ecosystem respiration	1.070
Temperature parameter 'thetaKA' for adjustment of reaeration	1.024
Oxygen inhibition model for ecosystem respiration	exponential
Oxygen inhibition parameter 'Kso' for ecosystem respiration (L/mg O2)	0.6
Respiratory quotient 'RQ' (moles CO2 eliminated per mole O2 consumed)	1.000
Limiting nutrient half saturation concentration 'Kp' (ug/L)	1 (for P); 7.2 (for N) [a]

[a] We selected these values for consistency with the QUAL2Kw model and with experimental literature. See the **Assessment of Model Sensitivity to Nitrogen and Phosphorus** section in Appendix G for explanation.

We used RMA's approximate Bayesian computation function to find optimal values for the main rate parameters. Because groundwater DO and pH data were not available, we paramterized these model inputs within certain bounds, to optimize model fit to observed instream data. This parameterization should not be construed as actual groundwater data, rather as reasonable inferences of what the groundwater characteristic may have been at a given reach and time. We performed this calibration for all models according to the following procedure:

- We estimated groundwater inflow based on available streamflow data according to the following equation:

$$G = \frac{\Delta Q \times 86400}{L \times W}$$

where: G = groundwater inflow (m/d)
ΔQ = increase in streamflow from upstream to downstream (cms)
L = stream distance across which the increase in streamflow occurred (m)
W = typical width of the stream (m)

Within PIKAIA, we set the bounds for the groundwater inflow parameter from 0.5 to 1.5 times this estimated value.

- We set the bounds for groundwater DO from 0 to 8 mg/L, and the bounds for groundwater pH from 6 to 8 S.U.
- We used the inverse modeling function to test appropriate bounds for the other rate parameters. We always constrained reaeration (Ka) below 200 /d, with a few exceptions. (See notes on Table H-3)
- In some cases the inverse modeling function produced model predictions with obvious phase-shift timing issues. For these cases, we calibrated reaeration manually to match the phase and timing of the observed diel DO pattern.
- We ran the approximate Bayesian function with 100 seeds to optimize Gross Primary Productivity, Ecosystem Respriation, Reaeration, Photosynthetic Quotient, Groundwater Inflow, Groundwater DO, and Groundwater pH.
- We recorded the results of this first calibration in a spreadsheet. For each location, we averaged the groundwater DO and groundwater pH results from multiple models. We then fixed the groundwater DO and pH values from multiple models at this average value, so that groundwater DO and pH values would be consistent across multiple models at a single location. If the resulting pH value was less than 7, then we used a value of 7 unless a value of less than 7 was absolutely necessary to get a good model fit.
- The groundwater DO and pH input values thus set, we ran the approximate Bayesian function again with 100 seeds to optimize Gross Primary Productivity, Ecosystem Respriation, Reaeration, Photosynthetic Quotient, and Groundwater Inflow.

Table H-3 lists the final rate parameter estimations for each model calibration.

Table H-3. RMA main rate parameters and groundwater input values.

Location ID	Survey Date	Rate parameter values				Groundwater input values			Remarks
		GPPmax ($gO_2/m^2/d$)	ER ($gO_2/m^2/d$)	Ka (/d)	PQ	Inflow (m/d)	DO (mg/L)	pH (S.U.)	
55LSR-46.7	Jul 2015	75.646	28.128	11.032	1.279	0.796	7.409	7.279	
	Aug 2015	78.135	25.913	8.955	1.222	0.447	7.409	7.279	
55DRY-00.4	Jul 2010	13.057	26.417	125.659	1.031	0.357	4.78	7	
	Aug 2010	3.277	0.246	53.618	1.462	0.624	4.78	7	
	Jul 2015	7.123	10.767	126.115	1.117	0.461	4.78	7	
	Aug 2015	14.127	41.508	196.08	1.004	0.156	4.78	7	slight low pH bias
55OTT-01.4	Jul 2015	9.623	4.738	19.631	1.31	0.373	6.443	7.531	
	Aug 2015	9.544	11.447	29.643	1.768	0.2	6.443	7.531	
55OTT-00.3	Jul 2010	11.562	30.015	212.162	1.306	0.78	5.637	7.148	Only able to calibrate DO, not pH; Ka bounds <400
	Aug 2010	6.138	0.094	218.718	1.718	0.806	5.637	7.148	Only able to calibrate DO, not pH; Ka bounds <400
	Jul 2015	20.571	14.721	231.853	1.002	0.67	5.637	7.148	Ka bounds <400
	Aug 2015	17.402	4.768	233.768	1.013	1.301	5.637	7.148	Ka bounds <400
55MOO-02.9	Jul 2015	4.473	2.468	13	1.002	0.288	4.433	6.628	Groundwater pH < 7 needed to calibrate
	Aug 2015	5.673	3.672	13	1.004	0.218	4.433	6.628	Groundwater pH < 7 needed to calibrate
55BUC-00.3	Jul 2015	2.12	3.728	11.148	1.713	0.034	6.967	7	Only able to calibrate DO, not pH
	Aug 2015	22.084	14.853	28.071	1.468	0.062	6.967	7	
55WBLS-07.7	Jul 2015	26.099	1.875	2.147	1.679	0.036	1.722	7	Only able to calibrate DO, not pH
	Aug 2015	13.315	2.053	0.741	1.788	0.094	1.722	7	
55BEAR-00.4	Jul 2015	0.556	1.978	20.156	1.591	0.061	5.291	7	
	Aug 2015	4.858	8.969	50.98	1.028	0.053	5.291	7	
55DEE-05.9	Jul 2015	2.027	6.321	18.486	1.086	0.103	7.933	6.13	Groundwater pH < 7 needed to calibrate
	Aug 2015	5.471	13.891	27.875	1.343	0.098	7.933	6.13	Groundwater pH < 7 needed to calibrate
55DEE-01.4	Jul 2015	1.891	1.455	9.945	1.639	0	n/a	n/a	
55DEE-00.1	Aug 2010	7.465	13.796	144.771	1.697	0.045	3.851	7.227	Only able to calibrate DO, not pH
	Jul 2015	8.75	5.051	76.696	1.007	0.113	3.851	7.227	
	Aug 2015	4.637	3.29	42.172	1.004	0.086	3.851	7.227	
55DRA-19.6	Aug 2015	6.585	3.896	3	1.785	0.028	1.142	7	
55SPR-00.4	Jul 2015	18.845	12.56	11.15	1.012	1.065	4.987	7.045	
	Aug 2015	28.988	11.257	9.085	1.675	1.811	4.987	7.045	
55DRA-16.4	Jul 2015	9.3	5.984	5	1.056	0.472	3.99	7.155	
	Aug 2015	9.017	3.821	3	1.019	0.255	3.99	7.155	
55DRA-13.2	Jul 2015	14.162	4.141	7	1.032	0.42	2.894	7.286	
	Aug 2015	14.208	5.702	5.696	1.162	0.137	2.894	7.286	
55WBDR-00.1	Jul 2015	13.697	10.722	16	1.788	0.251	6.679	7	
	Aug 2015	23.261	13.266	16	1.211	0.289	6.679	7	
55DRA-04.3	Jul 2015	33.33	11.68	8.628	1.756	0.094	3.341	7.674	
	Aug 2015	31.148	10.513	7.564	1.636	0.072	3.341	7.674	
55DRA-00.3	Jul 2010	6.254	1.992	30.988	1.129	0.107	6.945	6.633	Groundwater pH < 7 needed to calibrate
	Aug 2010	12.505	11.041	51.163	1.148	0.107	6.945	6.633	Groundwater pH < 7 needed to calibrate
	Jul 2015	19.1	17.929	60.678	1	0.043	6.945	6.633	Groundwater pH < 7 needed to calibrate
55SFLD-01.1	Jul 2015	1.435	1.761	31.429	1.789	0.035	1.472	7.911	Only able to calibrate DO, not pH
	Aug 2015	2.505	2.56	36.774	1.001	0.013	1.472	7.911	
55LDP-00.1	Jul 2015	23.333	12.536	55.911	1.736	0.338	3.102	7.325	
	Aug 2015	18.784	11.203	40.054	1.771	0.305	3.102	7.325	
55LDP-00.0	Jul 2010	20.034	21.632	75.09	1	0.211	3.102	7.325	
	Aug 2010	68.581	41.665	133.208	1.79	0.192	3.102	7.325	
55DEA-20.2	Aug 2015	13.933	9.25	95.067	1.247	0.093	1.124	7	
55DEA-13.8	Jul 2015	2.445	4.191	20.091	1.045	0.017	4.048	6.203	Only able to calibrate DO, not pH
	Aug 2015	3.333	2.567	11.516	1.371	0.01	4.048	6.203	
55DEA-09.2	Jul 2015	5.494	6.367	12	1.585	0.004	2.759	7.944	Only able to calibrate DO, not pH
	Aug 2015	13.404	7.627	11.281	1.013	0.005	2.759	7.944	
55DEA-00.6	Jul 2015	9.936	3.745	41.48	1.024	0.793	5.796	7.193	
	Aug 2015	11.015	7.657	41.489	1.005	0.742	5.796	7.193	
55DEA-00.2	Jul 2010	2.037	1.99	15	1.089	0.482	5.796	7.193	Only able to calibrate DO, not pH
	Aug 2010	22.282	9.296	58.377	1.281	0.745	5.796	7.193	
55DAR-00.2	Aug 2010	0.042	8.227	177.651	1.719	0.659	4.047	7.803	
	Aug 2015	15.608	21.418	135.286	1.011	0.423	4.047	7.803	

Model Goodness-of-fit

Table H-4 summarizes model goodness of fit to observed data for the Little Spokane RMA models. The Root Mean Squared Error (RMSE) statistic expresses the magnitude of typical model error for a variable in the same units as that variable. The overall bias statistic expresses the tendency of the model to over- or under-predict the value of a given variable. We calculated RMSE and bias by comparing modeled values for each 15-minute interval during the simulation to observed values from continuous Hydrolab® data.

The RMA models provide a good simulation of DO and pH in tributary streams and the upper Little Spokane River. The RMSEs for DO range from 0.03 – 0.36 mg/L, with a median value of 0.12 mg/L. RMSEs for pH range from 0.02 – 0.19 S.U. with a median value of 0.05 S.U. Median model bias was negligible; 0.00 for DO and +0.01 for pH.

These compare well to model results from other Ecology TMDL studies. Previous Ecology TMDL models had a mean RMSE for DO of 0.60 mg/L, with a range from 0.001 – 2.2 mg/L. Previous models had RMSE for pH ranging from 0.2 to 0.58 S.U. (Sanderson and Pickett, 2014).

Figure H-1 presents four selected calibration plots. The plots shown represent the best and the worst fits achieved for dissolved oxygen, and the best and the worst fits for pH. These plots demonstrate that even the worst RMA model fits achieved a reasonable simulation of dissolved oxygen and pH.

Table H-4. Summary statistics for goodness-of-fit for RMA models to observed data.

Location ID	Survey Date	DO RMSE (mg/L)	DO Overall bias (mg/L)	pH RMSE (S.U.)	pH Overall bias (S.U.)
55LSR-46.7	Jul 2015	0.30	+0.08	0.07	+0.02
	Aug 2015	0.23	-0.03	0.07	-0.04
55DRY-00.4	Jul 2010	0.05	-0.00	0.03	+0.00
	Aug 2010	0.06	-0.01	0.03	+0.02
	Jul 2015	0.06	-0.01	0.02	+0.01
	Aug 2015	0.05	+0.04	0.11	-0.11
55OTT-01.4	Jul 2015	0.19	+0.03	0.04	-0.02
	Aug 2015	0.09	+0.01	0.05	+0.03
55OTT-00.3	Jul 2010	0.14	+0.04	not calibrated for pH	
	Aug 2010	0.03	-0.00	not calibrated for pH	
	Jul 2015	0.07	+0.02	0.09	-0.02
	Aug 2015	0.04	-0.01	0.06	+0.01
55MOO-02.9	Jul 2015	0.15	-0.01	0.04	-0.00
	Aug 2015	0.11	-0.01	0.03	+0.00
55BUC-00.3	Jul 2015	0.06	-0.01	not calibrated for pH	
	Aug 2015	0.13	+0.01	0.04	+0.02
55WBLS-07.7	Jul 2015	0.10	-0.00	not calibrated for pH	
	Aug 2015	0.13	+0.02	0.05	-0.00
55BEAR-00.4	Jul 2015	0.05	-0.01	0.05	+0.03
	Aug 2015	0.05	-0.01	0.03	+0.00
55DEE-05.9	Jul 2015	0.10	-0.01	0.05	-0.00
	Aug 2015	0.19	-0.01	0.07	+0.05
55DEE-01.4	Jul 2015	0.12	-0.00	0.08	+0.05
55DEE-00.1	Aug 2010	0.07	-0.01	not calibrated for pH	
	Jul 2015	0.15	-0.02	0.12	-0.01
	Aug 2015	0.08	+0.02	0.06	-0.01
55DRA-19.6	Aug 2015	0.35	-0.04	0.07	+0.04
55SPR-00.4	Jul 2015	0.36	+0.15	0.04	-0.03
	Aug 2015	0.28	+0.10	0.10	+0.07
55DRA-16.4	Jul 2015	0.21	+0.10	0.05	+0.02
	Aug 2015	0.27	+0.04	0.05	-0.03
55DRA-13.2	Jul 2015	0.21	+0.09	0.08	+0.03
	Aug 2015	0.17	+0.07	0.08	-0.06
55WBDR-00.1	Jul 2015	0.19	+0.04	0.14	+0.10
	Aug 2015	0.18	+0.06	0.05	+0.03
55DRA-04.3	Jul 2015	0.33	+0.16	0.05	-0.02
	Aug 2015	0.22	+0.06	0.05	+0.02
55DRA-00.3	Jul 2010	0.11	-0.01	0.06	+0.01
	Aug 2010	0.09	-0.02	0.05	+0.02
	Jul 2015	0.14	-0.02	0.06	-0.02
55SFLD-01.1	Jul 2015	0.07	+0.01	not calibrated for pH	
	Aug 2015	0.13	+0.03	0.06	-0.06
55LDP-00.1	Jul 2015	0.12	+0.01	0.03	+0.01
	Aug 2015	0.13	+0.01	0.05	+0.04
55LDP-00.0	Jul 2010	0.18	+0.05	0.09	-0.08
	Aug 2010	0.20	+0.02	0.04	-0.00
55DEA-20.2	Aug 2015	0.04	-0.01	0.02	+0.01
55DEA-13.8	Jul 2015	0.08	-0.00	not calibrated for pH	
	Aug 2015	0.08	-0.01	0.07	+0.04
55DEA-09.2	Jul 2015	0.18	+0.02	not calibrated for pH	
	Aug 2015	0.34	+0.17	0.19	-0.13
55DEA-00.6	Jul 2015	0.09	-0.03	0.06	+0.02
	Aug 2015	0.05	-0.00	0.04	-0.01
55DEA-00.2	Jul 2010	0.08	-0.01	not calibrated for pH	
	Aug 2010	0.10	+0.01	0.03	+0.01
55DAR-00.2	Aug 2010	0.04	-0.00	0.04	+0.03
	Aug 2015	0.04	+0.00	0.03	-0.02

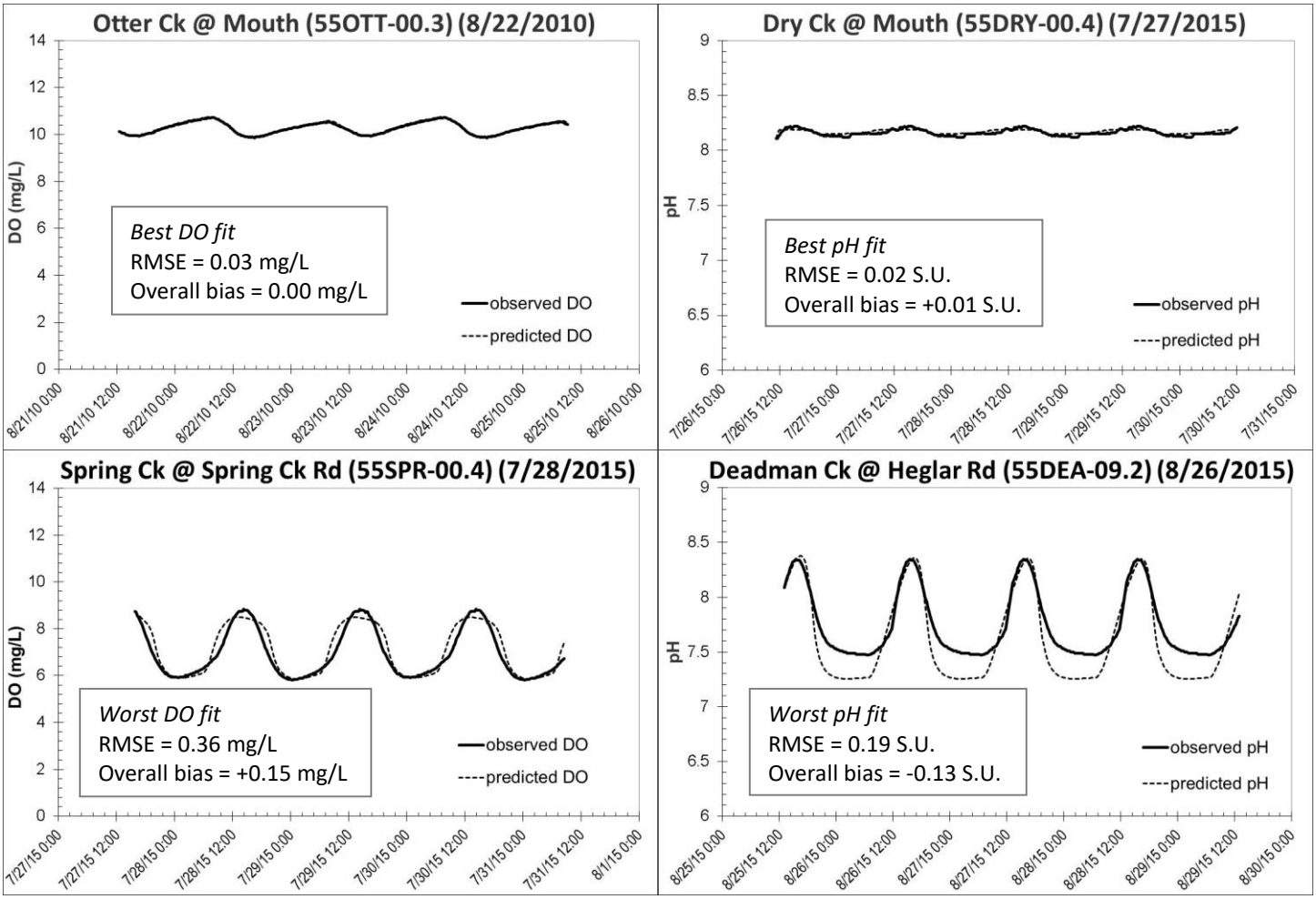


Figure H-1. Selected calibration plots for RMA models, showing the best and worst model fits for DO and pH.

$$RMSE = \sqrt{\frac{\Sigma(T_{modeled} - T_{observed})^2}{n}}$$

$$Bias = \frac{\sum(T_{modeled} - T_{observed})}{n}$$

Critical conditions scenarios

We used the calibrated RMA models to simulate critical climatic conditions. We adjusted water temperature inputs to reflect 90th percentile climate conditions. Appendix I details the methods used to estimate critical condition water temperatures.

Natural conditions scenarios

To simulate natural conditions, we adjusted a number of model inputs to reflect Ecology's best estimate of conditions that did not include human modifications. We made these input adjustsments to the critical conditions scenario, in order to represent natural conditions during extreme climatic conditions when streams are likely to be most responsive to changes in nutrients and other inputs.

Nutrients

Table H-5 presents natural condition nutrient inputs. We selected natural conditions phosphorus inputs by taking either 1) the lowest observed value from July-September 2015; or 2) the average of predicted natural conditions estimates for July-September as determined by the watershed analysis (Appendix F); whichever is lower.

We based natural conditions nitrogen inputs for groundwater-influenced areas on a value of 0.2 mg/L total nitrogen (see Appendix G for more discussion). For low-nitrogen sites, primarily in upland and low-groundwater areas, we used a value of 0.011 mg/L DIN . We calculated this value by taking the 10th percentile of DIN observed in Deadman Creek @ Park Bdy (55DEA-20.2) and Buck Creek @ Mouth (55BUC-00.3). Both these sites are good reference sites with respect to nitrogen. Neither site has any appreciable agricultural or residential development upstream. Upstream forest practices may impact Buck Creek, but this is unlikely to affect nitrogen. Because nitrogen levels with all their variability may be natural at these sites, taking the 10th percentile is a conservative assumption.

Table H-5. Current and natural conditions nutrient inputs for RMA models.

Location ID	Survey Date	Limiting nutrient	Current Limiting nutrient conc. (ug/L) [a b]	Natural Limiting nutrient conc. (ug/L) [a]
55LSR-46.7	Jul 2015	P	7.9	6 [c]
	Aug 2015	P	6	6 [c]
55DRY-00.4	Jul 2010	P	22.7	12.56 [d]
	Aug 2010	P	18.45	12.56 [d]
	Jul 2015	P	22.6	12.56 [d]
	Aug 2015	P	20.6	12.56 [d]
55OTT-01.4	Jul 2015	P	15.2	15.2 [c e]
	Aug 2015	P	17.7	15.99 [d e]
55OTT-00.3	Jul 2010	P	21.9	15.99 [d]
	Aug 2010	P	20.6	15.99 [d]
	Jul 2015	P	15.2	15.2 [c]
	Aug 2015	P	17.7	15.99 [d]
55MOO-02.9	Jul 2015	P	10.5	6.8 [c]
	Aug 2015	P	10	6.8 [c]
55BUC-00.3	Jul 2015	N	40	11 [f]
	Aug 2015	N	15	11 [f]
55WBLS-07.7	Jul 2015	N	17	11 [f]
	Aug 2015	N	32	11 [f]
55BEAR-00.4	Jul 2015	P	29.3	11.4 [c]
	Aug 2015	P	22.7	11.4 [c]
55DEE-05.9	Jul 2015	P	42	22.6 [c]
	Aug 2015	P	29	22.6 [c]
55DEE-01.4	Jul 2015	N	272.5	139.3
55DEE-00.1	Aug 2010	P	44.95	20 [c]
	Jul 2015	P	25.3	20 [c]
	Aug 2015	P	21.6	20 [c]
55DRA-19.6	Aug 2015	N	91	11 [f]
55SPR-00.4	Jul 2015	P	9.2	5.21 [d]
	Aug 2015	P	7.7	5.21 [d]
55DRA-16.4	Jul 2015	P	21.6	5.96 [d]
	Aug 2015	P	15.7	5.96 [d]
55DRA-13.2	Jul 2015	P	33.4	12.47 [d]
	Aug 2015	P	19.7	12.47 [d]
55WBDR-00.1	Jul 2015	P	52.1	30.2 [c]
	Aug 2015	P	38.7	30.2 [c]
55DRA-04.3	Jul 2015	P	17.3	12.94 [d]
	Aug 2015	P	21.5	12.94 [d]
55DRA-00.3	Jul 2010	P	38.55	12.35 [c]
	Aug 2010	P	32.35	12.35 [c]
	Jul 2015	P	20	12.35 [c]
55SFLD-01.1	Jul 2015	N	107	11 [f]
	Aug 2015	N	32	11 [f]
55LDP-00.1	Jul 2015	P	30.9	24.04 [c]
	Aug 2015	P	27.1	24.04 [c]

Location ID	Survey Date	Limiting nutrient	Current Limiting nutrient conc. (ug/L) [a b]	Natural Limiting nutrient conc. (ug/L) [a]
55LDP-00.0	Jul 2010	P	55.55	24.04 [c g]
	Aug 2010	P	25.55	24.04 [c g]
55DEA-20.2	Aug 2015	N	23	11 [f]
55DEA-13.8	Jul 2015	N	68	11 [f]
	Aug 2015	N	10	10 [c]
55DEA-09.2	Jul 2015	N	60.5	11 [f]
	Aug 2015	N	29.5	11 [f]
55DEA-00.6	Jul 2015	P	24.9	15.83 [d]
	Aug 2015	P	20.5	15.83 [d]
55DEA-00.2	Jul 2010	P	53.1	17.26 [d]
	Aug 2010	P	28.65	17.26 [d]
55DAR-00.2	Aug 2010	P	36.2	23.15 [d]
	Aug 2015	P	22.4	22.4 [c]

[a] Expressed as inorganic nutrient fraction; i.e. soluble reactive phosphorus (orthophosphate) or dissolved inorganic nitrogen.

[b] These are the same as the model inputs shown in Table H-1, we repeat them here for easy comparison. Refer to footnotes to Table H-1 for explanations of these values.

[c] Used lowest value observed during July-September 2015.

[d] Based on natural conditions TP estimations from watershed analysis (See Appendix F). Calculated as [Average inorg P:TP ratio observed during July-September 2015] * [Average of natural TP estimations from July-September 2015].

[e] Based on 55OTT-00.3.

[f] For N-limited sites with low background DIN, we used the 10th percentile of DIN values from reference sites.

[g] Calculated value for 55LDP-00.0 based on data from 55LDP-00.1. These sites are close together on the same stream with no obvious inputs occurring between them.

Shade

We applied the shade that would be expected to occur under natural conditions to the RMA models by adjusting the time-series temperature and PAR inputs to the model. Appendix I provides a detailed explanation of the calculation of this temperature adjustment. For PAR, we attenuated the above-canopy estimate obtained using SolRad using the system potential shade estimate from Appendix I.

Channel geometry

We used the RMA model to predict the effects of a 5% increase in water depth. This required two sets of changes:

- First, we adjusted the time-series temperature input to account for the temperature impacts of a depth increase. (See Appendix I, Table I-7.)
- Second, we adjusted the depth input in the RMA model to simulate the effects of increased depth on the ability of the water column to assimilate dissolved gasses.

Model sensitivity

The sensitivity algal productivity to instream nutrient concentrations in RMA is controlled by the rate parameter "limiting nutrient half-saturation concentration (Kp)". We set this parameter to 1 ug/L for phosphorus and 7.2 ug/L for nitrogen. These values are consistent with the assessed nutrient sensitivity of the QUAL2Kw model, and with experimental literature. See the **Assessment of Model Sensitivity to Nitrogen and Phosphorus** section in Appendix G, as well as Figure G-4 for further discussion and illustration.

One potential issue relating to RMA predictions of DO and pH under varying nutrient conditions has to do with the prevalence of subsaturated DO conditions in small tributary streams. RMA simulates DO and pH as a function of productivity, respiration, reaeration, and groundwater mixing. If DO values throughout the day average below the saturation point, and if low-DO groundwater mixing is insufficient to explain this, then RMA will require a Gross Primary Productivity-to-Ecosystem Respiration (GPP:ER) ratio of less than 1 to accurately predict this condition. This could indicate that some (or much) of the respiration is from sediment oxygen demand (SOD), heterotrophic bacteria, animals, or other sources not directly linked to algal productivity.

RMA assumes that, as nutrient concentrations are reduced and algal productivity is attenuated, ER drops proportionally to GPP. If ER was a lot higher than GPP to begin with, that will mean a much larger reduction in ER than GPP. This results in a prediction that, in addition to reducing the size of diel DO swings, reducing nutrients will also push overall DO upward. (GPP pushes DO upward and ER pushes DO downward.) If some or much of the respiration occurring in the stream is actually not linked to algal productivity, then this assumption might be inaccurate. Theoretically it might be possible to address this by designating a portion of the ER as "algal linked" and only attenuating that portion of the ER with GPP. However, this would require significant code modifications to RMA, and determining the portion of "algal linked" ER could be problematic.

As it is, these RMA model predictions may be conservative. That is, RMA may be overpredicting the sensitivity of instream DO and pH to nutrients in some locations, and using this model may result in more stringent allocations. This is an acceptable TMDL approach, and we are considering this part of an implicit margin of safety.

Table H-6 presents GPP:ER ratios for each RMA model. Models with extremely low ratios (perhaps below 0.5) are most likely to be affected by this issue. However, at some sites (e.g. 56OTT-00.3 and 56DAR-00.2) reaeration is so high that the model is not very sensitive to GPP or ER, and in such cases the ratios are almost meaningless. Refer to Table H-3 for reaeration parameters.

Table H-6. Predicted daily average GPP:ER ratios for calibration conditions in RMA models.

Location ID	RMA predicted daily average GPP:ER			
	Jul 2010	Aug 2010	Jul 2015	Aug 2015
55LSR-46.7			0.945	0.895
55DRY-00.4	0.187	4.385	0.246	0.109
55OTT-01.4			0.787	0.284
55OTT-00.3	0.157	23.928	0.562	1.292
55MOO-02.9			0.690	0.515
55BUC-00.3			0.192	0.339
55WBLS-07.7			3.751	1.757
55BEAR-00.4			0.105	0.175
55DEE-05.9			0.130	0.138
55DEE-01.4			0.541	
55DEE-00.1		0.188	0.671	0.470
55DRA-19.6				***0.573***
55SPR-00.4			0.589	0.861
55DRA-16.4			0.616	0.806
55DRA-13.2			1.394	0.884
55WBDR-00.1			0.499	0.588
55DRA-04.3			1.139	1.046
55DRA-00.3	1.296	0.411	0.431	
55SFLD-01.1			0.298	***0.277***
55LDP-00.1			0.735	0.573
55LDP-00.0	0.366	0.558		
55DEA-20.2				0.324
55DEA-13.8			***0.216***	0.261
55DEA-09.2			***0.333***	***0.530***
55DEA-00.6			1.073	0.496
55DEA-00.2	0.419	0.848		
55DAR-00.2		0.002		0.223

Legend:

Bold Italic Underline	Models that predict a nutrient-linked DO impact of 0.2 mg/L or more, indicating the need for a nutrient load reduction.
Unshaded	Low reaeration sites (Ka < 25)
Light green	Medium reaeration sites (25 < Ka < 100)
Dark green	High reaeration sites (Ka > 100)

Appendix I. Landscape shade and temperature analysis for RMA models

The RMA model does not simulate temperature. Rather, RMA accepts diel water temperature data, such as would be collected by a deployed Hydrolab® sonde, as an input. The model uses this specified temperature input to calculate dissolved oxygen and total inorganic carbon saturation points, as well as to adjust gross primary productivity (GPP) and ecosystem respiration (ER) rates for temperature effects.

However, it was important to evaluate the potential effects of temperature changes resulting from riparian shade improvements to DO and pH. This appendix summarizes the landscape shade and temperature analysis method that we used to perform this evaluation. This method is an adaptation of a method developed by the EPA (Leinenbach, 2016a-e). The results of this analysis form the basis of the load allocations for heat and shade for tributary streams and the upper Little Spokane River. We did *not* use this method for the mainstem Little Spokane River QUAL2Kw model, which instead used shade inputs based on those from the *Little Spokane River Fecal Coliform Bacteria, Temperature, and Turbidity TMDL* (Joy and Jones, 2012).

We used the shade.xls model (Ecology, 2003) to simulate shade on all perennial streams in the Little Spokane watershed, at 1-km segments.

GIS analyses

We performed Geographic Information System (GIS) analyses to provide the necessary inputs to the shade model. The inputs required at each 1-km segment include elevation, aspect, bankfull width, topographic shade, vegetation height, vegetation density, and vegetation overhang.

Elevation

We used the TTools toolbar for ArcGIS (Ecology, 2015) to sample the elevation at the downstream end of each 1-km segment.

Aspect

We used ArcGIS's Linear Direction Mean tool to calculate the average aspect of each 1-km stream segment. This provides the overall aspect for the entire segment, rather than just the aspect at a single node (Figure I-1).

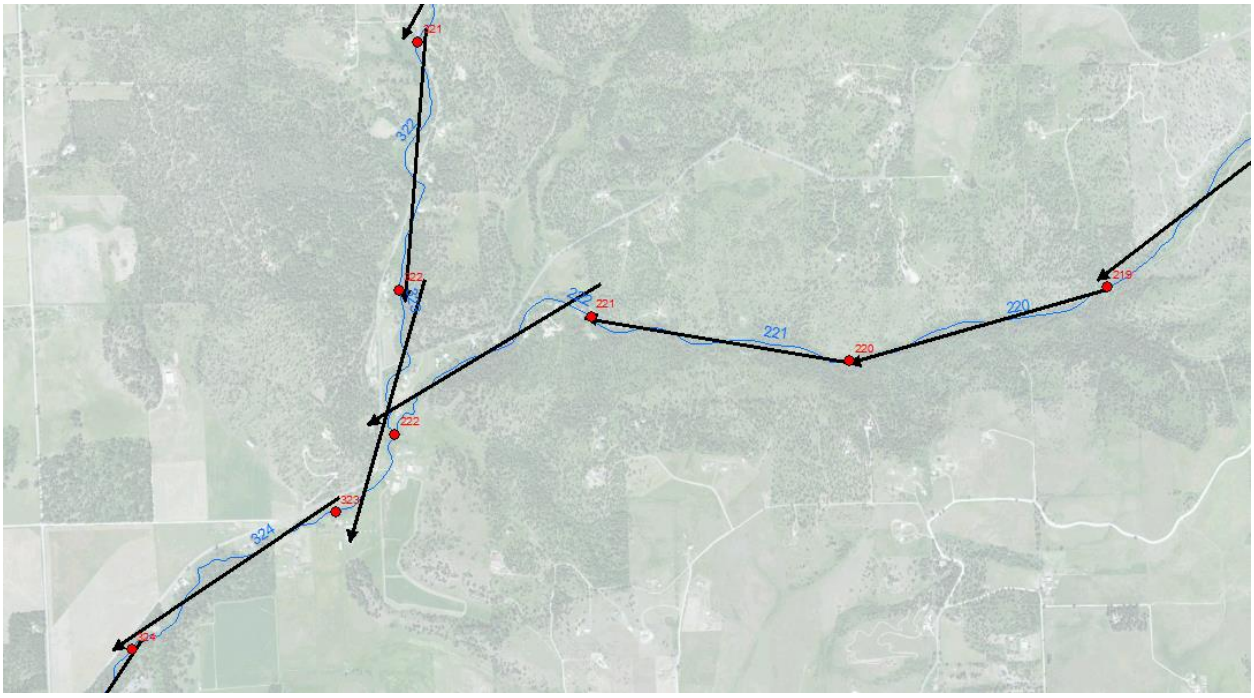


Figure I-1. Example of aspect directions calculated using Linear Direction Mean tool.

The blue and red numbers are segment/node labels, and do not represent direction.

Bankfull Width

We estimated bankfull width as a function of the upstream watershed area at each segment node, and of the average annual precipitation occurring in that drainage area. We used the ArcHydro toolbar and the Washington State 10m DEM to calculate the upstream watershed area at each segment node . We then sampled the average annual precipitation for the contributing drainage area to each node from the DayMet mean annual precipitation dataset. To accomplish this, Ecology GIS staff customized a specialized Python code block obtained from ESRI, which allows for the calculation of zonal statistics with a feature class containing overlapping polygons, in this case the heavily nested watershed boundaries representing upstream drainage areas for each node. (The Zonal Statistics tool in ArcGIS normally cannot handle feature classes containing overlapping polygons.)

We evaluated the relationship between contributing watershed area, mean annual precipitation, and bankfull width using all observed width data available. This included all locations where we performed channel surveys, as well as the Little Spokane River where we digitized the banks. We selected the widths corresponding to typical March-May flow conditions as an approximation of bankfull widths.

Davies et al. (2007) as well as Beechie and Imaki (2013) have described this relationship using an equation of the following form:

$$W_{bf} = x * A^{y} * P^{z}$$

where:

W_{bf} = bankfull width (m)
A = contributing watershed area (km^2)
P = mean annual precipitation in contributing watershed area (cm/yr)
x = coefficient
y = area exponent
z = precipitation exponent

We used the PIKAIA genetic algorithm (Charbonneau and Knapp, 1995) to find optimal values for *x*, *y*, and *z* for the Little Spokane watershed. Table I-1 presents the values used in this study, along with those used for ecoregion-level analyses in the Pacific Northwest.

Table I-1. Parameter values used to relate bankfull width to watershed area and precipitation in this and other area studies.

Region/Reference	*x* (coefficient)	*y* (area exponent)	*z* (precipitation exponent)
This study	0.063	0.508	0.462
Puget Sound (Davies et al., 2007)	0.042	0.480	0.74
Columbia basin (Beechie and Imaki, 2013)	0.177	0.379	0.453

Figure I-2 compares observed and predicted watershed area and bankfull widths in the Little Spokane watershed. Because of the inherent variability of channel geometry, we consider bankfull widths calculated by this method to be estimates.

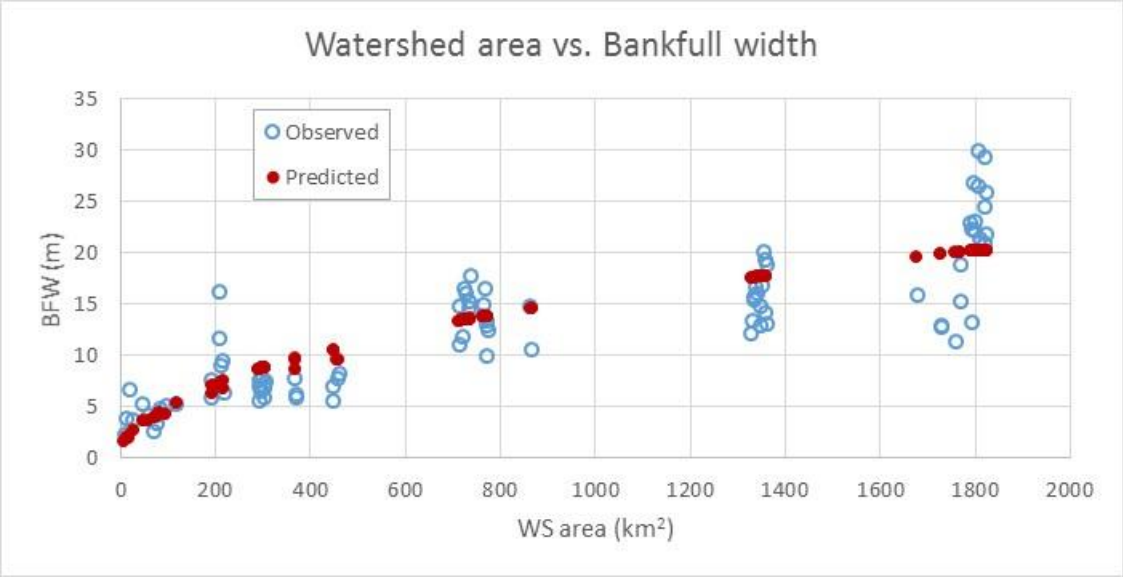


Figure I-2. Observed and predicted bankfull widths using watershed area and precipitation calculation method.

Topographic Shade

We used TTools (Ecology, 2015) to calculate topographic shade to the east, south, and west at the downstream end of each 1-km segment.

Vegetation height, density, and overhang

We sampled vegetation height and density from the U.S. Forest Service and U.S. Department of the Interior LANDFIRE spatial datasets (LANDFIRE, 2016). We used the Existing Vegetation Height (EVH) dataset to find height, and the Existing Vegetation Cover (EVC) dataset to find density.

For each of these spatial datasets, we assigned a height or density value to each pixel category according to the mid-range of described values. For example, in the EVH dataset, we assigned the "Forest Height 10 to 25 meters" category a height value of 17.5m; in the EVC dataset, we assigned the "Tree Cover >=40 and <50%" category a density value of 45%. For each 1km stream segment, we used a flat-end 100 ft buffer polygon defined around the stream center to sample a 1m resolution resampled version of the EVH or EVC cover (Figure I-3). Then, for each segment, we calculated a weighted average height or density based on the relative frequency of pixel types found in the 100-ft buffer zone, and the values assigned to each pixel type.

We defined vegetation overhang as 10% of vegetation height, a typical shade modeling practice where explicit overhang data is not available.

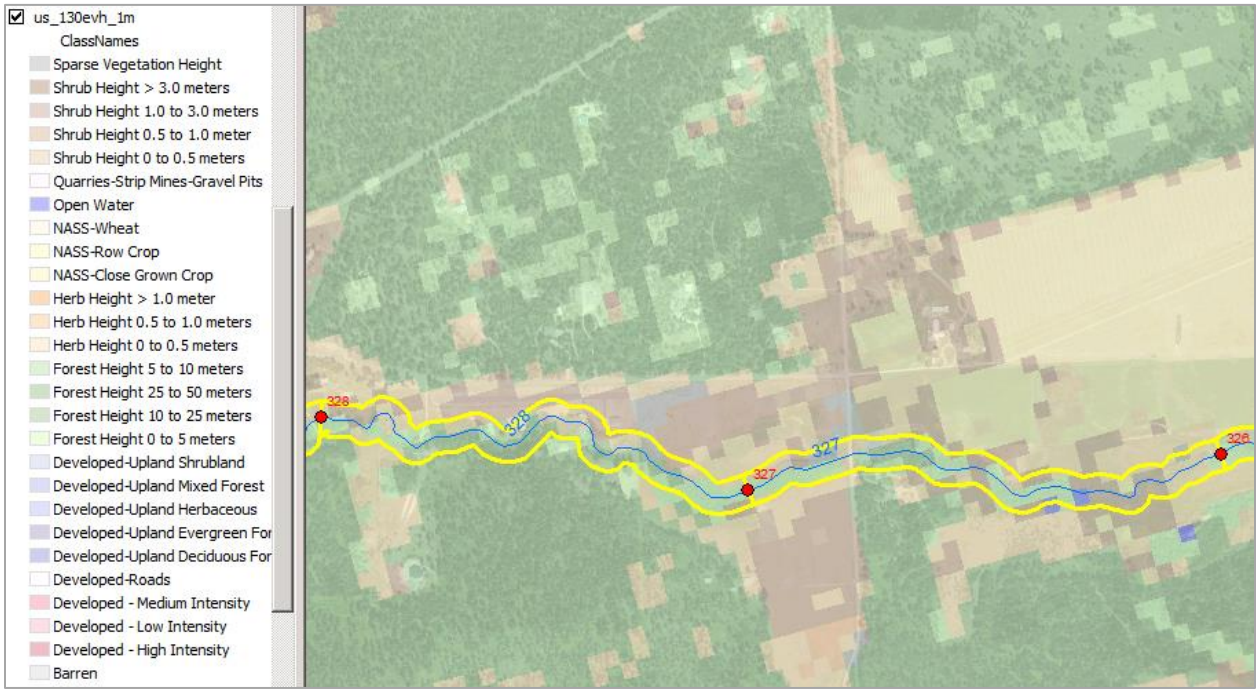


Figure I-3. Example of LANDFIRE Existing Vegetation Height (EVH) coverage and 100-ft flat end buffer polygons defined for each 1-km stream segment.

Watershed-wide shade results

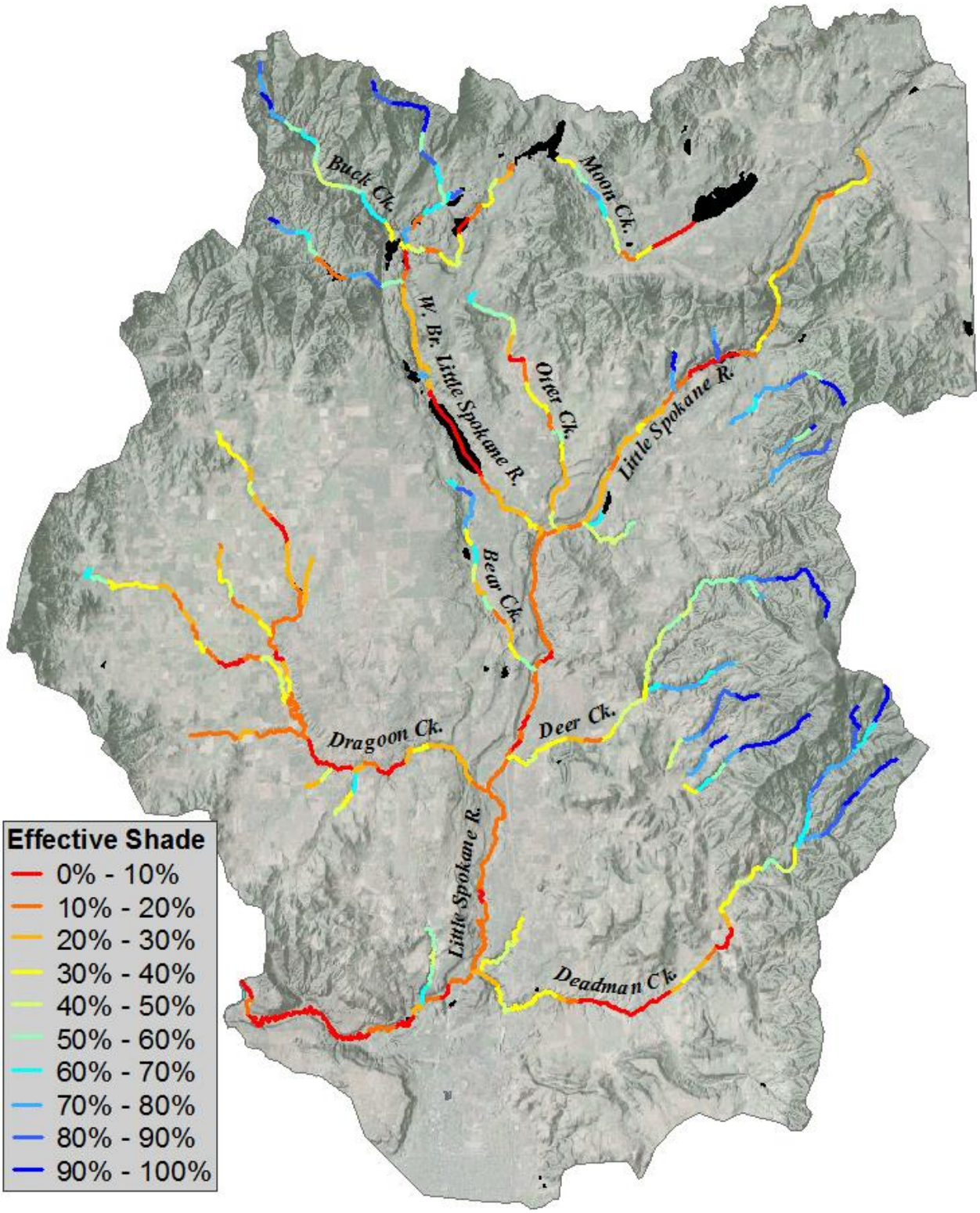


Figure I-4. Watershed-wide shade predictions

This map reflects shade conditions under current riparian conditions.

Comparison with mainstem shade model results

We evaluated the comparability between this watershed-wide shade modeling effort and the shade model from the Little Spokane River Fecal Coliform Bacteria, Temperature, and Turbidity TMDL (Joy and Jones, 2012), which we had adapted for use with the Little Spokane River QUAL2Kw model in this project. We compared longitudinal shade results along the Little Spokane River, the only area of overlap between the two approaches, side-by-side (Figure I-5). Although the results from the two approaches do not agree exactly, the two approaches do provide overall shade estimates in the same general range of values. Given the imprecise and heterogeneous nature of shade estimates generally, this is an adequate level of agreement.

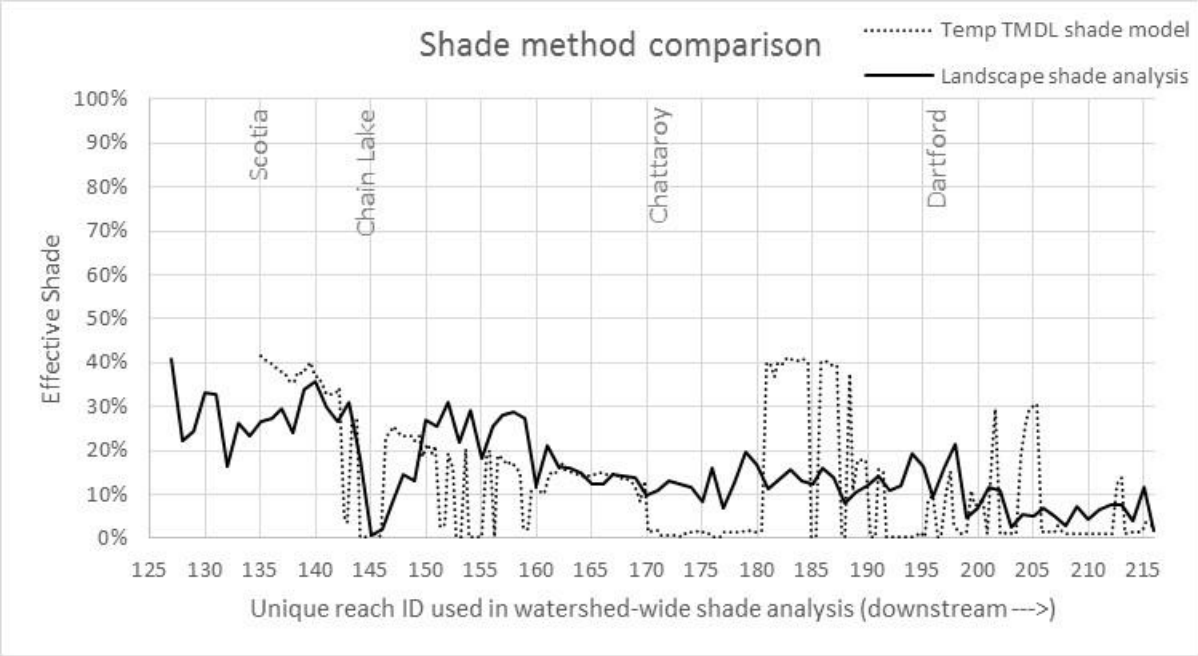


Figure I-5. Comparison between watershed-wide shade method and temperature TMDL shade model.

System Potential Shade

We defined system potential shade using the LANDFIRE Environmental Site Potential (ESP) dataset. We assigned each of 109 pixel categories to one of four potential vegetation categories with corresponding height and density characteristics (Table I-2).

Table I-2. Vegetation categories used to define system potential shade.

Potential Vegetation Category	Height (m)	Density
Conifer Forest	30	50%
Deciduous Riparian	10	60%
Prairie/Dryland Shrub/Open	1	50%
No Vegetation	0	0%

We used 100-ft flat-end buffer polygons to sample a 1-meter resolution resampled version of the ESP coverage, and calculated weighted averages for height and density in the same manner as we had done previously for current conditions height and density. We again defined overhang as 10% of height. We reduced bankfull widths by 5% compared to current conditions, consistent with the QUAL2Kw model natural condition scenario. We re-ran the shade model with these altered inputs. In the occasional instances where the system potential shade prediction was lower than the current shade prediction, we set the system potential shade prediction to the current shade prediction by default.

Figure I-6 shows current and system potential shade predictions throughout the watershed.

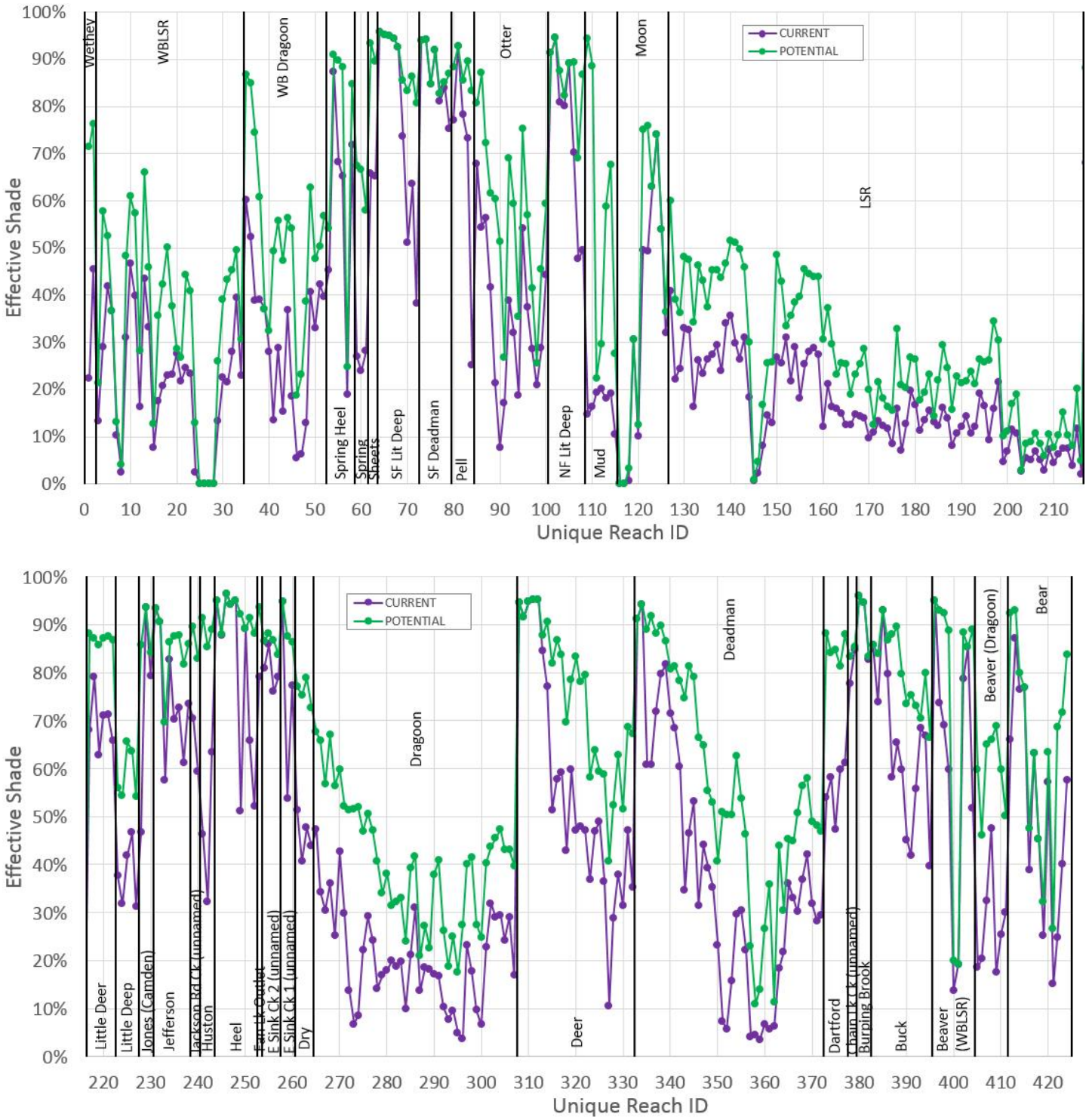


Figure I-6. Watershed-wide current and potential shade predictions.

Unique reach IDs run upstream to downstream within each stream. Each value of one unique reach ID corresponds approximately to 1km stream length.

Temperature modeling

We used the RMA modeling approach at 27 separate sites. Modeling temperature separately at each of these sites was not practical, both because of the amount of time that would be required, and because full-season continuous temperature data were not available for most of these sites. Instead, we used an approach which applied the results from representative locations to a variety of other locations.

Site categorization

First, we separated RMA model locations into three categories according to their degree of likely groundwater influence (Table I-3). We did this according to the average groundwater inflow value (m/d) used in RMA models for a given site (See Appendix H, Table H-3 and accompanying text). Figure I-7 illustrates how we made this determination. Generally, we expect locations with a large degree of groundwater influence to have smaller diel temperature swings, and to be cooler overall, while locations with little groundwater influence should have larger diel temperature swings, and be warmer overall. We also took seepage flow data into account. It is reasonable to expect that temperature in groundwater-dominated streams will be less sensitive to changes in shade than temperature in streams with minimal groundwater influence would be.

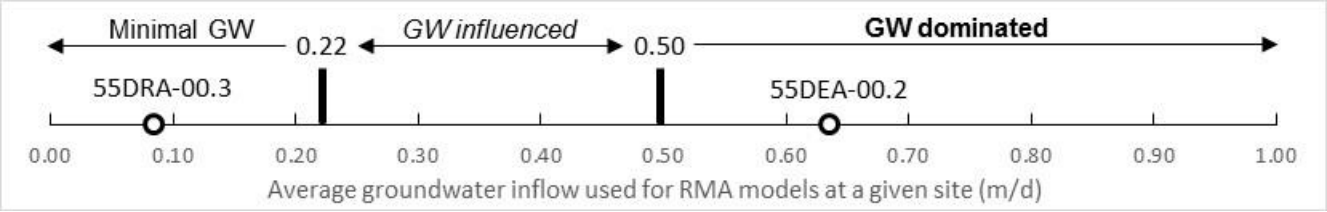


Figure I-7. Number line diagram showing groundwater categorization method.

We classified groundwater inflow volumes of less than 0.22 m/d as "minimal GW," volumes between 0.22 and 0.50 m/d as "GW influenced," and volumes of greater than 0.50 m/d as "GW dominated." We used 55DRA-00.3 (Dragoon Creek at mouth) to represent "minimal GW" locations, and 55DEA-00.2 (Deadman Creek blw Little Deep Ck) to represent "GW dominated" locations.

Table I-3. RMA model locations categorized by probable degree of groundwater influence.

Location ID	Sampling Location	Degree of GW influence
55LSR-46.7	LSR @ Scotia	**GW dominated**
55DRY-00.4	Dry Ck @ Mouth	*GW influenced*
55OTT-01.4	Otter Ck @ 2nd Valley Rd xing	minimal GW
55OTT-00.3	Otter Ck @ Mouth	**GW dominated**
55MOO-02.9	Moon Ck @ Hwy 211	*GW influenced*
55BUC-00.3	Buck Ck @ Mouth	minimal GW
55WBLS-07.7	WBLSR @ Fan Lk Rd	minimal GW
55BEAR-00.4	Bear Ck @ Mouth	minimal GW
55DEE-05.9	Deer Ck abv Little Deer Ck	minimal GW
55DEE-01.4	Deer Ck @ Elk-Chattaroy Rd	minimal GW
55DEE-00.1	Deer Ck @ Mouth	minimal GW
55DRA-19.6	Dragoon Ck @ Mongomery Rd	minimal GW
55SPR-00.4	Spring Ck @ Spring Ck Rd	**GW dominated**
55DRA-16.4	Dragoon Ck @ Hwy 395 nr Deer Park	*GW influenced*
55DRA-13.2	Dragoon Ck abv WB Dragoon Ck	*GW influenced*
55WBDR-00.1	WB Dragoon Ck @ Mouth	*GW influenced*
55DRA-04.3	Dragoon Ck @ North Rd	minimal GW
55DRA-00.3	Dragoon Ck @ Mouth	minimal GW
55SFLD-01.1	SF Little Deep Ck @ Day-Mt Spokane Rd	minimal GW
55LDP-00.1	Little Deep Ck @ Shady Slope Rd	*GW influenced*
55LDP-00.0	Little Deep Ck @ Mouth	*GW influenced*
55DEA-20.2	Deadman Ck @ Park Bdy	minimal GW
55DEA-13.8	Deadman Ck @ Holcomb Rd	minimal GW
55DEA-09.2	Deadman Ck @ Heglar Rd	minimal GW
55DEA-00.6	Deadman Ck @ Shady Slope Rd	**GW dominated**
55DEA-00.2	Deadman Ck blw Little Deep Ck	**GW dominated**
55DAR-00.2	Dartford Ck @ Mouth	**GW dominated**

rTemp model inputs and calibration

Having categorized the RMA sites, we then used the rTemp model (Pelletier, 2012) to predict the response of stream temperature to changes in shade on creeks with different degrees of groundwater influence:

- We chose Deadman Creek blw Little Deep Ck (55DEA-00.2) to represent groundwater-dominated locations.
- We chose Dragoon Creek at mouth (55DRA-00.3) to represent locations with minimal groundwater influence.
- We assumed that Groundwater-influenced locations would fall midway between the Deadman and Dragoon Creek results.

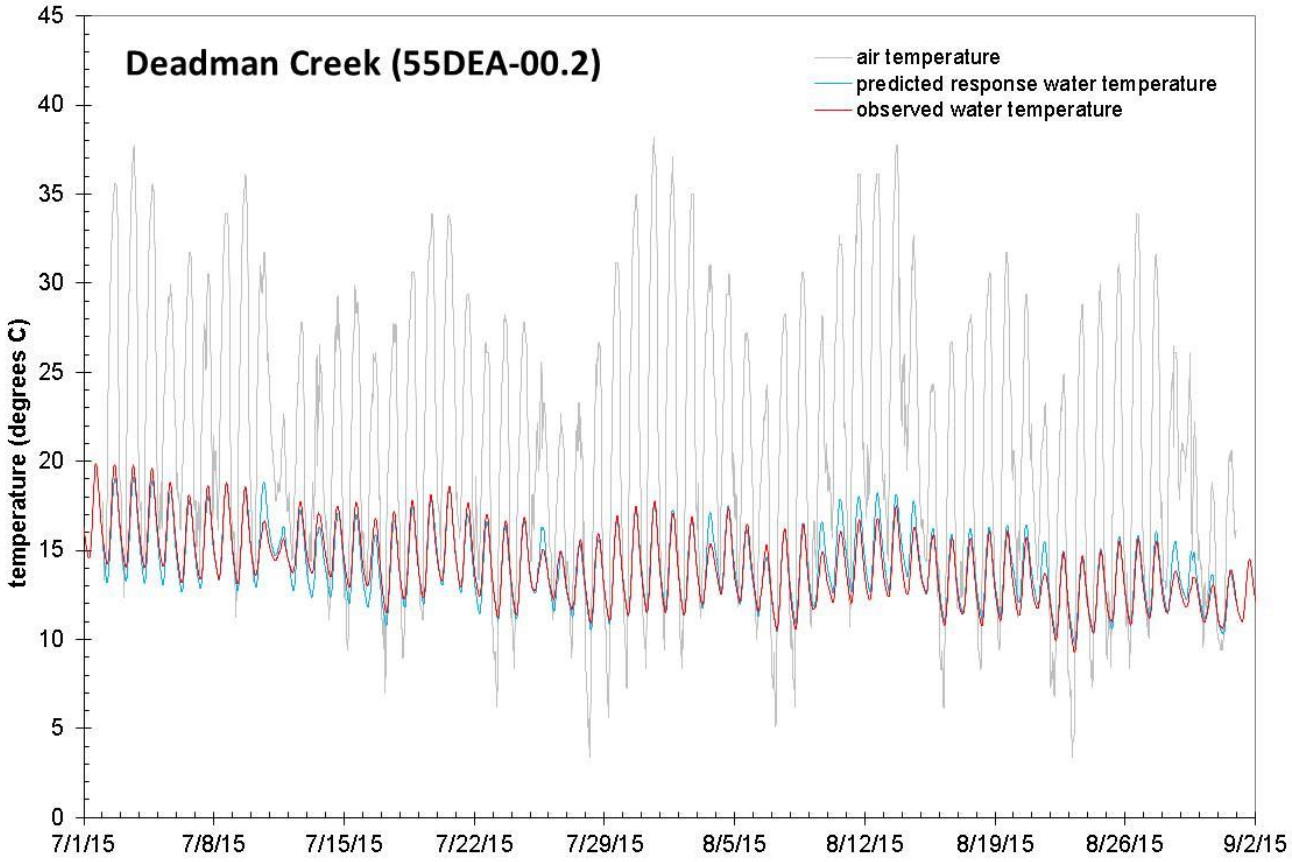
Table I-4 lists the model input and rate values used for these two rTemp models. Table I-5 shows the goodness-of-fit statistics for the temperature calibrations, and Figure I-8 shows model calibration plots. We ran both models for the time period from July 1 – August 31, 2015.

Table I-4. Model input and rate values for Deadman and Dragoon Ck rTemp models.

Input or rate description	Input value used Deadman Ck. (55DEA-00.2)	Input value used Dragoon Ck. (55DRA-00.3)	rationale
Meteorological input data	NWS Deer Park Airport (KDEW)		
Water depth (m)	0.32	0.40	Average of flow conditions during July and August 2015 diel Hydrolab® surveys, functional depth calculated from channel surveys
Effective shade (fraction)	0.33	0.27	Average of current shade estimated from watershed-wide shade analysis, across the 4 km (Deadman) and 6 km (Dragoon), or 12 hours travel time, upstream.
Effective windspeed (fraction)	1	1	Uncorrected wind data produced optimum model results
Groundwater temperature (°C)	11	11	Consistent with QUAL2Kw model
Groundwater inflow (m/day)	0.74	0.15	Deadman: 0.139 cms across 5.06m x 3.2km Dragoon: 0.042 cms across 6.97m x 3.5km
Sediment thermal conductivity (W/m/°C)	1.76	1.76	Recommended value for rocky substrate
Sediment thermal diffusivity (cm^2/sec)	0.0118	0.0118	Recommended value for rocky substrate
Sediment thermal thickness (cm)	50	50	Within range of recommended values when hyporheic exchange is occurring
Hyporheic exchange (m/day)	1	0.68	Deadman: 0.2 x 0.292 cms across 5.06m x 1km Dragoon: 0.15 x 0.368 cms across 6.97m x 1km
Ryan-Stolzenbach atmospheric transmission factor	0.8	0.8	Typical default value
Atmospheric longwave radiation model for clear sky	Satterlund	Satterlund	Commonly used longwave radiation model
All other rate settings	default/recommended values		

Table I-5. Goodness-of-fit statistics for Deadman and Dragoon Ck rTemp models.

Statistic	Deadman Ck. (55DEA-00.2) daily max	Deadman Ck. (55DEA-00.2) daily min	Deadman Ck. (55DEA-00.2) daily avg	Dragoon Ck. (55DRA-00.3) daily max	Dragoon Ck. (55DRA-00.3) daily min	Dragoon Ck. (55DRA-00.3) daily avg
RMSE (°C)	0.80	0.55	0.53	1.08	0.86	0.74
Overall bias (°C)	+0.18	-0.19	+0.08	+0.22	-0.57	-0.08



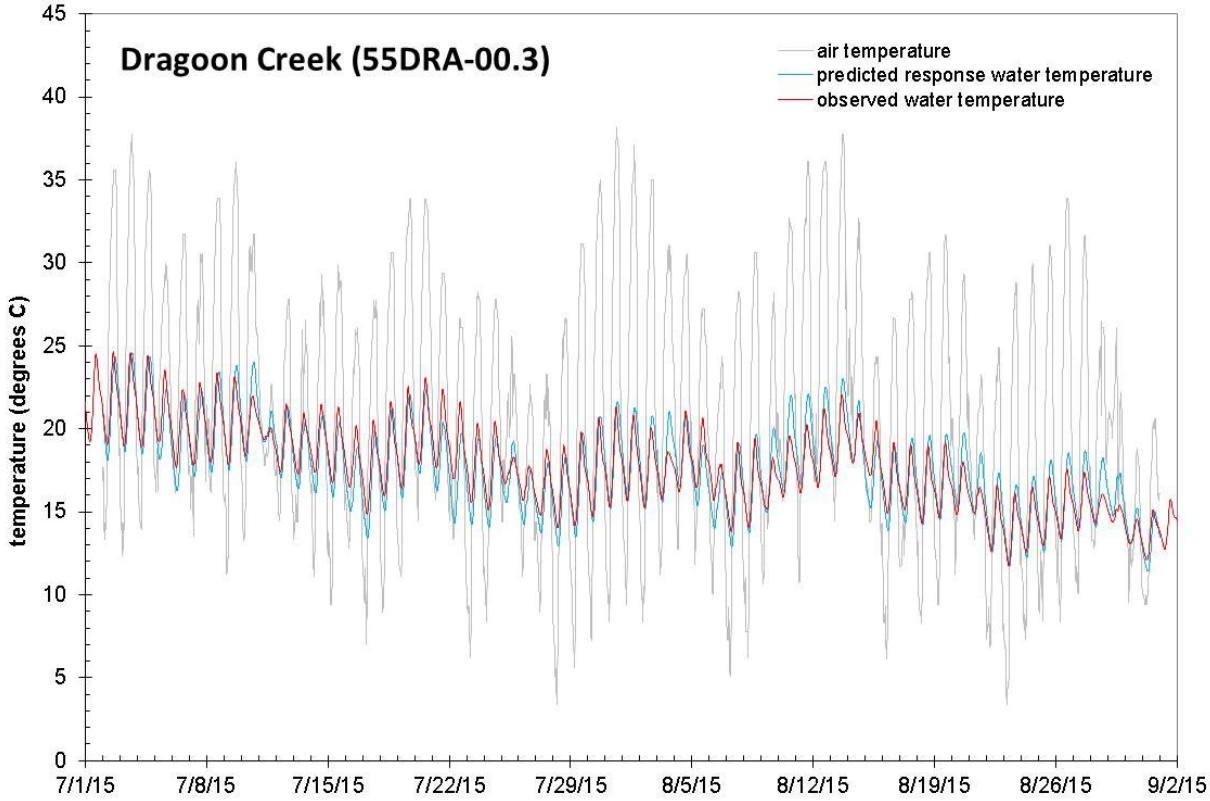


Figure I-8. Calibration plots for Deadman and Dragoon Ck rTemp models.

Sensitivity of stream temperature to shade

We used the calibrated rTemp models to evaluate the sensitivity of temperature to changes in shade for both of the two locations (Figure I-9). The models results predicted that the location with minimal groundwater influence (Dragoon Creek) would be considerably more sensitive to shade changes than the location with large groundwater influence (Deadman Creek). Table I-6 presents the predicted sensitivity expressed as expected temperature change (°C) per percentage point change in effective shade.

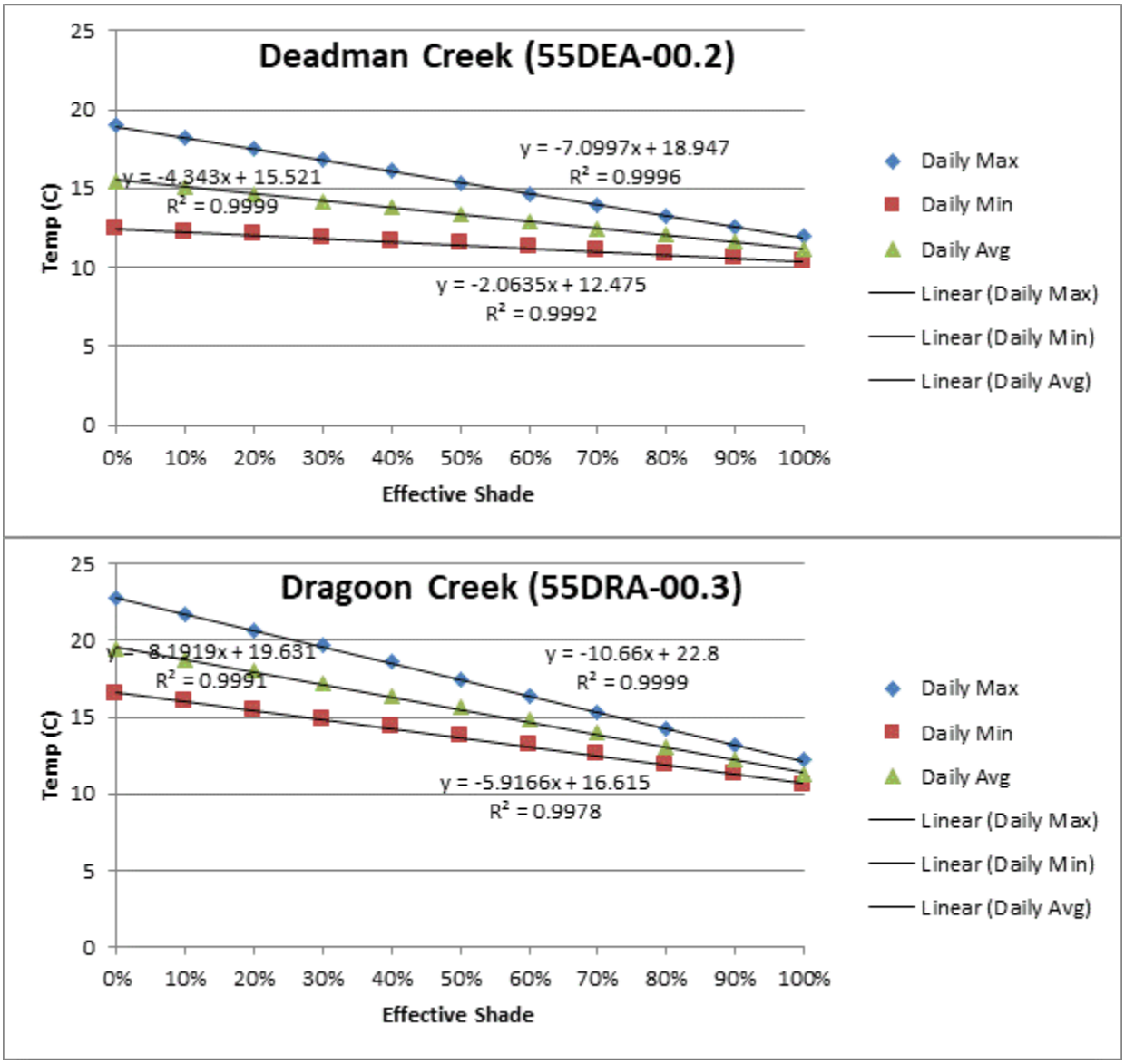


Figure I-9. Predicted sensitivity of stream temperature to shade for Deadman Creek (55DEA-00.2) and Dragoon Creek (55DRA-00.3).

The temperatures shown represent the average of predicted temperatures for each day starting 7/5/15 through the end of the model run on 8/31/15. The reason for starting the average on 7/5 rather than 7/1 is that the first few days of the model run function as a "warm-up" period to allow the model to equilibrate to the various shade inputs.

Table I-6. Predicted sensitivity of stream temperature to shade, expressed per percentage point change in effective shade, for each groundwater category.

Groundwater category	Representative location	Predicted change in stream temperature (°C) per percentage point change in effective shade		
		Daily max	Daily min	Daily avg
GW dominated	Deadman Ck (55DEA-00.2)	0.070	0.021	0.043
GW influenced	Values halfway between Deadman and Dragoon Cks	0.088	0.040	0.063

Groundwater category	Representative location	Predicted change in stream temperature (°C) per percentage point change in effective shade		
		Daily max	Daily min	Daily avg
Minimal GW	Dragoon Ck (55DRA-00.3)	0.106	0.059	0.082

To account for temperatures resulting from system potential shade in the RMA model, first we averaged the shade deficit across a distance upstream of the sampling location, corresponding to 12 hours travel time at 7Q10 flow conditions (See Appendix J). The shade deficit is the predicted difference between current and system potential shade (the difference between the purple and green lines in Figure I-6). Then, we adjusted the original diel temperature inputs to the RMA model according to the shade deficit and the groundwater category. For example, for a groundwater-dominated location with a shade deficit of 17%, we would reduce daily maximum temperatures by 1.19°C (17 x 0.070 = 1.19), and daily minimum temperatures by 0.357°C (17 x 0.021 = 0.357). We stretched values between the daily minimum and maximum proportionally.

Channel geometry

We used the calibrated rTemp models to predict the effects of a 5% increase in water depth. This is the same size adjustment that we made to the QUAL2Kw model for natural conditions. The models predict that an increase of water depth will have no appreciable impact on daily average water temperature, but will result in a small constriction in diel range; i.e. the daily maximum temperature will be lower and the daily minimum temperature will be higher (Table I-7). For natural conditions scenarios in RMA, we applied this by constricting the temperature input diel ranges by the amounts in Table I-7, while holding the daily average temperature constant.

Table I-7. Predicted change in diel temperature range resulting from +5% depth change.

Groundwater category	Representative location	Predicted change in diel temperature range resulting from +5% change in depth
GW dominated	Deadman Ck (55DEA-00.2)	-2.6%
GW influenced	Values halfway between Deadman and Dragoon Cks	-3.1%
Minimal GW	Dragoon Ck (55DRA-00.3)	-3.6%

Critical conditions

We applied additional temperature adjustments to reflect the 90th percentile air temperatures, so that RMA scenario predictions would reflect critical climate conditions. We achieved this by first comparing air temperatures at Deer Park Airport (KDEW) to water temperatures observed at Deadman Creek (55DEA-00.2) and Dragoon Creek (55DRA-00.3) for the months of July and August 2015 (Figure I-10). We then expressed the regressions between air and water temperature as water temperature change (°C) per degree C of air temperature change (Table I-8). We did not find any relationship between daily average water temperature and the magnitude of the diel temperature swing. Therefore, we did *not* apply the temperature adjustment for climate conditions as a scaled adjustment between daily maximum and minimum, as we did for the system potential shade temperature adjustment. Rather, we applied the temperature adjustment as a simple "nudge" based on daily average only.

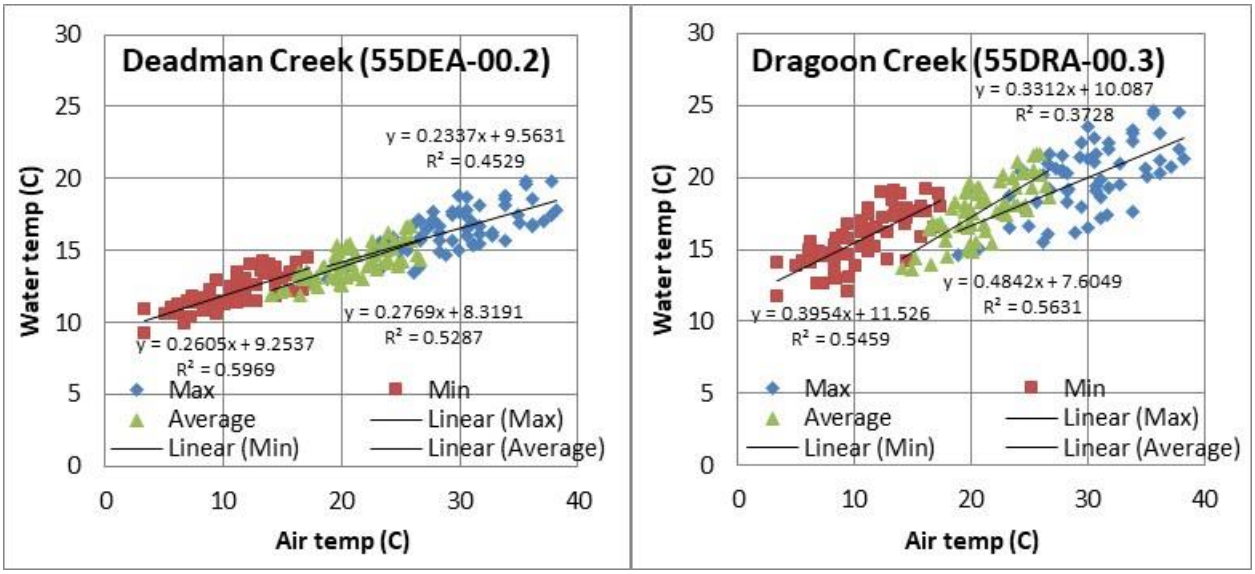


Figure I-10. Comparison of air and water temperatures at Deadman Creek (55DEA-00.2) and Dragoon Creek (55DRA-00.3) for July and August 2015.

Table I-8. Regression indicated sensitivity of stream temperature to air temperature, for each groundwater category.

Groundwater category	Representative location	Indicated change in daily average stream temperature (°C) per degree C change in daily average air temperature
GW dominated	Deadman Ck (55DEA-00.2)	0.2769
GW influenced	Values halfway between Deadman and Dragoon Cks	0.3806
Minimal GW	Dragoon Ck (55DRA-00.3)	0.4842

We applied this adjustment by comparing the daily average air temperature on the hottest day of the RMA model run, with the daily average air temperature on 7/31/2003, 23.9°C, which we used to represent 90th percentile climate conditions (Joy and Jones, 2012). For example, for the Bear Ck @ Mouth (55BEAR-00.4) July 2015 RMA model run, the hottest day of the deployment was 7/29/2015, with an average air temperature of 18.9°C. The difference between 7/29/2015 and 7/31/2003 was 5°C (23.9-18.9=5). This location is a "groundwater influenced" site, so we estimated the difference in water temperature between these dates to be 1.90°C (5 x 0.3806 = 1.90). Therefore, to reflect critical conditions, we increased all the temperature inputs for that RMA model by 1.90°C.

Figure I-11 shows an example of the effects of all of the adjustments that we applied to temperature inputs to RMA, as described above. The raw, or unadjusted temperature, represents the model calibration condition. The critical conditions temperature reflects the expected temperature under 90th percentile climate conditions but without changes to shade or channel geometry. The critical natural conditions temperature reflects 90th percentile climate conditions, along with the scaled changes to maximum and minimum reflecting system potential shade, as well as the changes to diel range reflecting the 5% increase to water depth.

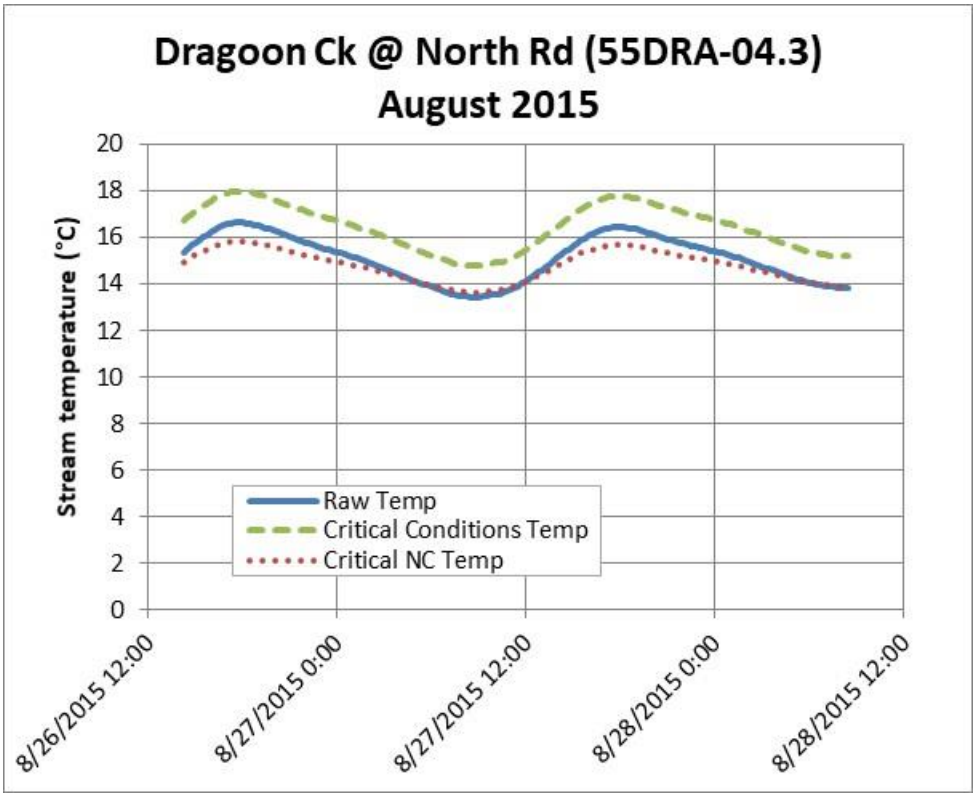


Figure I-11. Example of adjustments to RMA temperature inputs.

Appendix J. System-wide time of travel analysis

Analysis approach

Stream length

To calculate travel times, it is essential to have an accurate estimate of stream distances. For larger streams wide enough to be mostly visible in aerial photos, we digitized the stream course at a 1:1000 scale using ArcGIS, ensuring that we had adequately represented all meanders. This included the Little Spokane River, the West Branch Little Spokane River, Dragoon Creek, and the lower 14 miles of Deadman Creek. For smaller streams, we used the 1:24,000 NHD linework, which is derived from USGS quadrangle maps. The scale of this linework means that it frequently cuts across meanders, significantly underestimating actual channel distance in some creeks (Figure J-1).

We corrected this underestimation by performing a comparison of linework stream distances with distances measured in the field during channel surveys. This comparison confirmed that 1:1000 linework and field-measured distances were in excellent agreement, and suggested distance correction factors for 1:24,000 linework (Table J-1). We judiciously applied these correction factors to distances measured from the 1:24,000 linework. We did this by carefully examining aerial photos and linework for all stream reaches, to ensure that we only applied correction factors where it was appropriate to do so.



Figure J-1. Example of NHD 1:24,000 linework cutting across meanders on a small stream.

Table J-1. Distance correction factors for 1:24,000 linework, depending on topographic setting.

Topographic setting	Distance correction factor
Canyon	1 (i.e. no correction)
Sloped-sided valley	1.2
Flat valley bottom	1.3

Stream velocity

For the Little Spokane River downstream of Chain Lake, we used the QUAL2Kw model to predict velocity. We designed the channel geometry in the QUAL2Kw model to match the times of travel observed during the 2013 dye study, and we expect the model to provide excellent velocity predictions across a range of flow conditions.

For the Little Spokane River upstream of Chain Lake and for tributary streams, we used channel survey data to predict velocity, as follows (Figure J-2):

- We developed a stage-discharge was developed based on flow and stage data from a nearby sampling or gaging station.

- For a given flow condition, we compared the expected stage at that flow condition to the stage at the time when the channel survey was performed.
- We raised or lowered the water level in the surveyed channel by the appropriate amount to reflect the given flow condition.
- We recalculated the channel cross-section area for the given flow condition and resulting stage.
- We calculated the velocity as the flow divided by the cross-section area.
- We repeated this process for each of the (usually) 10 transects for a channel survey location.
- We calculated the average velocity for the channel survey location as the geometric mean of the expected velocities from the 10 transects.[8]
- We applied the velocity results from the channel surveys to nearby reaches of the same stream that had similar gradient and channel environment.

[8] Where W = width; D = depth; V = velocity; and Q = flow,
Given multiple channel survey transects where for each transect; $W_i * D_i * V_i = Q$
There is a mathematical property where the product of the arithmetic means will exceed the flow; $\overline{W} * \overline{D} * \overline{V} > Q$
However the product of the geometric means will equal the flow; $\overline{W} * \overline{D} * \overline{V} = Q$.

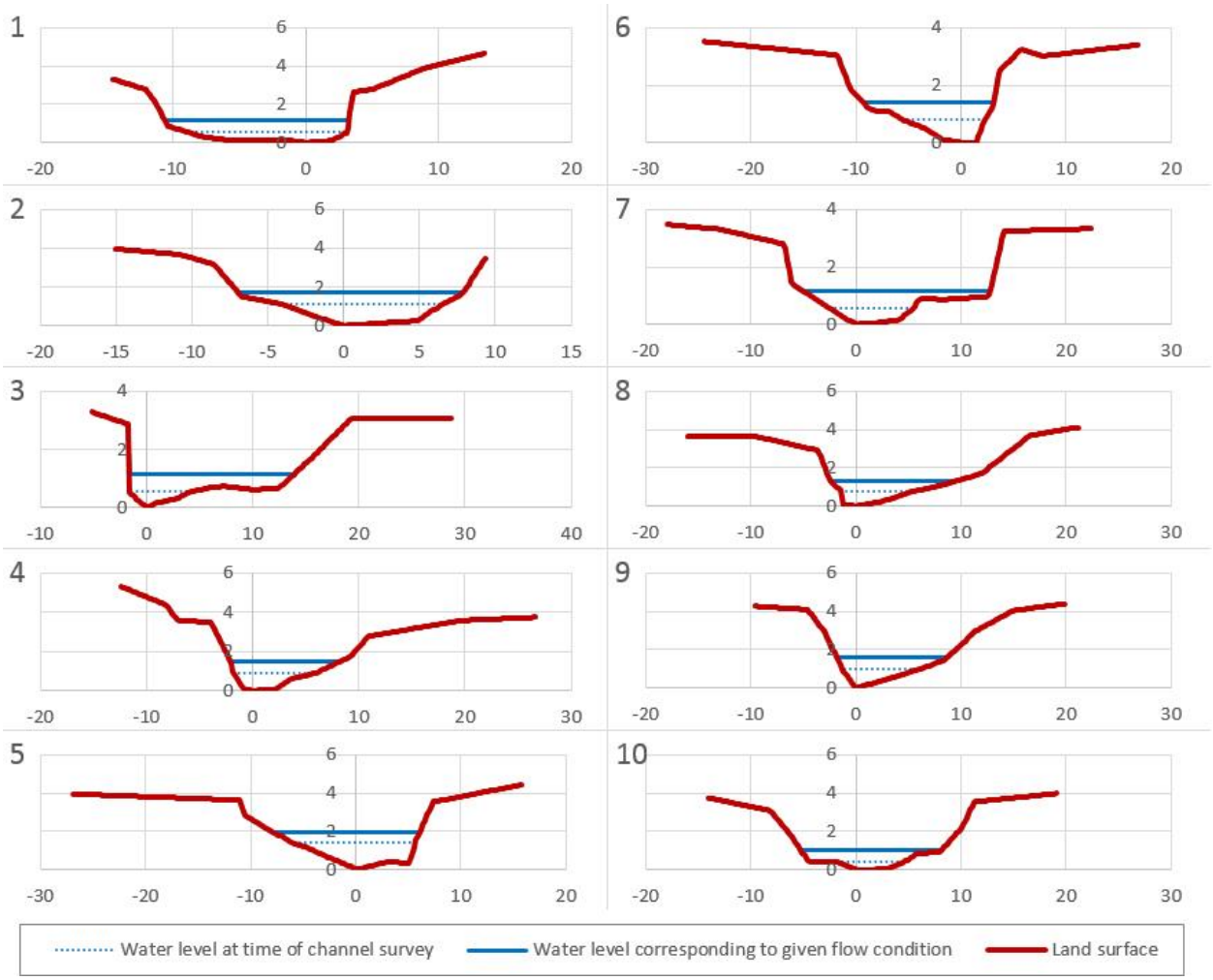


Figure J-2. Example of analysis of channel survey data, showing water level adjustment to reflect higher flows than were present at time of channel surveys.

Horizontal and vertical distances are in feet, referenced to the deepest point in the channel. The location shown is Deer Creek at Bruce Rd.

Lakes, Ponds, and Wetlands

For lakes located along major flowing streams, we obtained the lake volume from literature if available, or calculated it by digitizing historic Washington State Department of Fish and Game bathymetric maps where necessary. For wetlands and ponds, we obtained the area by digitizing the outline from orthophotos in GIS, and estimating the average depth using best professional judgment. For wetlands, we made an allowance for varying depth depending on flow conditions, based on stage-discharge relationships from nearby sampling stations. We calculated residence times as volume divided by flow.

Level of confidence in analysis

Because we used a variety of methods and data sources for calculating water velocities, travel times, and residence times, our degree of confidence in the analysis varies from location to location. Figure J-3 shows water bodies in the Little Spokane watershed, categorized according to our level of confidence, along with time-of-travel study and channel survey locations. We defined confidence categories as follows:

- High – Stream reaches with time-of-travel dye study data; Stream reaches with extensive channel suvey data, or with multiple agreeing channel survey sites describing a single reach type; Lakes of known volume and outflow rate.
- Medium – Stream reaches with some channel survey data, typically with one channel survey site characterizing each reach.
- Low – Stream reaches where we used channel survey data from a different but similar creek, or a reach of the same creek with somewhat different character; ponds and wetlands with estimated depths. Wetland estimates should be considered to be very approximate.
- Velocity unknown – Insufficient data to estimate velocity.

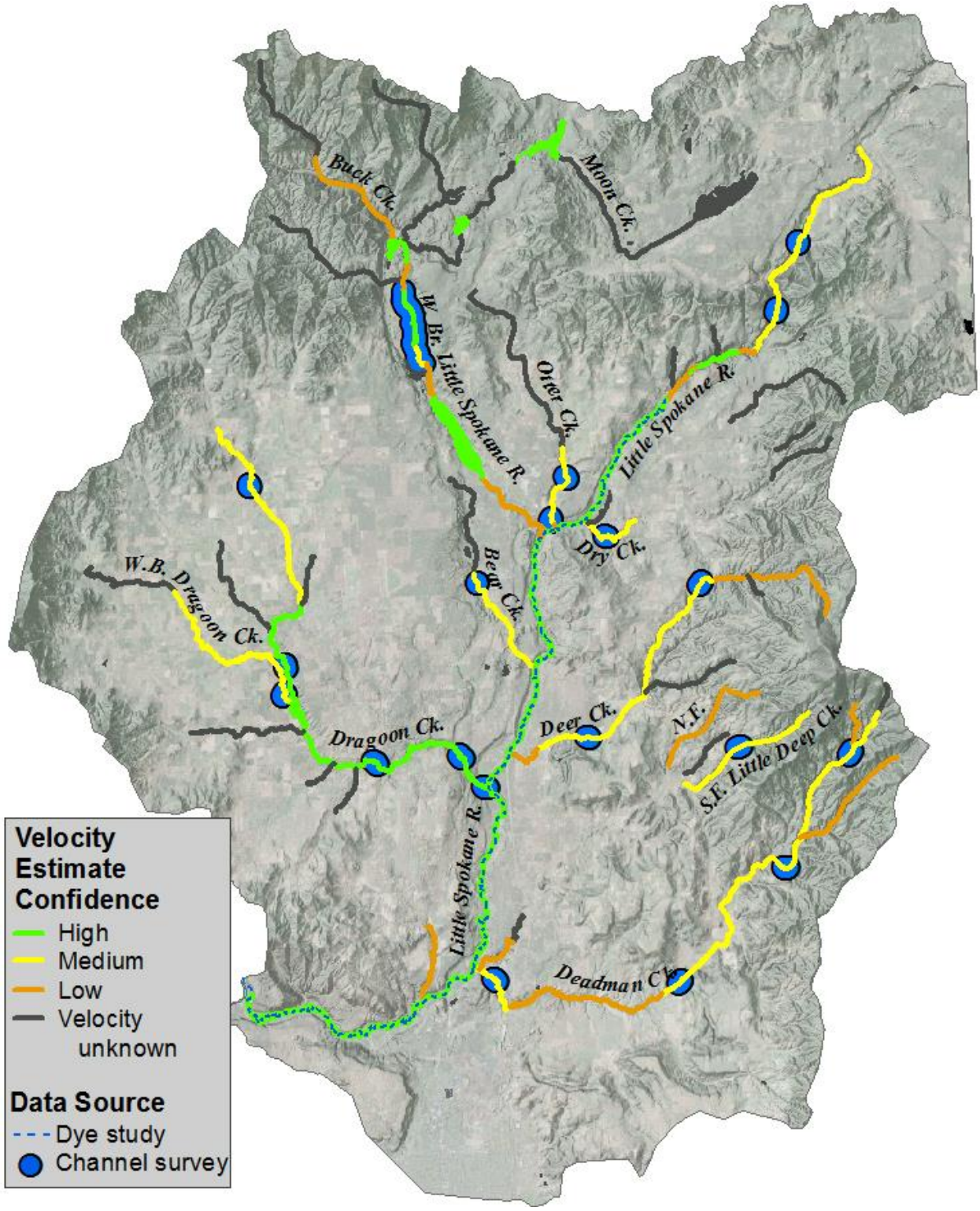


Figure J-3. Map showing level of confidence in velocity and time-of-travel estimates.

Water Velocity and Time of Travel results

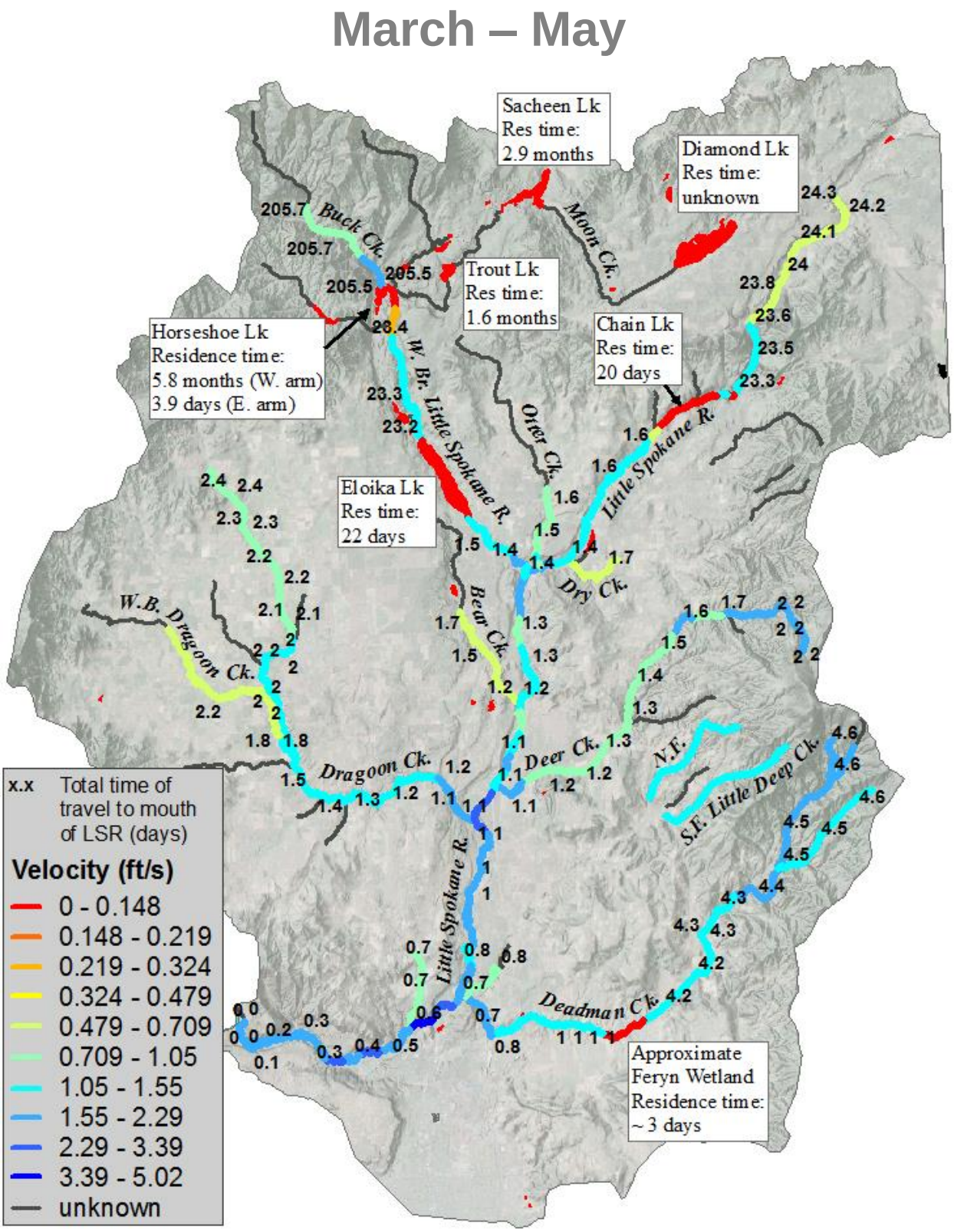


Figure J-4. Water velocity and travel times for median flow condition during March – May.

June

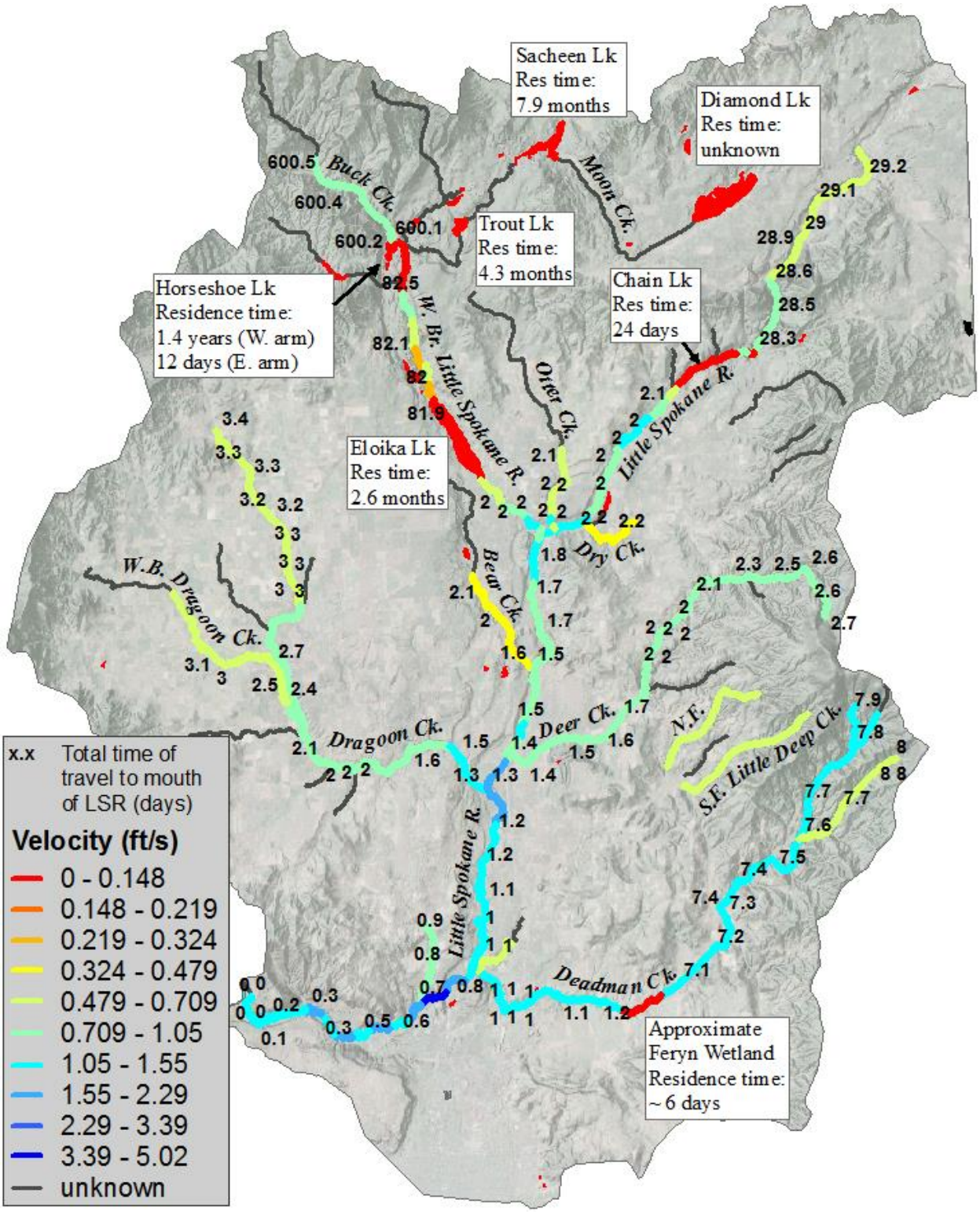


Figure J-5. Water velocity and travel times for median flow condition during June.

July - October

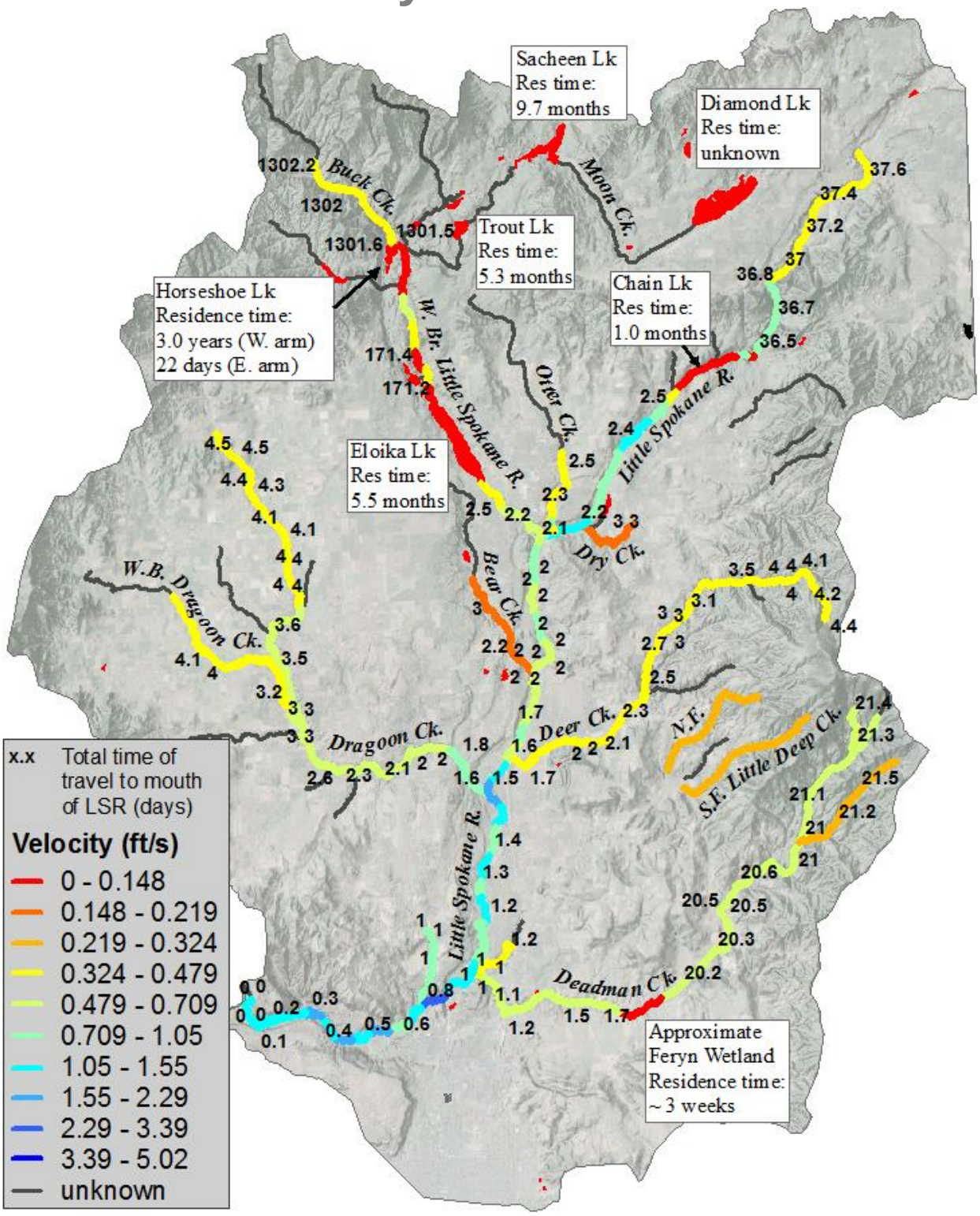


Figure J-6. Water velocity and travel times for median flow condition during July – October.

7Q10

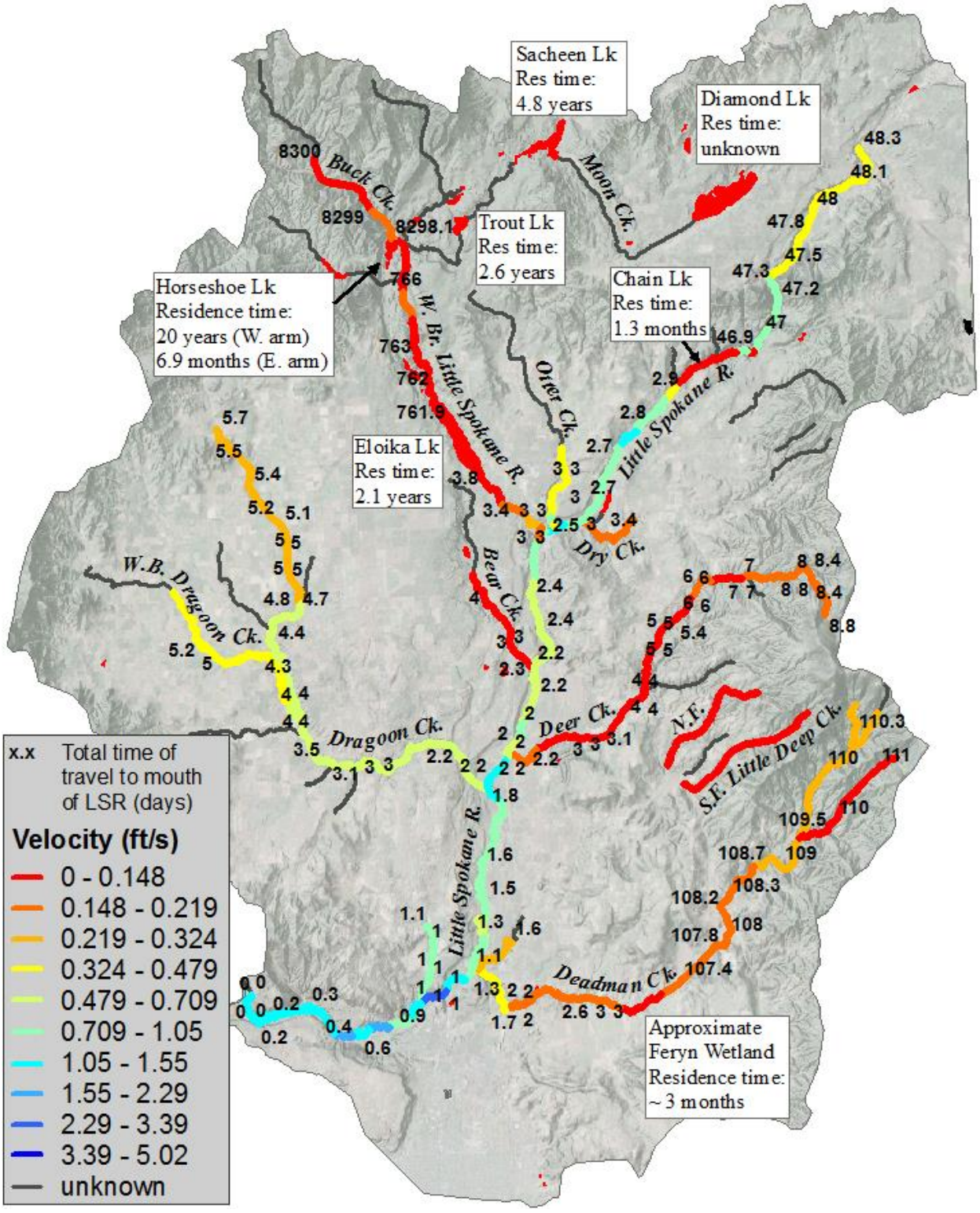


Figure J-7. Water velocity and travel times for 7 day, 10 year (7Q10) critical low flow condition.

Appendix K. Periphyton Taxonomy Analysis

Periphyton taxonomy data collected by Ecology at six locations during 2015, as well as one location during 2011, informed decisions about how to calibrate the nutrient sensitivity of the QUAL2Kw and RMA models. To assess the likely growth response tendencies to nutrients of periphyton communities, we followed the following analytical steps:

1.) For each location, we identified the several most abundant taxa. This included the taxa constituting together at least 80% of the total organisms counted, or the 10 most abundant taxa, whichever was fewer. In only two cases was this less than 80%, and it was always at least 60% of the total count.

2.) For each taxon, we assigned a nutrient indicator value of -1 for low nutrient indicators, and +1 for high nutrient indicators, as assessed by Potapova and Charles (2007). We assigned a value of zero for taxa not included in Potapova and Charles' list, which they either did not assess for nutrient indicator status, or did assess and found not to be strong indicators.

3.) For each location, we calculated the weighted average of the nutrient indicators by weighting the nutrient indicator for each abundant taxon according to the Percent Relative Abundance (PRA) for that taxon.

4.) This weighted average provides an overall indication of the nutrient tendencies of the periphyton community at each location. The value can range from -1 to +1, with negative numbers reflecting a greater abundance of low-nutrient taxa, and positive numbers reflecting a greater abundance of high-nutrient taxa.

Table K-1 summarizes the weighted average nutrient indication for each location.

Table K-1. Periphyton taxa weighted average nutrient indicator status by location.

Location	Weighted average of taxon nutrient indicator status
LSR @ Elk Park (55LSR-37.5)	-0.59
LSR @ Chattaroy (55LSR-23.4)	-0.49
LSR @ Pine River Park (55LSR-11.7)	-0.16
WBLSR @ Fan Lk Rd (55WBLS-07.7)	-0.41
Dragoon Ck @ DNR Campground (55DRA-05.4)	-0.17
Deadman Ck @ Holcomb Rd (55DEA-13.8)	+0.63
Burping Brook (BIO06600-BURP15) [a]	-0.67

[a] Sampled during 2011 as part of Ecology's ambient bioassessment program.

Low nutrient indicator taxa predominated throughout the Little Spokane watershed. Six out of seven locations had a greater abundance of low-nutrient taxa than high-nutrient taxa. The one exception was Deadman Ck. at Holcomb Rd. This suggests that the general literature consensus that diatom periphyton growth in streams can be saturated by very low concentrations of nutrients (e.g. Bothwell, 1985; Rier and Stevenson, 2006) likely holds true for the Little Spokane.

Table K-2 provides the details of this analysis.

Table K-2. Nutrient indicator analysis of periphyton taxa.

Taxa	Percent relative abundance (PRA)	Nutrient indicator status per Potapova and Charles (2007) [a]		Determined nutrient indicator value [c]
		Total Phosphorus	Total Nitrogen	
LSR @ Elk Park (55LSR-37.5)				
Achnanthidium minutissimum	37.95%	-69; -66wm [b]	-67; -63wm	-1
Achnanthidium pyrenaicum	35.18%			0
Cymbella affinis	6.84%	-41	-47	-1
Achnanthidium deflexum	5.86%	-24*	-21	-1
			wtd avg:	**-0.59**
LSR @ Chattaroy (55LSR-23.4)				
Achnanthidium druartii	28.71%			0
Achnanthidium minutissimum	21.69%	-69; -66wm	-67; -63wm	-1
Achnanthidium pyrenaicum	12.28%			0
Achnanthidium deflexum	10.05%	-24*	-21	-1
Cymbella affinis	8.13%	-41	-47	-1
			wtd avg:	**-0.49**
LSR @ Pine River Park (55LSR-11.7)				
Achnanthidium pyrenaicum	33.06%			0
Achnanthidium deflexum	10.42%	-24*	-21	-1
Nitzschia fonticola	9.93%		+37wm	+1
Cymbella turgidula	9.28%			0
Cymbella affinis	8.47%	-41	-47	-1
Achnanthidium minutissimum	7.82%	-69; -66wm	-67; -63wm	-1
Gomphonema parvulum	3.58%	+47; +64wm	+45; +61wm	+1
			wtd avg:	**-0.16**
WBLSR @ Fan Lk Rd (55WBLS-07.7)				
Achnanthidium minutissimum	27.57%	-69; -66wm	-67; -63wm	-1
Staurosira construens v. venter	5.81%			0
Cocconeis placentula sensu lato	4.65%			0
Nitzschia acidoclinata	3.99%			0
Staurosira construens	3.65%			0
Eolimna minima	3.32%			0
Nitzschia archibaldii	3.32%			0
Adlafia minuscula	2.82%	-6* wm	-*	-1
Nitzschia supralitorea	2.82%		+*; +9*wm	+1
Nitzschia dissipata	2.49%	+43wm	+31	+1
			wtd avg:	**-0.41**
Dragoon Ck @ DNR Campground (55DRA-05.4)				
Achnanthidium pyrenaicum	71.31%			0
Achnanthidium deflexum	14.10%	-24*	-21	-1
			wtd avg:	**-0.17**

(continued on next page)

(continued)

Taxa	Percent relative abundance (PRA)	Nutrient indicator status per Potapova and Charles (2007) [a]		Determined nutrient indicator value [c]
		Total Phosphorus	Total Nitrogen	
Deadman Ck @ Holcomb Rd (55DEA-13.8)				
Rhoicosphenia abbreviata	33.28%	+38	+44	+1
Eolimna minima	7.83%			0
Nitzschia dissipata	4.57%	+43wm	+31	+1
Gomphonema minutum	4.40%		+29	+1
Planothidium lanceolatum	4.08%		+32	+1
Planothidium frequentissimum	4.08%	+*wm	+*; +23*	+1
Nitzschia bacillum	3.43%			0
Cocconeis placentula sensu lato	3.26%			0
Achnanthidium minutissimum	2.94%	-69; -66wm	-67; -63wm	-1
Reimeria sinuata	2.77%	-37; -7wm	-53; -51*wm	-1
			wtd avg:	**+0.63**

Burping Brook (BIO06600-BURP15)				
Achnanthidium minutissimum	47.50%	-69; -66wm	-67; -63wm	-1
Karayevia suchlandtii	15.58%	-*wm	-*wm	-1
Planothidium lanceolatum	9.00%		+32	+1
Diatoma mesodon	3.00%	-8*; -20wm	-9; -15wm	-1
Gomphonema kobayasii	3.58%			0
Gomphonema angustatum	2.17%			0
Gomphonema minutum	2.25%		+29	+1
Achnanthidium rivulare	3.25%	-32	-21	-1
			wtd avg:	**-0.67**

[a] See Appendix A (pages 60-69) in Potapova and Charles (2007) for detailed information on the meanings of these symbols and numbers.

[b] "wm" refers to an indicator status specific to "western mountains" portion of the U.S.

[c] In no instance did the indicator signs (+ or -) for total phosphorus and total nitrogen ever disagree. The determined nutrient indicator value was assigned to +1 if the taxa was a high nutrient indicator for either nutrient, and to -1 if the taxa was a low nutrient indicator for either nutrient.

Appendix L. Natural Conditions Modeling Checklist

Ecology has created a checklist to ensure that modeling and TMDL development staff consider and document the most important elements of a model designed to represent natural conditions. Table L-1 provides the checklist for the watershed analysis. Table L-2 provides the checklist for the instream DO and pH analysis. These tables provide a broad summary of the considerations that went into modeling natural conditions. However, detailed discussions of these model inputs are located in Appendix F (watershed analysis), Appendix G (QUAL2Kw model), Appendix H (RMA model), and Appendix I (landscape shade/temperature analysis for RMA model).

Table L-1. Natural conditions modeling checklist for watershed analysis.

Minimum Elements	How applied	Sources/References
Boundary conditions *(set to match upstream criteria or known value which supports uses)*	We set TP concentrations to lowest levels found during wet season conditions from the least developed upstream stations in similar geology. We set concentrations higher than the background values to background, and left lower values unchanged.	Data collected by Ecology. Standard practice.
Channel morphology changes *(restore to natural channel)*	No change.	
Flow reductions or increases *(restore to match natural flow)*	• Removed surface withdrawals • Removed point sources . • Increased groundwater inflows to remove the effect of groundwater withdrawals. We estimated these from the estimate of groundwater withdrawal impacts found by a basin water balance, prorated by water rights volumes for wells close to the modeled streams.	• Spokane County, 2006. Watershed Management Plan – Water Resource Inventory Area 55 - Little Spokane River & Water Resource Inventory Area 57 - Middle Spokane River. • Ecology water rights data base
Hydrologic modifications	• No change to surface runoff • No change to flow characteristics	
Invasive species *(remove)*	Not applicable	
Microclimate *(adjust to match natural)*	Not applicable	

Minimum Elements	How applied	Sources/References
Natural nutrient concentrations *(required only for DO and pH natural conditions determinations – remove human caused portion)*	• For tributaries and surface runoff, we selected background TP from the lowest levels found in surveys when runoff was occurring and from watershed areas with relatively little development that have similar geology. We set concentrations higher than the background values to background, and left lower values unchanged. • For groundwater above Dartford, we selected values that reflected low values from wells in the area, and the lowest values during surveys under baseflow conditions from locations with relatively little development. We set concentrations higher than the background values to background, and left lower values unchanged. • For the SVRP aquifer, we used the background concentrations from the *Spokane River and Lake Spokane DO TMDL*.	Data collected by Ecology. Standard practice. *Spokane River and Lake Spokane DO TMDL (Moore and Ross, 2010)*
Nonpoint sources *(remove human caused portion)*	• For surface runoff and groundwater, we determined human nonpoint source contributions by difference: 2015-16 survey conditions minus natural background. • We also evaluatedthe source/sink terms to assess whether some may represent unidentified loads. We selected eight unknown source values as likely nonpoint sources that were at or above 1 kg/day and above 10% of the load at the downstream end of the reach. We attributed positive loads that were similar in magnitude to a negative load in the next reach upstream or downstream to a monitoring outlier and removed these from the analysis. We set the background levels for these values at values similar to other surveys at that location.	Data collected by Ecology. Standard practice.
Point source effluent *(remove)*	Removed Loading	
System potential shade *(utilize full shade potential)*	n/a	
Any biological measures or indices that indicate the water body has high quality biological integrity (or a narrative of how the water body is achieving its use through temporal use, refugia, etc.)	n/a	
Discuss how errors and uncertainty in modeling are addressed		

Minimum Elements	How applied	Sources/References
• There is some uncertainty in the dry season groundwater and wet season surface water flow estimates. We recognize this uncertainty and have taken it into account in making recommendations. • We tracked the residual left between the observed and calculated loads as a “source/sink” term. We considered this to be part of the uncertainty except where large enough to indicate an unidentified load, as discussed above. The unidentified loads include uncertainty, including the possibility that they represent surface runoff, local groundwater, or poorly quantified point source load sources. We will address this in implementation. • We evaluated uncertainty caused by timing offset during dynamic conditions and took this into consideration in interpreting results. • We addressed uncertainty caused by the lack of dynamic phosphorus uptake by including large “sink” terms and comparing them to reaches of high productivity in the mainstem LSR model and to upstream lakes and identified areas of wetlands. • In evaluating human sources, small loading values are more uncertain than large values, and we took this into account in prioritizing sources for TMDL implementation.		
Describe the model or other predictive method chosen and why it is the most appropriate method		
This analysis uses a mass-balance approach. We developed watershed-wide budgets for flow and phosphorus loading. We explored more complex models, and deemed this simplified approach sufficient to meet study objectives. The modeling method was reviewed at a regional modelers meeting where attendees expressed their acceptance of the approach.		

Table L-2. Natural conditions modeling checklist for instream DO-pH analysis.

Minimum Elements	How applied	Sources/References/Explanation
Upstream Boundary conditions	**QUAL2Kw** Unchanged from current conditions. **RMA** Concept not applicable (RMA does not model constituent transport so there is no boundary)	**QUAL2Kw** Upstream model boundary is outlet of Chain Lake. Conditions in lake not expected to change. Nutrients already extremely low at this location.
Channel morphology changes	**QUAL2Kw** Depth +5%; Width -5% from current. **RMA** Depth +5%; modified temperature time-series input to reflect +5% depth increase using rTemp model.	The channel morphology of the Little Spokane River is largely intact, without much incidence of the out-and-out mechanical straightening and widening that is seen in many other river systems. However, these small model input changes represent an assumption that present-day channel geometry may have deteriorated incrementally from natural conditions, through riparian vegetation removal and resulting bank erosion.
Flow reductions or increases	**QUAL2Kw** Turned off surface water withdrawals (+8.2cfs total change); Added additional groundwater reflect expected increase in groundwater inflows absent well pumping (+6cfs change) **RMA** N/A (RMA does not model streamflow)	• Estimated surface withdrawals as 20% of certificated surface water rights which specifically name the Little Spokane River or a tributary as a source. • Baseflow depletion estimate of 6cfs from well pumping based on MIKE SHE modeling by Golder Associates Inc (Golder Associates, Inc., 2004; Spokane County, 2006. Watershed Management Plan – Water Resource Inventory Area 55 - Little Spokane River & Water Resource Inventory Area 57 - Middle Spokane River).
Hydrologic modifications	No changes	
Invasive species	N/A	
Microclimate	**QUAL2Kw** Air temperature inputs -1°C; Dew point inputs +0.5°C **RMA** N/A (The method for incorporating rTemp results into RMA did not lend itself to incorporating changes in microclimate)	These are small inputs, which reflect that the differences between current and system potential vegetation are moderate, and the channel wide enough that large microclimate changes are unlikely.

Minimum Elements	How applied	Sources/References/Explanation
Natural nutrient concentrations	**QUAL2Kw** *Phosphorus:* Groundwater and tribs not associated with SVRPA: lowest observed value from July-September 2015, or NC estimate from watershed analysis, whichever is lower. SVRPA: TP = 4 ug/L *Nitrogen:* Upstream of Elk: TN = 100 ug/L. Downstream of Elk, including SVRPA: TN = 200 ug/L **RMA** *Phosphorus:* Lowest observed value from July-September 2015, or NC estimate from watershed analysis, whichever is lower. *Nitrogen:* Groundwater influenced sites: TN = 200ug/L. Low-DIN N-limited sites: DIN = 11ug/L	**QUAL2Kw** *Phosphorus:* See watershed analysis portion of this report. SVRPA: *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010) *Nitrogen:* Based on USGS well data, as well as study of Idaho hillside drainages to SVRPA (Clarkson and Buchanan, 1998) **RMA** *Phosphorus:* See watershed analysis portion of this report. *Nitrogen:* Based on USGS well data, as well as study of Idaho hillside drainages to SVRPA (Clarkson and Buchanan, 1998). Low-DIN value calculated from 10th percentile of data from reference sites.
Nonpoint sources	See Channel Morphology, Microclimate, Nutrients, and Shade.	
Point source effluent	Reduced nutrient concentrations at Griffith Springs (which includes Spokane Hatchery effluent) to natural levels. Colbert Landfill outfall already at natural levels.	Spokane Hatchery essentially represents a groundwater input with human impacts to nutrient concentrations. Assume groundwater would still reach river but without human impacts. Colbert Landfill essentially represents a groundwater input, without apparent human nutrient impacts.
System potential shade	**QUAL2Kw** Calculated system potential shade using Ecology shade model, based on a band of Hawthorn 10m tall, 75% canopy density, 1m overhang. **RMA** Watershed-wide analysis of system potential vegetation based on LANDFIRE Environmental Site Potential (ESP) spatial dataset. Assessed relationship between shade and temperature using rTemp model. Calculated photosynthetically active radiation (PAR) using SolRad model, and attenuated this based on system potential shade.	LANDFIRE, 2016 https://www.landfire.gov/
Any biological measures or indices that indicate the water body has high quality biological integrity (or a narrative of how the water body is achieving its use through temporal use, refugia, etc.)	N/A	
Discuss how errors and uncertainty in modeling are addressed		

Minimum Elements	How applied	Sources/References/Explanation
QUAL2Kw We assessed the effect of compound uncertainty from multiple natural conditions inputs using YASAIw to perform a Monte Carlo simulation. We defined ranges of uncertainty for each natural conditions input parameter, and performed 1000 model runs using inputs randomly selected from the probability distribution for each parameter. YASAIw then used the results of these model runs to define a range of result uncertainty for key model outputs, and to account for how much output uncertainty was attributable to each input parameter's uncertainty. **RMA** We did not quantitatively analyze effects of natural conditions input uncertainty, but we considered these qualitatively in interpreting results.		
Describe the model or other predictive method chosen and why it is the most appropriate method		
QUAL2Kw is Ecology's principal water quality model for well-mixed, flowing river systems. It is typically used for modeling a long reach of a river mainstem, as in this study. The model framework captures all the key physical and biological processes that drive DO and pH in the Little Spokane River. RMA is a modeling tool that simplifies stream systems to a single, zero-dimensional, point. The model is driven by a diel time-series of DO and pH data. It simulates DO and pH as a function of productivity, respiration, reaeration, and photosynthetic quotient. The version of RMA used in this project also simulates bulk mixing of groundwater. Because of the highly branched nature of the tributary streams in the Little Spokane watershed, meeting the data requirements for a complex model like QUAL2Kw or WASP for each tributary would have been prohibitive. RMA, while much simpler than QUAL2Kw, still allows a mechanistic assessment of the sensitivity of DO and pH to nutrients and temperature in a given stream.		

Definitions:

Upstream Boundary conditions – Considers upstream inputs to the water body or segment being evaluated for natural conditions. Also must ensure downstream uses and criteria are not adversely affected.

Channel morphology changes – Considers channel straightening, dredging, levees, aggregation, and incision

Flow reductions or increases - Considers groundwater and surface water changes such as withdrawals and inputs

Hydrologic modifications – Considers hydrologic controls such as dams and weirs

Invasive species – Considers whether other organisms are affecting the biology or chemistry of the water. For example plants influencing DO/pH levels or carp influencing turbidity and sediment oxygen demand

Microclimate – Considers changes in temperature and relative humidity due to increased riparian vegetation to the system potential shade level.

Point source effluent – Removes all effect of permitted discharges.

Natural nutrient concentrations – Considers whether there are natural nutrient sources contributing to the water chemistry and biology or if there is legacy nutrient contamination. This is required only for DO and pH natural conditions determinations.

Nonpoint sources – Factors in land use changes, vegetation removal, and diffuse pollution from human activities.

System potential shade – Ensures full water body shading possible under a natural condition is applied.

Appendix M. Calculation of Wasteload Allocations

This appendix describes the method used to calculate wasteload allocations for point sources. For Spokane Hatchery, Colbert Landfill, Spokane County Municipal Stormwater, and Spokane Recycling Industrial Stormwater, the receiving waters are not sensitive to nitrogen. The DIN wasteload allocations for these sources is "N/A" (not zero), and only the TP allocations are described below. For Construction Stormwater, both TP and DIN allocations are described. The remaining sources have zero WLAs for both TP and DIN.

Spokane Hatchery

Washington Department of Fish and Wildlife (WDFW) operates the Spokane Fish Hatchery. The facility discharges through 8 separate outfalls to Griffith Slough, an old oxbow of the Little Spokane River, which carries hatchery effluent plus bypass water from Griffith Spring a short distance to the lower Little Spokane River at RM 7.0.

The travel time from the hatchery to the mouth of the Little Spokane River is about 7-8 hours during low-flow conditions. This means that there is little time for instream processes to attenuate phosphorus discharged by the hatchery. The Little Spokane River essentially passes the phosphorus from the hatchery directly through to Lake Spokane.

To compare hatchery loading under various hypothetical conditions, we evaluated several loading scenarios (Table M-1). Note that all hatchery concentrations and loads are calculated as *net* loads; in other words, we are only counting the phosphorus that the hatchery adds. The hatchery is not responsible for the background phosphorus already present in the intake water.

- *Current conditions*: Estimates of loading from the hatchery developed for the 2015-16 survey dates, as described in **Watershed Loading TMDL Analysis** section of the main report body.
- *Hatchery maximum:* Hatchery loading estimates scaled up to reflect the maximum loading described in the Spokane Hatchery NPDES application (WDFW, 2015b).
- *TMDL Loading*: The overall basin seasonal load balances scaled up or down to match the TMDL Load Allocations for the Spokane River DO TMDL.
- *Hatchery @ 0.01 mg/L*: Multiple sources suggest that a net concentration of 0.01 mg/L TP is a potentially achievable target for well-treated fish hatchery wastewater effluent
    - Idaho Waste Management Guidelines for Aquaculture Operations (IDEQ, 1997).
    - EPA Fact Sheet for the General Wastewater Discharge Permit for Aquaculture Facilities in Idaho (EPA, 2006)
    - The Platte River Fish Hatchery in Michigan, which raises salmon and has a state-of-the-art wastewater treatment system, is able to meet 0.01 mg/L over 90% of the time (Switzer, 2017).

- The recently-upgraded WDFW Issaquah Fish Hatchery's performance data show net total phosphorus in their effluent averaging 0.01 mg/L (Mains, 2017).

Table M-1. Spokane Hatchery TMDL loading scenarios

Scenario	Calculation	Mar - May	June	July - Oct
Current conditions - all	Average TP Net Load (kg/day)	1.18	0.57	1.11
	% of basin human loading	2.4%	7.5%	30.9%
	Flow-weighted conc. (mg/L)	0.020	0.013	0.022
Current conditions with Hatchery maximum	Average TP Net Load (kg/day)	1.44	0.69	1.35
	% of basin human loading	2.9%	9.0%	35.3%
	Flow-weighted conc. (mg/L)	0.024	0.015	0.026
TMDL loading with Hatchery maximum	Average TP Net Load (kg/day)	1.44	0.69	1.35
	% of basin human loading	5.1%	5.6%	25.1%
	Flow-weighted conc. (mg/L)	0.024	0.015	0.026
TMDL loading w Hatchery @ 0.01 mg/L [a]	Average TP Net Load (kg/day)	0.51	0.51	0.51
	% of basin human loading	1.9%	4.3%	11.3%
	Flow-weighted conc. (mg/L)	0.010	0.010	0.010

[a] For this scenario, we assumed a constant total outfall flow of 21cfs, regardless of season.

The wasteload allocation for Spokane Hatchery is based on the 0.01 mg/L net concentration scenario. The reflects the need for advanced treatment and maximum phosphorus reductions from a point source that is a *de facto* direct contributor to Lake Spokane. This will require a reduction of net phosphorus of about 50% from levels observed during 2014-2015. A discharge volume of 21 cfs is based on the sum total discharge of the 8 outfalls, as measured by Anchor QEA during 2014-2015. We calculated the WLA for TP as follows:

$$\text{WLA} = \left(0.010\ \frac{\cancel{\text{mg}}}{\cancel{\text{L}}}\right)\left(21\ \frac{\cancel{\text{ft}}^3}{\cancel{\text{s}}}\right)\left(\frac{28.3168\ \cancel{\text{L}}}{1\ \cancel{\text{ft}}^3}\right)\left(\frac{86400\ \cancel{\text{s}}}{1\ \text{d}}\right)\left(\frac{1\ \text{kg}}{1{,}000{,}000\ \cancel{\text{mg}}}\right) = 0.51\ \frac{\text{kg}}{\text{d}}$$

Colbert Landfill

The Spokane County owned Colbert Landfill Superfund Site was a sanitary landfill that operated from 1968 through 1986. The landfill was used to dispose of organic solvent wastes, resulting in groundwater contamination. Since 1994, Spokane County has been operating a "pump and treat" facility to remediate contamination through air stripping (Ecology, 1996). Remediated groundwater discharges to the Little Spokane River at RM 19.8, about 1½ miles downstream of the Dragoon Creek confluence.

Comparison of effluent total phosphorus data to nearby tributaries and available nearby groundwater data shows that phosphorus concentrations in Colbert Landfill's discharge are entirely consistent with other groundwater sources in that area. There is no evidence that the landfill adds any phosphorus to the groundwater; i.e. it appears there is no net load. Therefore, Ecology is not concerned about Colbert Landfill as a source of phosphorus.

The wasteload allocation for Colbert Landfill is based on the TP concentration observed by Ecology in 2010 (0.022 mg/L), along with the 99th percentile of daily effluent flow during 2007-2014 as reported by Spokane County's discharge monitoring reports (1.7cfs). This allows continued discharge of TP at current levels, but would not allow any substantial increase. We calculated the WLA for TP as follows:

$$\text{WLA} = \left(0.022\ \frac{\cancel{\text{mg}}}{\cancel{\text{L}}}\right)\left(1.7\ \frac{\cancel{\text{ft}^3}}{\cancel{\text{s}}}\right)\left(\frac{28.3168\ \cancel{\text{L}}}{1\ \cancel{\text{ft}^3}}\right)\left(\frac{86400\ \cancel{\text{s}}}{1\ \text{d}}\right)\left(\frac{1\ \text{kg}}{1{,}000{,}000\ \cancel{\text{mg}}}\right) = 0.092\ \frac{\text{kg}}{\text{d}}$$

Spokane County Municipal Stormwater

Spokane County's municipal stormwater permit coverage applies to areas outside the city limits of Spokane, but within the Urban Growth Area (UGA). Spokane County's stormwater infrastructure is based around infiltration, and there are generally not storm sewers with outfall pipes to water bodies. We calculated the WLA for TP as follows:

Step 1:
We calculated the 99th percentile of daily rainfall for Spokane (data from Spokane Airport; 2008-2018) for the TMDL season of March-October. This value is 0.502 inches.

Step 2:
We used the simple method (Schuler, 1987; Lubliner, 2007) to estimate the runoff in inches for completely impervious areas such as streets, for a 99th percentile daily rainfall:

$$R = P * P_j * R_v = 0.502\ \text{in} * 0.27 * 0.95 = 0.129\ \text{in}$$

Where the parameters were derived as follows:

- $P = 0.502$ in, the 99th percentile daily rainfall during March-October
- $P_j = 0.27$. The commonly quoted literature value for this parameter is 0.9. However, it has been observed that this value greatly overestimates runoff values for eastern Washington's climate. The City of Spokane used empirical observations of rainfall (inches) and outfall discharge from the Cochran Basin (gallons) to derive a relationship of $D = 11{,}481{,}742.5P - 356{,}857$ (City of Spokane, 2017). Using the City's impervious fraction estimate for the Cochran Basin of 0.274, we used this relationship to calibrate the simple method P_j parameter to 0.27.
- Given an impervious fraction $I_a = 1$, $Rv = 0.05 + 0.9Ia = 0.95$.

Step 3:
Using geographical information systems (GIS) software, we estimated the total acreage of roads within the permit coverage area that are close enough to a stream to be likely to discharge stormwater runoff to it, estimated as within 100 ft. We estimated this to be 3.45 acres.

Step 4:
We then used the simple method to calculate a daily phosphorus load:

$$\text{WLA} = \left(\frac{0.226}{2.22}\right) * R * C * A = \left(\frac{0.226}{2.22}\right) * 0.129 * 0.26 * 3.45 = 0.012\ \text{kg/d}$$

Where:

- 0.226 is a unit conversion factor specified by the simple method
- 2.22 is another unit conversion factor to convert the result from lbs to kg
- $R = 0.129$ in, calculated in Step 2
- $C = 0.26$ mg/L. This is a national median concentration value for total phosphorus (Smullen and Cave, 1998). This compares to observed values in 2018 from 4 outfalls in Spokane of 0.164 - 0.62 (Median = 0.46). Using the somewhat lower national value reflects the protective nature of the WLA being calculated.
- $A = 3.45$ acres, calculated in Step 3

Note that although the simple method documentation emphasizes annual (or seasonal) loads, we used it to calculate a daily load, by using daily rainfall and runoff volumes instead of annual or seasonal ones.

Washington Department of Transportation stormwater

Washington State Department of Transportation (WSDOT) stormwater permit coverage applies to WSDOT properties and infrastructure within the Urban Growth Area (UGA). There are three highway crossings within the permit area that have the potential to discharge stormwater runoff: 1) US-395 bridge over the Little Spokane River at Wandermere; 2) US-2 crossing of Deadman Ck. near Mead; and 3) US-2 crossing of Little Deep Ck. at Colbert.

We calculated the WLA for TP using exactly the same method described previously for Spokane County stormwater. We estimated the road acreage likely to discharge storwater runoff to be 1.80 acres. Therefore the WLA calculation is as follows:

$$\text{WLA} = \left(\frac{0.226}{2.22}\right) * R * C * A = \left(\frac{0.226}{2.22}\right) * 0.129 * 0.26 * 1.80 = \ 0.0061 \text{ kg/d}$$

Where:

- 0.226 is a unit conversion factor specified by the simple method
- 2.22 is another unit conversion factor to convert the result from lbs to kg
- $R = 0.129$ in, described in Step 2 of the Spokane County stormwater WLA calculation
- $C = 0.26$ mg/L. This is a national median concentration value for total phosphorus (Smullen and Cave, 1998). This compares to observed values in 2018 from 4 outfalls in Spokane of 0.164 - 0.62 (Median = 0.46). Using the somewhat lower national value reflects the protective nature of the WLA being calculated.
- $A = 1.80$ acres, the calculated runoff area described above.

Spokane Recycling (Former Kaiser site)

Spokane Recycling (Former Kaiser site) discharges stormwater to Deadman Creek under the industrial stormwater general permit. Unusually for stormwater, this facility discharges directly to Deadman Creek through an outfall pipe. The WLA is based on the national median concentration value for total phosphorus of 0.26 mg/L (Smullen and Cave, 1998; see the calculation for Spokane County municipal stormwater in this appendix) and a *de minimus* flow of 0.01 cfs. We calculated the WLA for TP as follows:

$$\text{WLA} = \left(0.26\ \frac{\cancel{\text{mg}}}{\cancel{\text{L}}}\right)\left(0.01\ \frac{\cancel{\text{ft}}^3}{\cancel{\text{s}}}\right)\left(\frac{28.3168\ \cancel{\text{L}}}{1\ \cancel{\text{ft}}^3}\right)\left(\frac{86400\ \cancel{\text{s}}}{1\ \text{d}}\right)\left(\frac{1\ \text{kg}}{1{,}000{,}000\ \cancel{\text{mg}}}\right) = 0.0064\ \frac{\text{kg}}{\text{d}}$$

Bubble Allocation: Industrial stormwater, Construction stormwater, sand and gravel

These general permits cover potential stormwater discharges relating to industrial and construction sites, as well as potential discharges from sand and gravel sites. This permit covers most of Washington State, including all of the Little Spokane Watershed. Unlike the other point source permits, the construction stormwater permit could potentially cover discharges to nitrogen-sensitive streams (See **Loading Capacity** and **Instream DO and pH TMDL Analysis** sections in the main report body). Therefore it is necessary to provide wasteload allocations for both total phosphorus and dissolved inorganic nitrogen.

Note that this permit does not include Spokane Recycling (former Kaiser site) industrial stormwater. That facility has its own wasteload allocation due to its unusual direct discharge configuration.

TP

Unlike other permits, these three general permits covers activities and sites which are many are found in location throughout the watershed. For construction stormwater, the permits are temporary in nature, lasting for the duration of construction projects. The number of construction sites, and the acreage involved, can vary greatly year to year, and by season.

These three permits all specify benchmark values for turbidity, as follows:

- Industrial Stormwater: 25 NTU
- Construction Stormwater: 25 NTU
- Sand & Gravel: 50 NTU

The TP wasteload allocation is an estimate based the concentration of total phosphorus equivalent to turbidity value of 25 NTU. The calculation method is similar to the one we used for Spokane County municipal stormwater.

Step 1:
We calculated the 99th percentile of daily rainfall for Spokane (data from Spokane Airport; 2008-2018) for the TMDL season of March-October. This value is 0.502 inches.

Step 2:
We used the simple method (Schuler, 1987; Lubliner, 2007) to estimate the runoff in inches for a 99th percentile daily rainfall:

$$R = P * P_j * R_v = 0.502 \text{ in} * 0.27 * 0.059 = 0.0080 \text{ in}$$

Where the parameters were derived as follows:

- $P = 0.502$ in, the 99th percentile daily rainfall during March-October
- $P_j = 0.27$. See calculation for Spokane County municipal stormwater, for discussion.
- Because the vast majory of acreage at these sites is pervious (typically sand/gravel pits and gravel parking lots), we assumed an impervious fraction of $I_a = 0.01$. Given this, $Rv = 0.05 + 0.9Ia = 0.059$. For some sites, this impervious fraction estimate may be low, but using a low value produces a more conservative and therefore protective estimate.

Step 3:
Using geographical information systems (GIS) software, we estimated the footprint of facilities covered by the industrial stormwater permit (excluding Spokane Recycling) as 9 acres, and those covered by the sand and gravel permit as 456 acres. For construction stormwater, we estimated 100 acres as a reasonable footprint, recognizing that this value will continually change from season to season and year to year. All of these estimates should be considered very approximate.

Step 4:
Using the relationship between TP and turbidity observed at the mouth of the Little Spokane River (Figure M-1), we determined the TP concentration equivalent to the permit-specified turbidity of 25 NTU:

$$0.0143(25)^{0.5891} = 0.0952 \text{ mg/L}$$

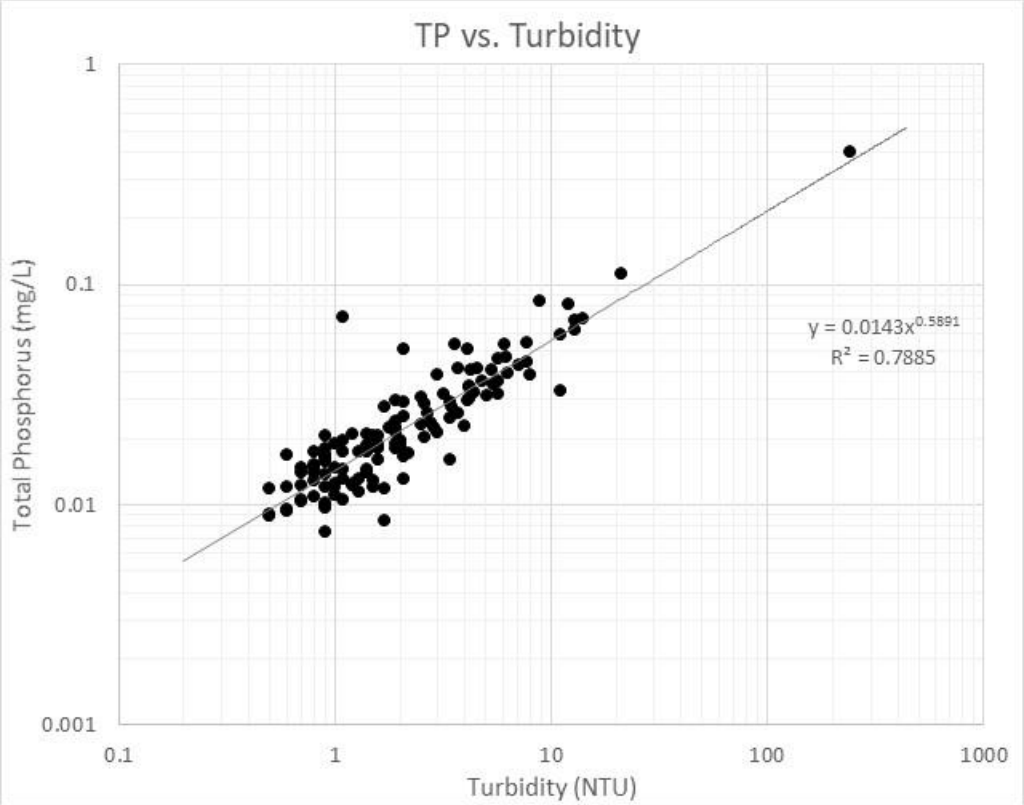


Figure M-1. Total phosphorus and turbidity at the ambient monitoring site at the mouth of the Little Spokane River (55B070), 2007-2018.

Step 5:
We then used the simple method to calculate a daily phosphorus load:

$$\text{WLA} = \left(\frac{0.226}{2.22}\right) * R * C * A = \left(\frac{0.226}{2.22}\right) * 0.0080 * 0.0952 * 565 = 0.044 \text{ kg/d}$$

Where:

- 0.226 is a unit conversion factor specified by the simple method
- 2.22 is another unit conversion factor to convert the result from lbs to kg
- R = 0.0080 in, calculated in Step 2
- C = 0.0952 mg/L, calculated in Step 4
- A = 565 acres, the sum of the estimated footprints from Step 3

Note that although the simple method documentation emphasizes annual (or seasonal) loads, we used it to calculate a daily load, by using daily rainfall and runoff volumes instead of annual or seasonal ones.

DIN

The DIN wasteload allocation is based on giving a minimal fraction (not more than 5%) of the DIN loading capacity to the bubble allocation for these three general permits, while reserving the rest for nonpoint load allocations. We did this by taking 5% of the smallest reach DIN human load capacity (Upper Dragoon Creek; 0.019 kg/day; See **Loading Capacity** and **Instream DO and pH TMDL Analysis** sections in the main report body). For the remaining five nitrogen-sensitive reaches, we set wasteload allocations for DIN proportionally to this one, by reach length (Table M-2).

Table M-2. Calculation of DIN bubble wasteload allocation for industrial stormwater, construction stormwater, and sand and gravel.

Reach	Total load capacity (kg/day)	Human load capacity (kg/day) [a]	Reach length (river miles) [b]	WLA (kg/day)	WLA % of human load capacity
Little Spokane R. between Chain Lake and Elk	1.36	0.214	2.9	0.00038	0.2%
Little Spokane R. between Elk and WBLSR confluence	30.9	24.8	4.6	0.00059	0.0%
Upper Dragoon Ck., abv Spring Ck.	0.035	0.019	7.4	0.00096	5.0%
S.F. Little Deep Ck	0.023	0.020	4.8	0.00063	3.1%
Deadman Ck. from state park bdy to Holcomb Rd.	0.140	0.097	6.3	0.00081	0.8%
Deadman Ck. in Peone Prairie from Holcomb Rd. to Heglar Rd.	0.085	0.047	4.6	0.00060	1.3%
			Total:	**0.0040**	

[a] We calculated human load capacity from "TMDL DIN" and "7Q10 Flow" found in the **Instream DO and pH TMDL Analysis section**; Table 39.

[b] Includes perennial stream length only.

Appendix N. Climate Change and Future Conditions

Climate change summary for Pacific Northwest

Changes in climate are likely to affect both water quantity and quality in the Pacific Northwest (Snover et al., 2013; Mote et al., 2014). Factors affecting these changes include natural climate variability, which influences regional climate on annual and decadal scales, and long-term increases in air temperature due to rising greenhouse gas emissions. Chapter 21 of the U.S. National Climate Assessment report *Climate Change Impacts in the United States* (Mote et al., 2014) described observed and projected changes in air temperatures across the region:

- *"Temperatures increased across the region from 1895 to 2011, with a regionally averaged warming of about 1.3°F."*
- *"An increase in average annual temperature of 3.3°F to 9.7°F is projected by 2070 to 2099 (compared to the period 1970 to 1999), depending largely on total global emissions of heat-trapping gases. The increases are projected to be largest in summer."*

A warming climate affects snowpack and hydrology in important ways. Climate scientists project that Washington's spring snowpack will decline -38% to -46% by the 2040s and -56% to -70% by the 2080s under low and moderate warming scenarios, respectively (Snover et al., 2013). The impact of this snow loss on hydrology will vary by basin, as noted in Mote et al., 2014:

> *"Hydrologic response to climate change will depend upon the dominant form of precipitation in a particular watershed, as well as other local characteristics including elevation, aspect, geology, vegetation, and changing land use. The largest responses are expected to occur in basins with significant snow accumulation, where warming increases winter flows and advances the timing of spring melt. By 2050, snowmelt is projected to shift three to four weeks earlier than the 20th century average, and summer flows are projected to be substantially lower, even for an emissions scenario that assumes substantial emissions reductions (B1)."*

By the 2040s, summer streamflows are projected to decrease by 30% to over 50% in the rivers draining the Cascade Mountains, Olympic Mountains, and western front of the Rocky Mountains in Washington. These lower flows, combined with rising air temperatures, are likely to cause increased summer stream temperatures. Mantua et al. (2010) presented climate change modeling scenarios that projected annual maximum weekly average water temperatures that by the 2080s are from 1 to 6 ^{o}C higher than 1980s conditions. Higher stream temperatures degrade or eliminate habitat for salmonids and can increase disease and predation. Increased water temperatures can also decrease dissolved oxygen levels and increase the impacts of pollutants on receiving waters.

An expected increase in extreme precipitation events may also affect water quality . According to Mote et al., 2014:

> *"Averaged over the region, the number of days with more than one inch of precipitation is projected to increase 13% in 2041 to 2070 compared with 1971 to 2000 under a scenario that assumes a continuation of current rising emissions trends (A2), though these projections are not consistent across models."*

More extreme precipitation events, combined with warming winter temperatures, increase the risk of winter flooding in mixed rain-snow and rain-dominant watersheds. This will likely increase stormwater management challenges in urban areas. Increased erosion and pollutant runoff is also an expected consequence of more intense storms.

Other climate change impacts identified by Mote et al. (2014) that may result in degraded water quality in rivers and streams include:

- Increasing wildfires, resulting in increased post-fire erosion and pollutant loading
- Changes to watershed vegetation from changes to temperature, moisture, and fire regimes
- Increased agricultural pesticide use to control increased disease, pests, and weeds

In 2015, the University of Washington Climate Impacts Group published *State of Knowledge: Climate Change in Puget Sound* (Mauger et al., 2015). This report summarized current research on the impacts of climate change in the Puget Sound region for issues ranging from snowpack to human health. It identified numerous likely changes in freshwater and marine water quality. These changes include:

- Decreased summer freshwater flows
- Increased sediment loads in winter and spring
- Warmer freshwater and marine water temperatures
- Decreased dissolved oxygen levels
- Changes in estuarine circulation
- Increased harmful algal blooms
- Increased acidification (lower marine pH levels)
- Rising sea levels and increased coastal erosion

The projected future changes to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool and provide thermal refugia for fish. Growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global climate change by increasing stream temperature resiliency. The sooner such restoration actions begin and the more complete they are, the more effective we will be in offsetting some of the detrimental effects of climate change on our freshwater and estuarine resources.

In summary, increased rainfall intensity and changes to watershed vegetation and land uses may increase storm event pollutants. The cumulative impact of climate change is likely to increase the vulnerability of receiving waters to pollutant runoff. This emphasizes the importance of increasing receiving water resiliency and reducing pollutant sources.

Ecology is writing this water quality improvement report to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature and other receiving water conditions associated with global climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the health of our streams, rivers, and estuaries as possible.

Information on climate change in Washington State is available from the University of Washington Climate Impacts Group website: https://cig.uw.edu/, and from Ecology's Climate Change website: http://www.ecy.wa.gov/climatechange/index.htm.

Climate projections for Little Spokane watershed

As described above in the **Climate Change Summary for the Pacific Northwest** section, researchers have downscaled results from Global Climate Models to Pacific Northwest regional conditions. Projections for the rest of this century are indicating an ongoing shift towards hotter, drier summers and winters that are wetter and relatively warmer. Several impacts can be expected on waters of the Little Spokane River basin:

- Summer water temperatures will increase with more intense heat waves. For example, Figure N-1 shows a projection of maximum temperatures at the Deer Park Airport (centrally located in the Little Spokane basin) in June-August using high emissions scenarios and the MACAv2 downscaled modeling data sets, provided by the University of Idaho's Northwest Climate Toolbox[9]. Maximum temperatures are expected to climb by almost 5 ^{o}F over the next several decades, and by around 12 ^{o}F by the end of the century.
- Increased precipitation will likely lead to increased stormwater, erosion, and wash-off of pollutants. Figure N-2 shows climate model projections for March-May at Deer Park. Precipitation could increase by one-half inch over the next two decades and by about 2 inches by the end of the century. This does not take into account the intensity of individual storms, which is also likely to increase.
- Increased water temperatures will contribute to the depression of DO levels. Figure N-3 shows temperature modeling results from the U.S. Forest Service NorWeST project[10]. This figure illustrates the spread of much warmer temperatures to higher elevation tributaries as well as the general increase in temperatures.

[9] https://climatetoolbox.org/tool/Future-Climate
[10] https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST/ModeledStreamTemperatureScenarioMaps.shtml

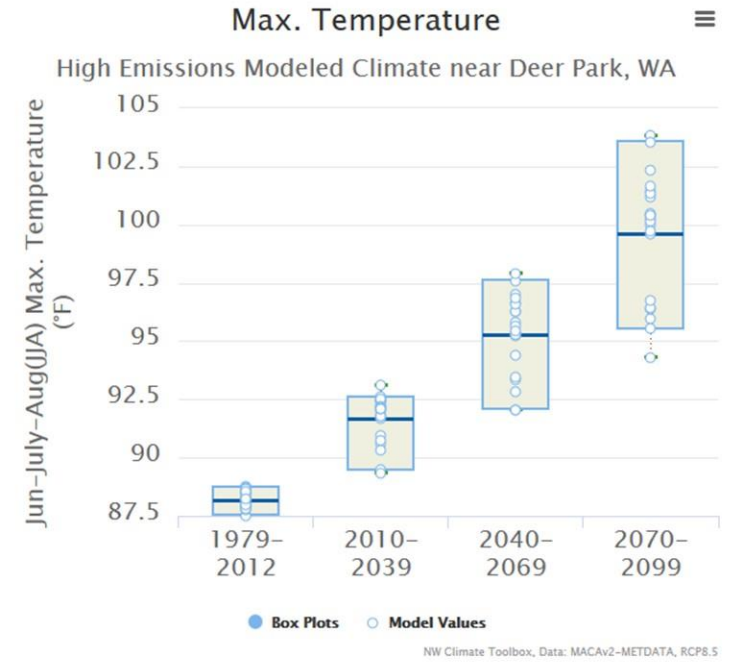


Figure N-1. Maximum temperature projections for Deer Park, WA from the MACA climate dataset.

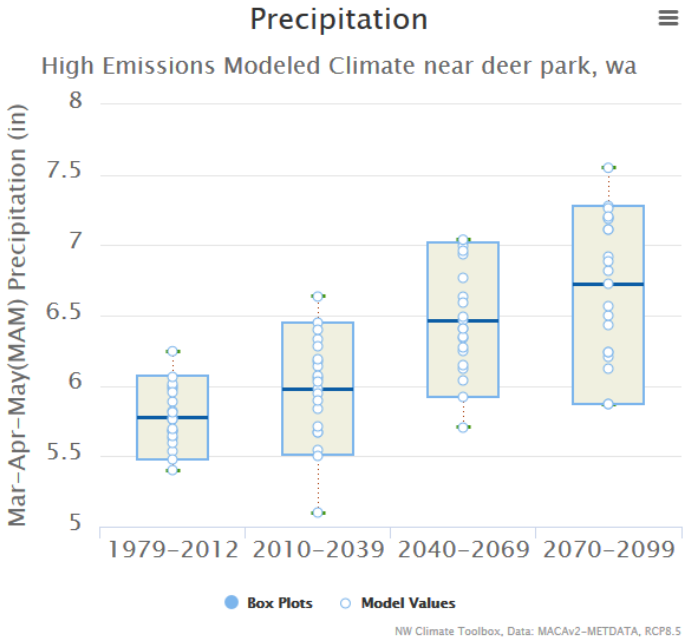


Figure N-2. March-May precipitation projections for Deer Park, WA from the MACA climate data set.

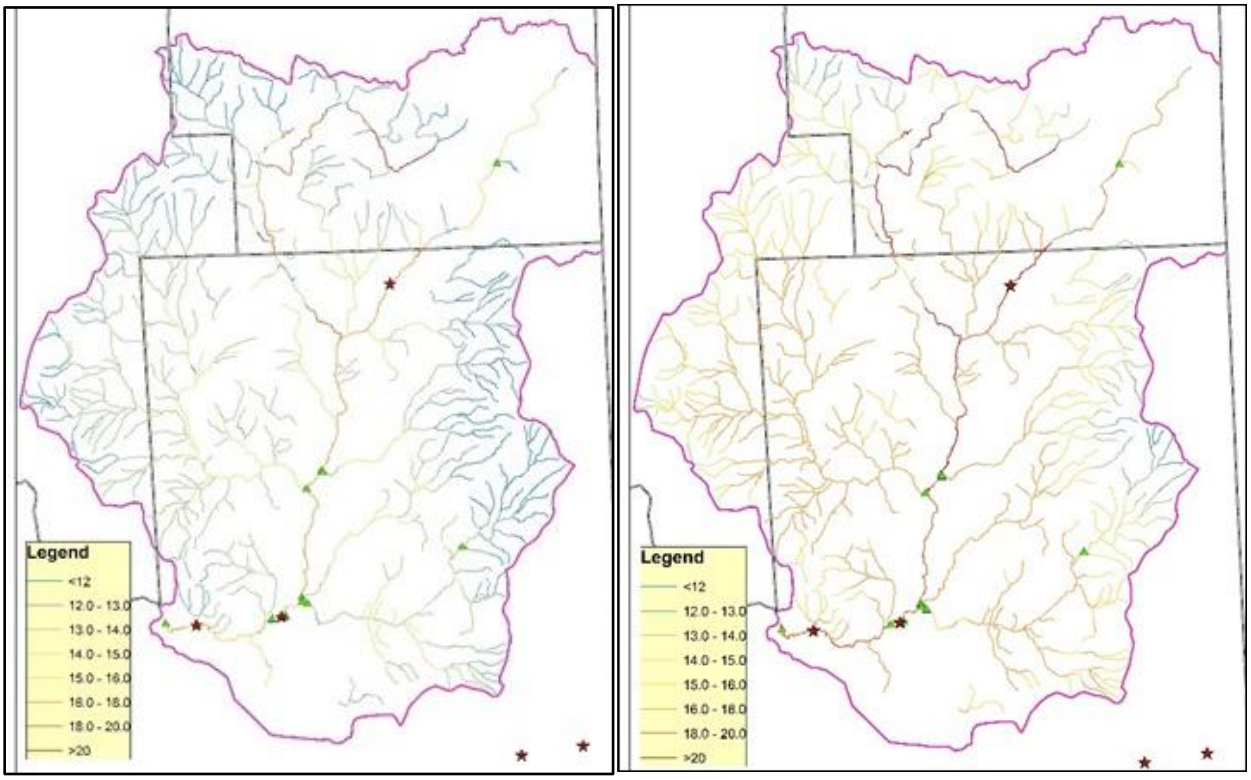


Figure N-3. Results from NorWeST stream temperature model scenarios for the Little Spokane River basin.

Left: Historical composite scenario representing 19-year average August mean stream temperatures for 1993-2011.

Right: Future August mean stream temperature scenario based on global climate model ensemble average projected changes in August air temperature and stream discharge for the A1B warming trajectory in the 2040s (2030-2059).

Temperatures in degrees C.

The EPA conducted a climate change pilot TMDL study of the South Fork Nooksack River, which included a qualitative assessment of TMDL implementation strategies (EPA, 2016). The report notes that:

> *This qualitative assessment is a comprehensive analysis of climate change impacts on freshwater habitat and Pacific salmon in the South Fork. … The objective of the assessment is to identify and prioritize climate change adaptation strategies or recovery actions for the South Fork that explicitly include climate change as a risk.*

A key finding of the EPA study is that:

> *…the most important actions to implement to ameliorate the impacts of climate change in the South Fork watershed are riparian restoration, floodplain reconnection, wetland restoration, and placement of log jams.*

The main principle for addressing climate change impacts on the Little Spokane River is to increase resilience within the watershed. Increased shading and habitat complexity creates microclimates where fish can hold over during hot spells. These “cold water refuges” can be locations where cool tributaries, shallow groundwater seeps, groundwater upwelling, and hyporheic flow can be enhanced by the restoration of channel and flood plain processes.

We have identified two key ways this TMDL will help protect the Little Spokane River and its tributaries from human impacts to the watershed from climate variability. First, the results of this study indicate that riparian shading and reduction of nutrient inputs can enhance the overall health of the stream with cooler water and higher DO levels. Second, implementation of the TMDL stream restoration will also enhance cold water refuges and habitat complexity that will help to build resilience to offset the impacts of more extreme weather events such as heat waves and intense storms.

Appendix O. Summary of Load and Wasteload Allocations by Impairment Reach

This *Little Spokane River DO, pH, and TP Total Maximum Daily Load Water Quality Improvement Report and Implementation Plan* is intended to be a holistic water cleanup plan to address dissolved oxygen, pH, and nutrient issues throughout the LSR watershed. However, the process for approval of this plan by the U.S. Enviromental Protection Agency (EPA) requires that load and wasteload allocations be linked to specific water quality impairments. Table O-1 in this appendix provides a list of the impaired reaches in the Little Spokane River watershed, along with a summary of the TP, shade/heat, and DIN allocations that apply to each. Table O-2 provides a more detailed look at point source wasteload allocations as they apply to each reach.

We are including 303(d) listed reaches for DO and pH (see Table 1), as well as "impaired but not listed" reaches that are not on the current 303(d) list, but which do not meet water quality standards (see Table 2). We are also including "threatened" reaches where we observed impairments, but the quantity of data we collected does not meet Ecology's listing policy (Policy 1-11).

Table O-1. Load and Wasteload Allocations by impairment reach

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Little Spokane River (near Scotia)	47875 (DO)	17010308000083	Not Applicable					No (except GP bubble)	1.43 kg/d Mar-May 1.68 kg/d June 0.86 kg/d July-Oct	[e]	0	[f]	165 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River (near Frideger Rd)	IBNL[g] (DO)	17010308000081	Not Applicable					TP controlled by LA further downstream (Little Spokane River near Elk) [h]					154 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River (near Elk)	IBNL[g] (DO)	17010308000080	0.00038 kg/d (GP bubble)	1.36 kg/d	0	0	1.36 kg/d [i]	No (except GP bubble)	2.16 kg/d Mar-May 3.23 kg/d June 1.21 kg/d Jul-Oct	[e]	0	[f]	125 W/m2	No TP reductions; DIN and heat are surrogates for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane R. between Elk and WBLSR confluence	Thr [j] (DO)	17010308000079 17010308000078	0.00059 kg/d (GP bubble)	30.9 kg/d	0	0	30.9 kg/d [i]	TP controlled by LA further downstream (Little Spokane River - Chattaroy) [h]					178 W/m2	DIN and heat are surrogates for "unofficial" (but observed) DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River - Chattaroy	IBNL[g] (DO) 50436 (pH)	17010308000077	Not Applicable					No (except GP bubble)	10.84 kg/d Mar-May 6.03 kg/d June 10.84 kg/d Mar-May	[e]	0	[f]	178 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES
	IBNL[g] (DO) IBNL[g] (pH)	17010308007197													YES
Little Spokane River (Dragoon to Deadman Creeks)	47133 (DO) 50434 (pH)	17010308001158	Not Applicable					No (except GP bubble)	23.56 kg/d Mar-May 9.30 kg/d June 4.33 kg/d Jul-Oct	[e]	0	[f]	186 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane. WLAs for both Colbert Landfill and Spokane County Muni SW NPDES Permit WAR046506	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Little Spokane River (Darford USGS Gage)	IBNL[g] (DO)	17010308000024	Not Applicable					Yes	TP controlled by LA further downstream (Little Spokane River near mouth) [h]				254 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane. WLAs for Spokane Co Muni SW (WAR046506) & WA State Dept of Transportation (WAR043000A)	YES
Little Spokane River (near mouth)	42597 (DO)	17010308000018	Not Applicable					No (except GP bubble)	46.00 kg/d Mar-May 23.75 kg/d June 13.71 kg/d Jul-Oct	[e]	0	[f]	254 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dry Creek	IBNL[g] (DO) 50373 (pH)	17010308000156	Not Applicable					No (except GP bubble)	1.42 kg/d Mar-May 0.51 kg/d June 0.31 kg/d Jul-Oct	[e]	0	[f]	68 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Otter Creek	47070 (DO)	17010308000365	Not Applicable					No (except GP bubble)	0.64 kg/d Mar-May 0.70 kg/d June 0.97 kg/d Jul-Oct	[e]	0	[f]	122 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Moon Creek	47861 (DO)	17010308000099	Not Applicable					No (except GP bubble)	0.14 kg/d Mar-May 0.09 kg/d June 0.04 kg/d Jul-Oct	[e]	0	[f]	173 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River, West Branch, Between Sacheen and Horseshoe Lakes	47863 (DO)	17010308006689	Not Applicable					No (except GP bubble)	1.2 kg/d Mar-May 0.32 kg/d June 0.15 kg/d Jul-Oct	[e]	0	[f]	157 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Buck Creek	47872 (DO)	17010308000142	Not Applicable					No (except GP bubble)	2.13 kg/d Mar-May 0.62 kg/d June 0.07 kg/d Jul-Oct	[e]	0	[f]	55 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River, West Branch, between Horseshoe Lake and the mouth of Beaver Ck.	Thr [j] (DO)	17010308000090	Not Applicable					No (except GP bubble)	3.56 kg/d Mar-May 1.08 kg/d June 0.14 kg/d Jul-Oct	[e]	0	[f]	174 W/m2	Heat is surrogate for "unofficial" (but observed) DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Beaver Creek	47869 (DO)	17010308000101	Not Applicable					No (except GP bubble)	1.12 kg/d Mar-May 0.05 kg/d June 0.01 kg/d Jul-Oct	[e]	0	[f]	28 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River, West Branch, from the mouth of Beaver Ck. to Eloika Lake	47862 (DO)	17010308000088	Not Applicable					No (except GP bubble)	3.85 kg/d Mar-May 1.84 kg/d June 0.41 kg/d Jul-Oct	[e]	0	[f]	174 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Little Spokane River, West Branch - Eloika Lake - Mouth	47073 (DO) 50379 (pH)	17010308000085	Not Applicable					No (except GP bubble)	4.33 kg/d Mar-May 1.03 kg/d June 0.25 kg/d Jul-Oct	[e]	0	[f]	172 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES
Bear Creek	47074 (DO)	17010308001818	Not Applicable					No (except GP bubble)	0.46 kg/d Mar-May 0.17 kg/d June 0.08 kg/d Jul-Oct	[e]	0	[f]	99 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Deer Creek, above Little Deer Creek.	IBNL[g] (DO)	17010308000066	Not Applicable					TP controlled by LA further downstream (Deer Creek, Mouth) [h]					44 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Deer Creek, Mouth	IBNL[g] (DO)	17010308000065	Not Applicable					No (except GP bubble)	3.73 kg/d Mar-May 0.50 kg/d June 0.01 kg/d Jul-Oct	[e]	0	[f]	117 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Upper Dragoon Creek(abv Dragoon Dr to Spring Ck)	47094 (DO)	17010308000119	0.00096 kg/d (GP bubble)	0.034 kg/d	0	0	0.035 kg/d [k]	No (except GP bubble)	2.82 kg/d Mar-May 0.69 kg/d June 2.82 kg/d Mar-May	[e]	0	[f]	128 W/m2	DIN and heat are surrogates for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES
	8445 (DO)	17010308000125													YES
Spring Creek	IBNL[g] (DO)	17010308000397	Not Applicable					No (except GP bubble)	0.46 kg/d Mar-May 0.21 kg/d June 0.11 kg/d Jul-Oct	[e]	0	[f]	101 W/m2	No TP reductions; Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dragoon Creek (Spring Creek to Beaver Creek)	8443 (DO)	17010308000118	Not Applicable					No (except GP bubble)	3.43 kg/d Mar-May 0.55 kg/d June 0.16 kg/d Jul-Oct	[e]	0	[f]	191 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dragoon Creek (avb W.B. Dragoon Ck. near Burroughs Rd)	IBNL[g] (DO)	17010308000116	Not Applicable					No (except GP bubble)	3.82 kg/d Mar-May 1.02 kg/d June 0.28 kg/d Jul-Oct	[e]	0	[f]	191 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
West Branch Dragoon Creek	IBNL[g] (DO)	17010308000477	Not Applicable					No (except GP bubble)	2.35 kg/d Mar-May 0.87 kg/d June 0.62 kg/d Jul-Oct	[e]	0	[f]	135 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dragoon Creek (near North Rd.)	IBNL[g] (DO)	17010308000110	Not Applicable					No (except GP bubble)	6.42 kg/d Mar-May 2.27 kg/d June 0.92 kg/d Jul-Oct	[e]	0	[f]	198 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dragoon Creek - Above Mouth	11368 (DO) 11370 (pH)	17010308000107	Not Applicable					No (except GP bubble)	7.08 kg/d Mar-May 2.03 kg/d June 1.00 kg/d Jul-Oct	[e]	0	[f]	160 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES
Deadman Creek (HW-St Park Bdy)	Thr [j] (DO)	17010308000048	Not Applicable					No (except GP bubble)	1.11 kg/d Mar-May 0.58 kg/d June 0.17 kg/d Jul-Oct	[e]	0	[f]	24 W/m2	Heat is surrogate for "unofficial" (but observed) DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Deadman Creek (Park Bdy - Holcomb Rd)	Thr [j] (DO)	17010308000041	0.00081 kg/d (GP bubble)	0.139 kg/d	0	0	0.14 kg/d [k]	No (except GP bubble)	3.69 kg/d Mar-May 0.81 kg/d June 0.25 kg/d Jul-Oct	[e]	0	[f]	59 W/m2	DIN and heat are surrogates for "unofficial" (but observed) DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Deadman Creek (Near Heglar Rd)	42357 (DO) 50411 (pH)	17010308000038	0.00060 kg/d (GP bubble)	0.084 kg/d	0	0	0.085 kg/d [k]	TP controlled by LA further downstream (Deer Creek near Bruce Rd) [h]					166 W/m2	DIN and heat are surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Peone Creek	47055 (DO)	17010308000033	Not Applicable					TP controlled by LA further downstream (Deer Creek near Bruce Rd) [h]					166 W/m2 [l]	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Deadman Creek (near Bruce Rd)	41981 (DO) 50410 (pH)	17010308000031	Not Applicable					No (except GP bubble)	5.21 kg/d Mar-May 1.19 kg/d June 0.32 kg/d Jul-Oct	[e]	0	[f]	166 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane.	YES
Deadman Creek (below Bruce Rd to SR2)	41982 (DO)	17010308001185	Not Applicable					Yes for both Listing IDs and NHD reaches	5.64 kg/d Mar-May 0.75 kg/d June 5.64 kg/d Mar-May	[e]	0	[f]	158 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane. WLAs for Spokane Co. Muni SW NPDES Permit WAR046506 (41982, 11388), WA State Dept of Transp., NPDES Permit WAR043000A (11388) and Spokane Recycling, Permit WAR304975 (11388)	YES
Deadman Creek (SR2 to Little Deep Creek)	11388 (pH)	17010308000026													YES
SF Little Deep Creek	Thr [j] (DO)	17010308000539	0.00063 kg/d (GP bubble)	0.022 kg/d	0	0	0.023 kg/d [k]	Not Applicable					28 W/m2	DIN and heat are surrogates for "unofficial" (but observed) DO impairment.	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Little Deep Creek (above mouth at Deadman Creek)	47097 (DO) 50401 (pH)	17010308000052	Not Applicable					Yes for both Listing IDs	2.29 kg/d Mar-May 0.16 kg/d June 0.12 kg/d Jul-Oct	[e]	0	[f]	116 W/m2	Heat is surrogate for DO and pH impairments. TP is surrogate for DO downstream in Lake Spokane. WLAs for Spokane Co. Muni SW NPDES Permit WAR046506 (47097, 50401) and WA State Dept of Transp., NPDES Permit WAR043000A (47097, 50401)	YES
Deadman Creek (Little Deep Creek to Mouth)	11385 (DO)	17010308000025	Not Applicable					No (except GP bubble)	7.93 kg/d Mar-May 0.91 kg/d June 0.62 kg/d Jul-Oct	[e]	0	[f]	158 W/m2	Heat is surrogate for DO impairment. TP is surrogate for DO downstream in Lake Spokane.	YES
Dartford Creek	50416 (pH)	17010308000151	Not Applicable					Yes	0.57 kg/d Mar-May 0.63 kg/d June 0.35 kg/d Jul-Oct	[e]	0	[f]	42 W/m2	No TP reductions. Heat is surrogate for pH impairment. TP is surrogate for DO downstream in Lake Spokane. WLA for Spokane County Muni SW NPDES Permit WAR046506.	YES
Griffith Spring (DS of hatchery, mouth at LSR)	70444 (pH)	17010308001179	Not Applicable					Yes	No LAs	[e]	0	[f]	254 W/m2 [m]	Heat is surrogate for pH impairment. TP is surrogate for DO downstream in Lake Spokane. WLA for Upland Fish Hatchery GP (Permittee: WDFW Spokane Hatchery, WAG137007)	YES

[a] Where 303(d) listings occur, we use the waterbody/reach name assigned to that listing. Elsewhere, we use the reach names from load allocation tables in this TMDL.

[b] WLA = Wasteload allocation; LA = Load allocation; MOS = Margin of Safety; FA = Future Allocation; LC = Load Capacity

[c] For heat, the load allocation is equal to the load capacity. Point sources do not contribute heat in any meaningful way (see **Wasteload Allocations** section).

[d] YES = Ecology is requesting official TMDL approval for this impairment from the EPA. We are requesting TMDL approval for 303(d) listed reaches, "impaired-but-not-listed" reaches, and "threatened" reaches.

[e] The Margin of Safety for TP is defined for the entire watershed. 0.421 kg/day (Mar-May); 0.631 kg/day (June); 0.831 kg/day (Jul-Oct).

[f] The Loading Capacity for TP is defined for the entire watershed. 46.49 kg/day (Mar-May); 24.45 kg/day (June); 32.2 kg/day (Jul-Oct).

[g] IBNL = Impaired but not listed. For these reaches, Ecology collected enough data to confirm an impairment, according to the requirements of our listing policy (Ecology policy 1-11). However these reaches have not yet been captured by a Water Quality Assessment (WQA) cycle and added to the 303(d) list. See Table 2.

[h] These impaired reaches do not line up perfectly with the monitoring locations where we defined TP load allocations. A TP load allocation downstream of this reach will require load reductions (or prevent load increases, where we did not specify reductions). Typically the applicable TP LA is the next row in this table, i.e. the next impaired reach downstream.

[i] The load capacity for these reaches appear to be the same as the load allocations. That is because the general permit bubble wasteload allocation for these reaches is so small in relative terms, as to constitute a rounding error.

[j] "Threatened" reach. We observed DO impairments at these locations. However, our dataset for these locations does not meet the requirements of Ecology's listing policy. This is similar to a Category 2 listing (see Appendix A).

[k] The difference between the load capacity and the sum of load plus wasteload allocations appears to be constitute a small amount of extra capacity at these locations. However, in reality this is just a rounding error.

[l] As indicated in footnote to Table 9, Load Allocations for heat apply to tributary streams as well. Peone Ck. is a small intermittent tributary to Deadman Ck. The applicable heat allocation here is the one shown for Deadman Ck. from Holcomb Rd. to Bruce Rd.

[m] As indicated in footnote to Table 9, Load Allocations for heat apply to tributary streams as well. Griffith Spring is a very short tributary (which includes the Little Spokane Hatchery) to the Little Spokane River. The applicable heat allocation here is the one shown for the Little Spokane River from N. LSR Dr. to the mouth.

Table O-2. Wasteload Allocations by impairment reach

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Little Spokane River (Dragoon to Deadman Creeks)	47133 (DO) 50434 (pH)	17010308001158	Not Applicable					0.092 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	Colbert Landfill (TCP Cleanup Groundwater)	YES
Little Spokane River (Dragoon to Deadman Creeks)	47133 (DO) 50434 (pH)	17010308001158	Not Applicable					0.012 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	Spokane County Muni SW NPDES Permit WAR046506	YES
Little Spokane River (Darford USGS Gage)	IBNL[g] (DO)	17010308000024													YES
Deadman Creek (below Bruce Rd to SR2)	41982 (DO)	17010308001185													YES
Deadman Creek (SR2 to Little Deep Creek)	11388 (pH)	17010308000026													YES
Little Deep Creek (above mouth at Deadman Creek)	47097 (DO) 50401 (pH)	17010308000052													YES
Dartford Creek	50416 (pH)	17010308000151													YES
Little Spokane River (Darford USGS Gage)	IBNL[g] (DO)	17010308000024	Not Applicable					0.0061 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	WA Dept of Transportation NPDES Permit WAR043000A (Municipal SW GP)	YES
Deadman Creek (SR2 to Little Deep Creek)	11388 (pH)	17010308000026													YES
Little Deep Creek (above mouth at Deadman Creek)	47097 (DO) 50401 (pH)	17010308000052													YES
Deadman Creek (SR2 to Little Deep Creek)	11388 (pH)	17010308000026	Not Applicable					0.0064 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	Spokane Recycling NPDES WAR304975 (Industrial SW)	YES
Griffith Spring (DS of hatchery, mouth at LSR)	70444 (pH)	17010308001179	Not Applicable					0.51 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	WDFW Spokane Hatchery, NPDES Permit WAG137007 (Upland Fish Hatchery GP)	YES

Waterbody/Reach [a]	Assessment listing ID	NHD Reach Code	Dissolved Inorganic Nitrogen (DIN) [b]					Total Phosphorus (TP) [b]					Heat	Comments	Requesting approval? [d]
			WLA	LA	MOS	FA	LC	WLA	LA	MOS	FA	LC	LA [c]		
Throughout Watershed			0.0040 kg/d May-Nov	Not Applicable				0.044 kg/d Mar-Oct	(see Table O-1)	[e]	0	[f]	N/A	Bubble allocation for: • Industrial SW GP [h] • Construction SW GP • Sand & Gravel GP TP WLA applies everywhere. DIN WLA applies to N-sensitive streams (LSR from Chain Lk. To WBLSR; Dragoon Ck. abv Spring Ck; SF Little Deep Ck; Deadman Ck. from State Park bdy to Heglar Rd.) DIN WLA is N/A for other reaches.	YES

[a] Where 303(d) listings occur, we use the waterbody/reach name assigned to that listing. Elsewhere, we use the reach names from load allocation tables in this TMDL.

[b] WLA = Wasteload allocation; LA = Load allocation; MOS = Margin of Safety; FA = Future Allocation; LC = Load Capacity

[c] For heat, the load allocation is equal to the load capacity. Point sources do not contribute heat in any meaningful way (see **Wasteload Allocations** section).

[d] YES = Ecology is requesting official TMDL approval for this impairment from the EPA.

[e] The Margin of Safety for TP is defined for the entire watershed. 0.421 kg/day (Mar-May); 0.631 kg/day (June); 0.831 kg/day (Jul-Oct).

[f] The Loading Capacity for TP is defined for the entire watershed. 46.49 kg/day (Mar-May); 24.45 kg/day (June); 32.2 kg/day (Jul-Oct).

[g] IBNL = Impaired but not listed. For these reaches, Ecology collected enough data to confirm an impairment, according to the requirements of our listing policy (Ecology policy 1-11). However these reaches have not yet been captured by a Water Quality Assessment (WQA) cycle and added to the 303(d) list. See Table 2.

[h] That is, all industrial stormwater sources except Spokane Recycling (Former Kaiser Site), which has its own WLA.