Memorandum **March 1, 2017**

To: Gretchen Hayslip, USEPA

From: Peter Leinenbach, USEPA

Subject: Estimates of plume volume associated with five tributary/Columbia River confluence sites using USEPA field data collected in 2016

Summary

This table below presents volume of "cold" water observed during summer monitoring activities at several tributary confluence zones with the Columbia River (**Table 1**).

Table 1. "Cold" water volume (m^3), within specific temperature ranges, observed at the confluence zone between several sampled tributaries and Columbia River during the summer of 2016

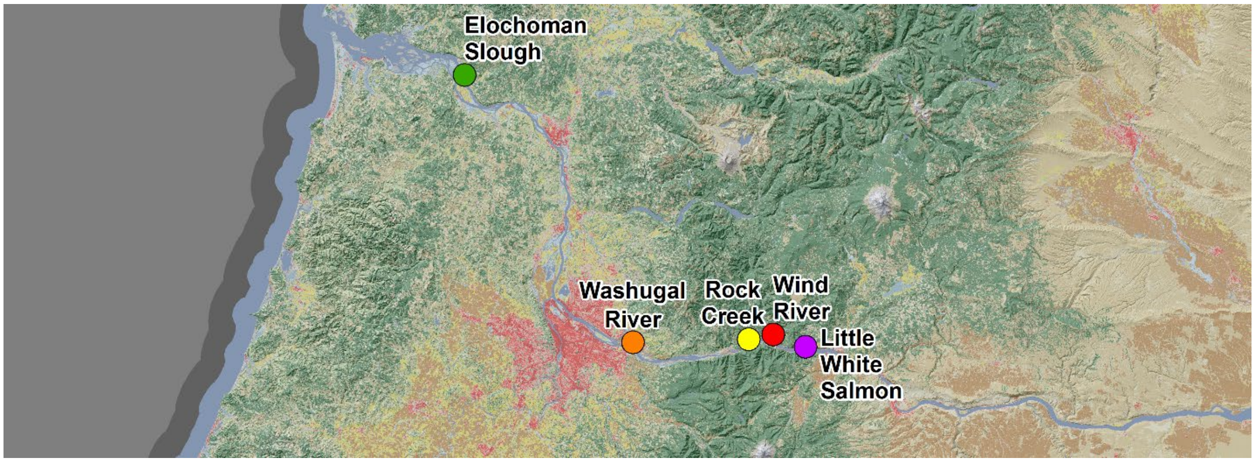
River and Sample Date	Less than 16*C	Between 16*C and 18*C	Between 18*C and 20*C
Elochoman Slough 8/18/2016	0	0	0
Washougal River 8/16/2016	0	0	0
Rock Creek 8/17/2016	0	0	8,845
Wind River 8/15/2016	0	20,390	123,616
Little White Salmon River 8/17/2016	90,723	440,801	1,267,874

Background

The potential of tributary discharge to create cold water refugia (CWR) plumes in Columbia River was evaluated through two methods: 1) CorMix modeling; and 2) direct measurement through field monitoring. The ultimate goal of these efforts was to calculate the volume of the cold water plume in the Columbia River created by the discharge of these monitored tributaries: This information will be utilized as an input parameter in the HexSim modeling effort for this project. This memo presents the results associated with the summer monitoring activities, along with the calculated plume volumes.

Tributaries chosen for field monitoring based on the following criteria: 1) the confluence zone between tributary and the Colombia River was determined to be too hydrologically complex to model with the CorMix model; and 2) that the tributary had a high potential to create CWR plumes (i.e., relatively high summer stream discharge, and low tributary temperatures). Accordingly, five tributary confluence zone sampled as part of this effort were: 1) Elochoman Slough; 2) Washougal River; 3) Rock Creek (Washington), 4) Wind River; and 5) Little White Salmon (**Figure 1**).

Figure 1. Tributary/Columbia Plume Monitoring Locations



Results - Elochoman Slough

Cold Water Plume Volume Results – Elochoman Slough

Results - No cold water plume in the Columbia River was observed during this sampling effort.

Methods – Evaluation of field data.

Field Sampling Results – Elochoman Slough

No thermal cold water plume was observed in the Columbia River resulting from the Elochoman River on the date of sampling (**Figures 2 and 3**). Measured water temperatures were slightly cooler within Elochoman than observed in the Columbia River, however the temperature differences were often less than 1.0*C (see **Figure 2**). Also, there was almost no thermal stratification at any of the sampling locations (see **Figure 3**).

Elochoman River temperatures were near annual maximum on the date of sampling (**Figure 4**) and measured stream flow in Elochoman River was only 33.1 cfs on the date of sampling (**Figure 5**): Both of these factors limit the potential magnitude and spatial extent of a CWR zone produced by Elochoman River discharge to the Columbia River.

Measured dissolve oxygen levels did not indicate a limiting condition on the date of sampling (**Figure 6**).

Figure 2. Measured Water Temperatures at a 1 meter depth in the Elochoman Slough and Columbia River Confluence on August 18, 2016.

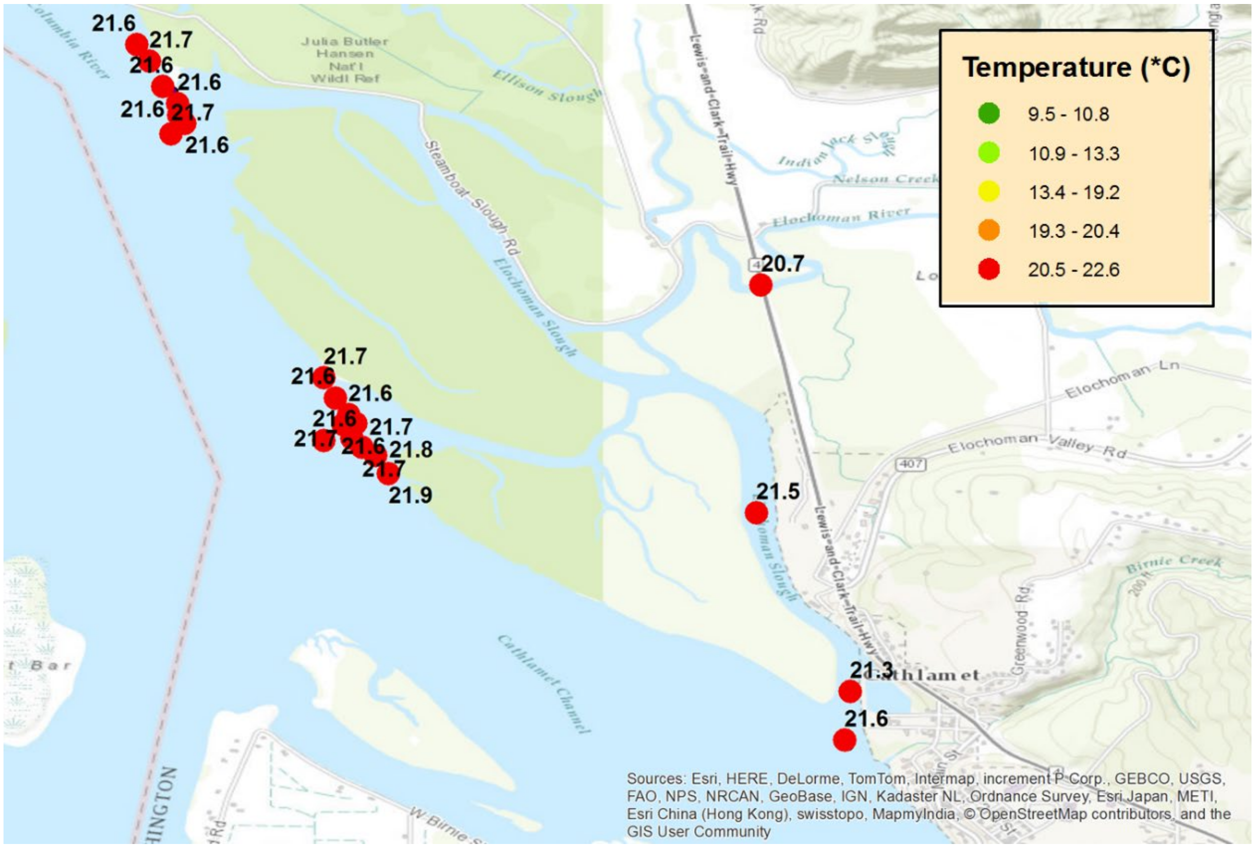
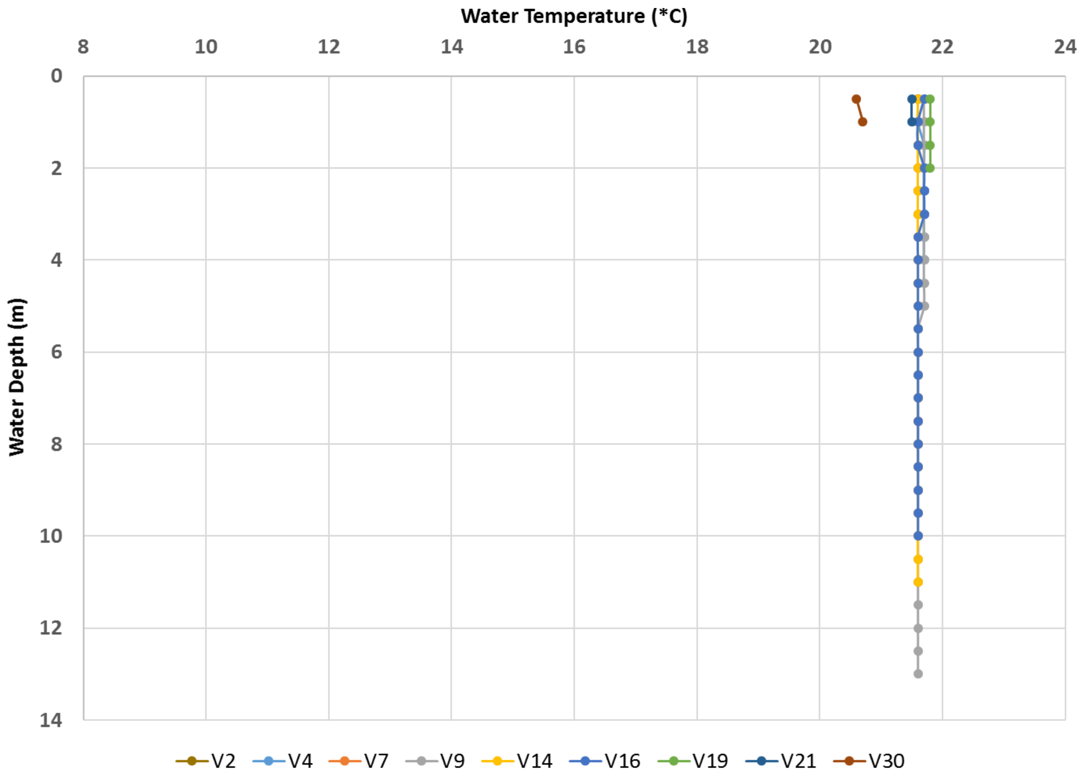


Figure 3. Measured Water Temperature Profile at Selected Locations at the Elochoman Slough and Columbia River Confluence on August 18, 2016.



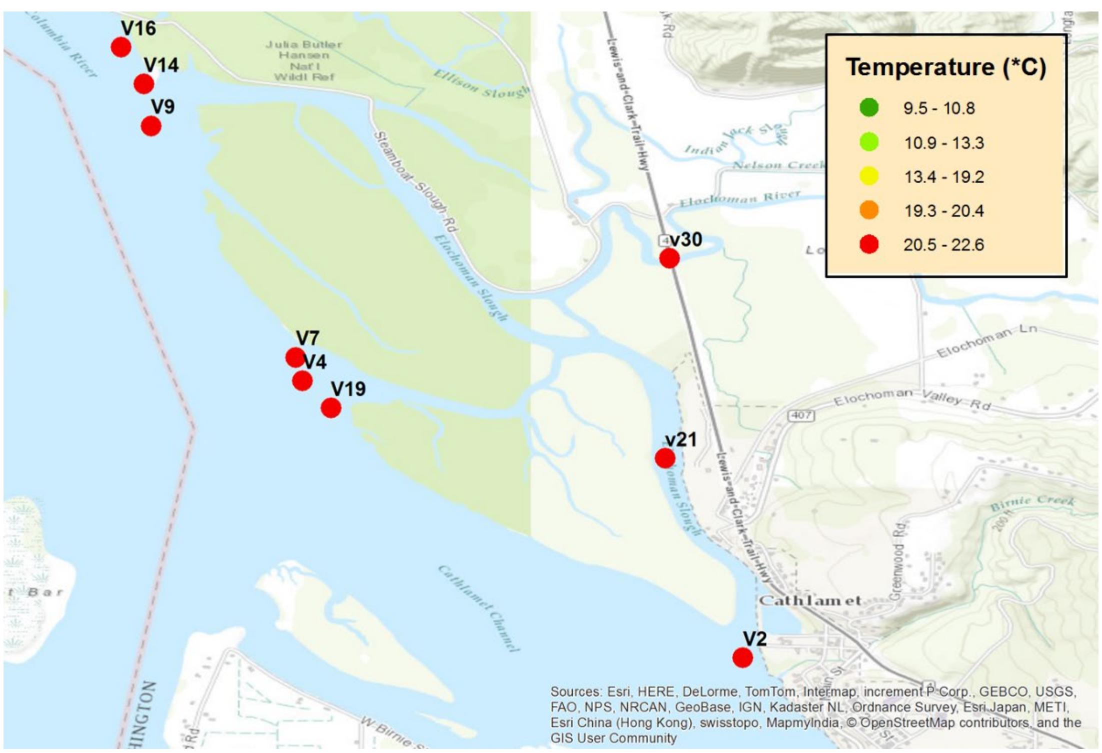
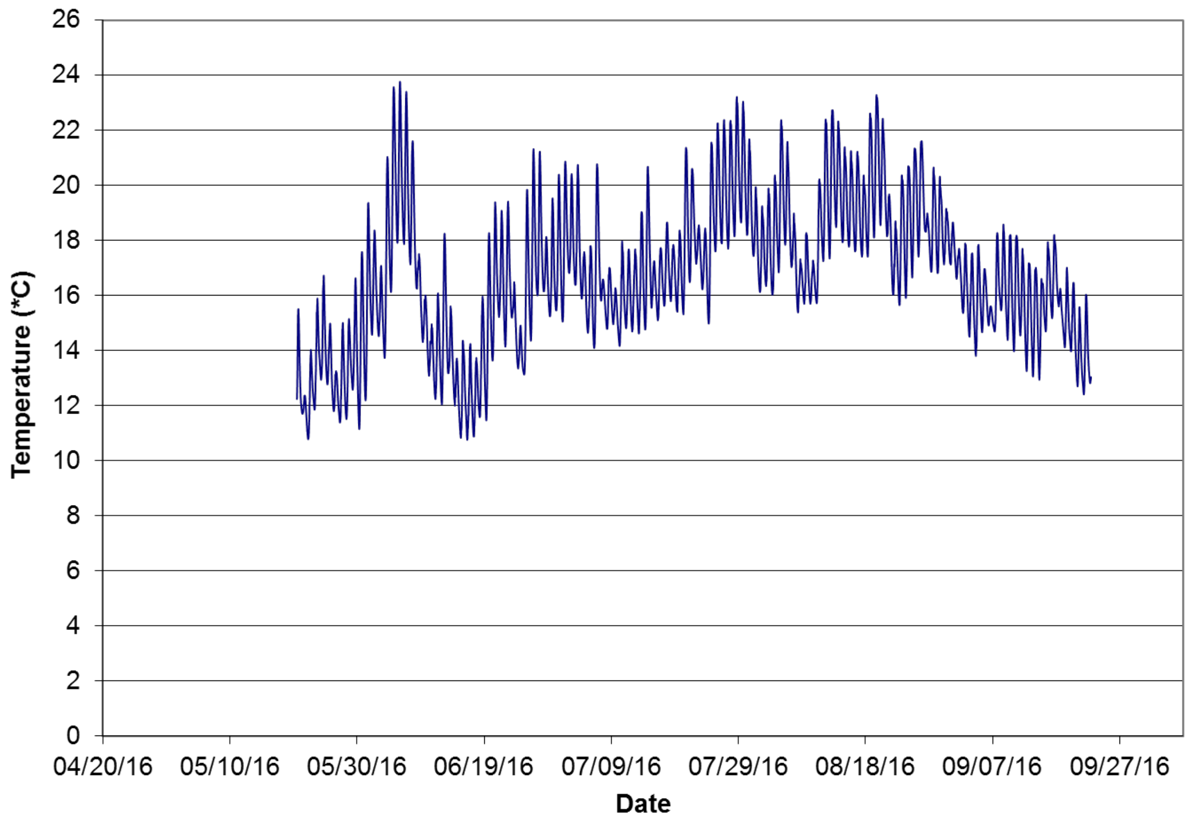


Figure 4. Measured Water Temperature Seasonal Profile Elochoman Slough near the mouth[1] during the summer of 2016



[1] Site located near the Beaver Creek Hatchery on the Elochoman River (46.22572, -123.33079)

Figure 5. Measured Elochoman River discharge (cfs) – Water Year 2016

[Source - https://fortress.wa.gov/ecy/eap/flows/station.asp?sta=25C060#block2]

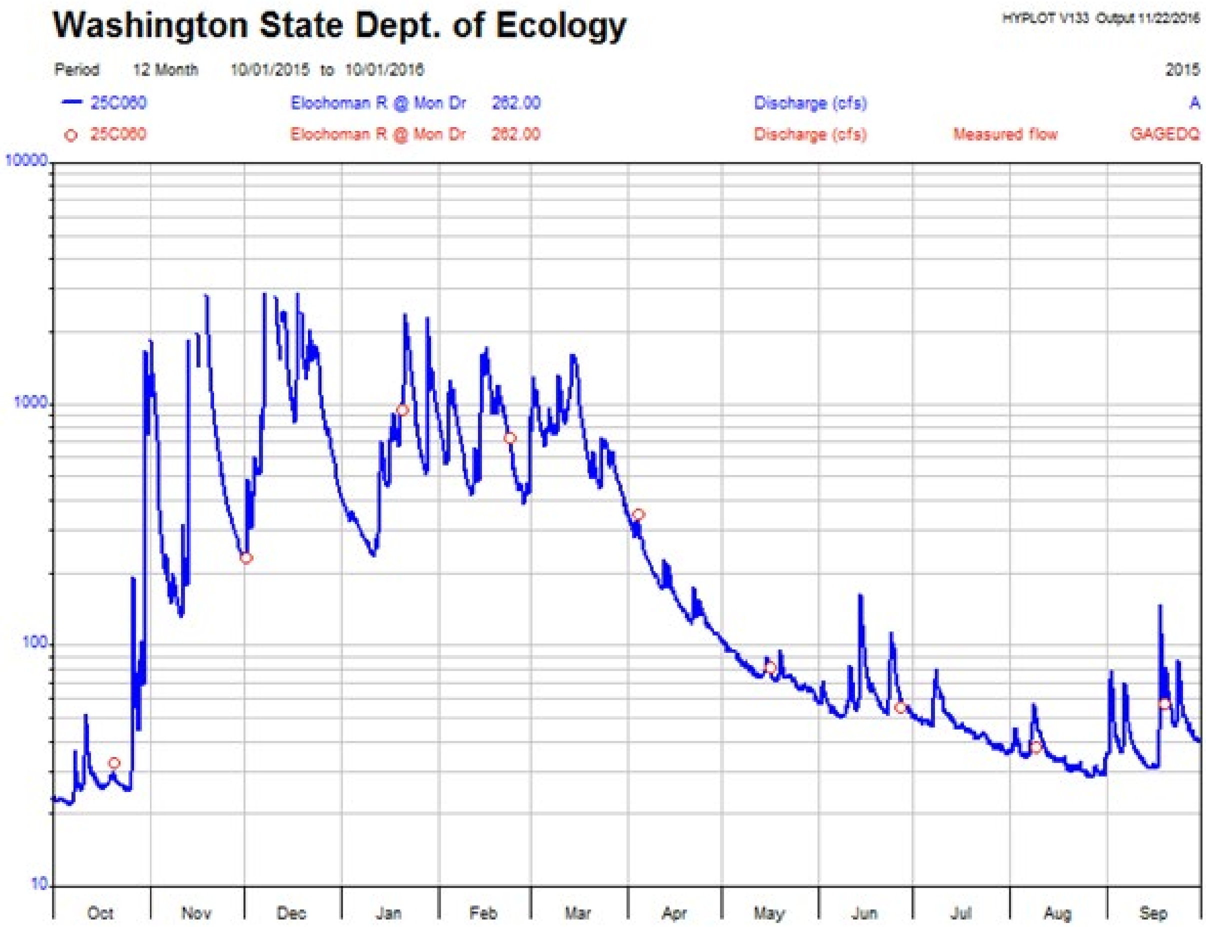
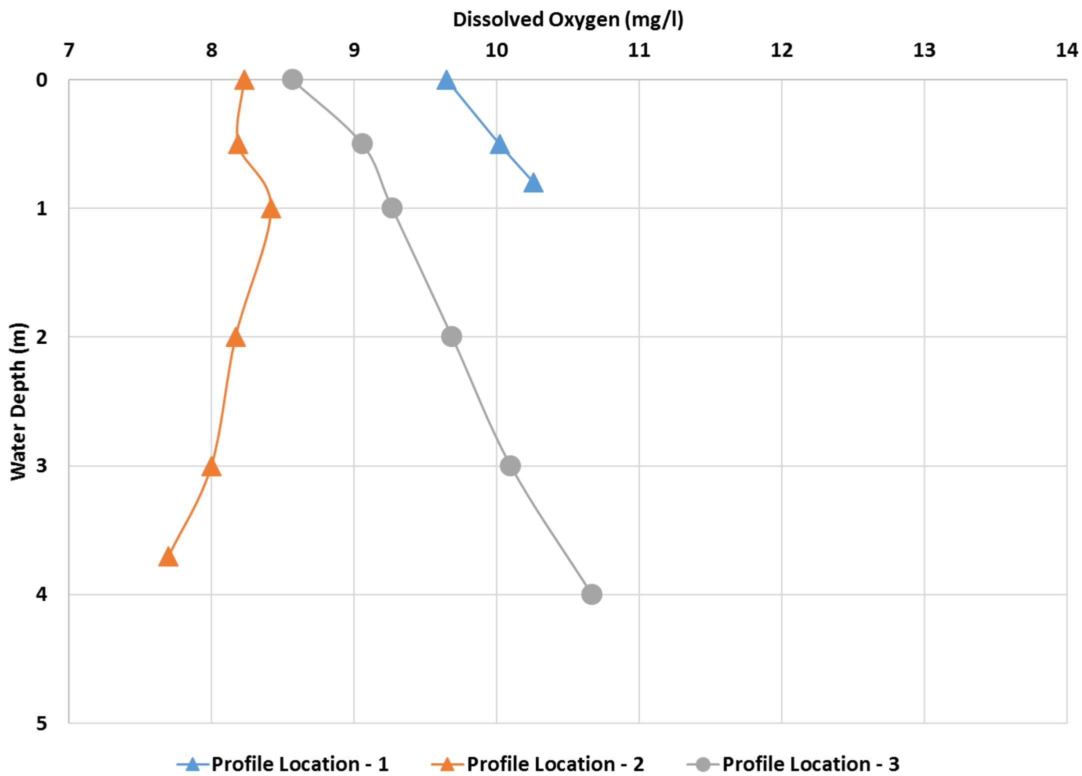
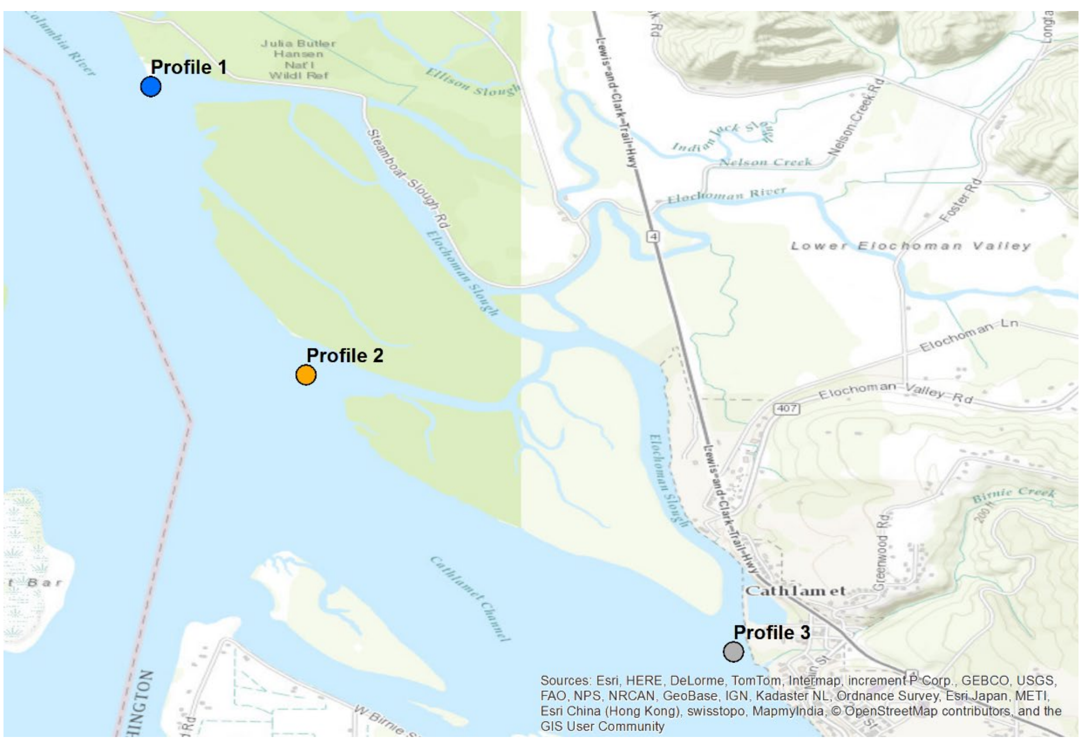


Figure 6. Measured Dissolved Oxygen at the Elochoman Slough and Columbia River Confluence on 8/18/16.





Results - Washougal River

Cold Water Plume Volume Results – Washougal River

Results - No cold water plume in the Columbia River was observed during this sampling effort.

Methods – Evaluation of field data.

Field Sampling Results – Washougal River

The confluence of the Washougal River and Columbia River was monitored on August 16, 2016. The confluence zone is tidally influenced: Sampling occurred at low tide conditions which provided the best opportunity to observe potential Cold Water Refugia (CWR) resulting from Washougal River discharge at this confluence location.

Measured water temperatures indicated that there was no "cold" water present within this confluence zone on the date of sampling (**Figure 7**). In addition, warm water temperatures were measured throughout the vertical profile at this location (**Figure 8**).

Washougal River temperatures were near annual maximum on the date of sampling (**Figure 9**), with temperatures near or greater than the Columbia River mainstem on this date (i.e., **Site V4 in Figure 8** is undiluted Columbia River water as a result of the flow patterns entering this location at low flow conditions). In addition, Washougal River discharge rates were near annual minimums on the sampling date (i.e., 78.3) (**Figure 10**).

Measured dissolve oxygen levels did not indicate a limiting condition on the date of sampling (**Figure 11**).

Figure 7. Water Temperatures (1-meter depth) at the Washougal/Columbia River Confluence - 8/16/16.

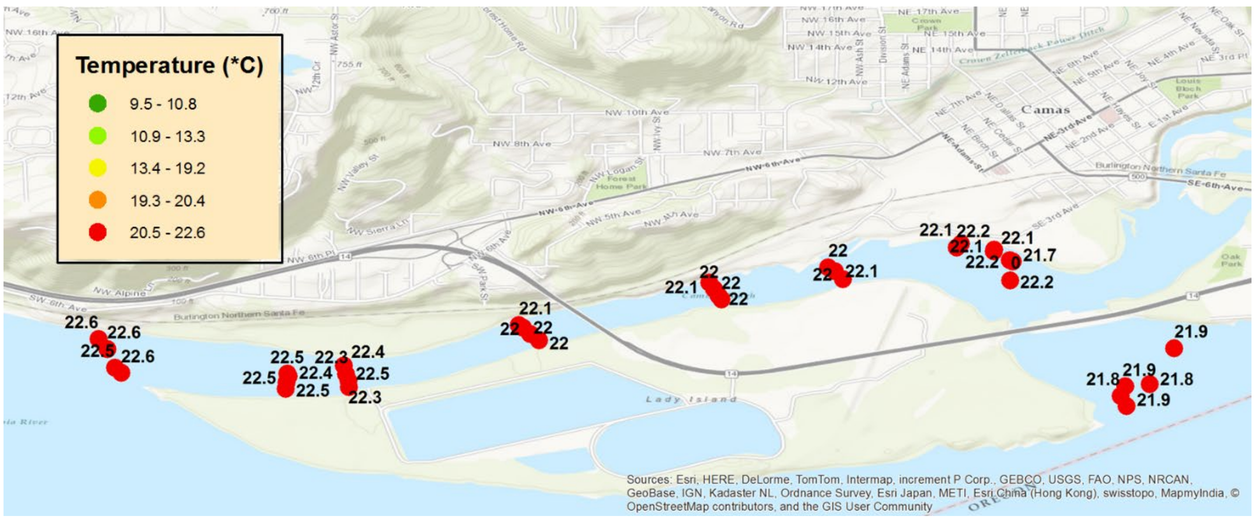
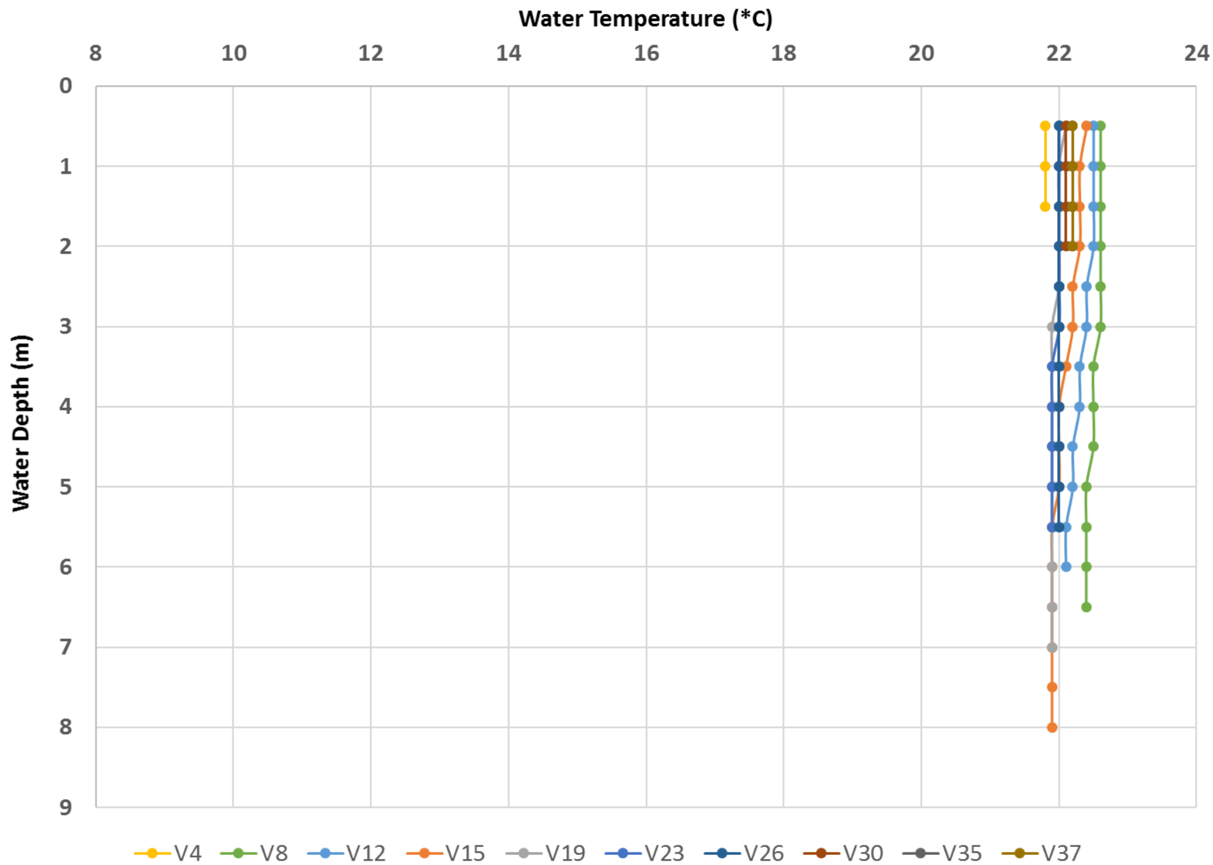


Figure 8. Measured Water Temperature Profile at Selected Locations at the Washougal and Columbia River Confluence on August 16, 2016.



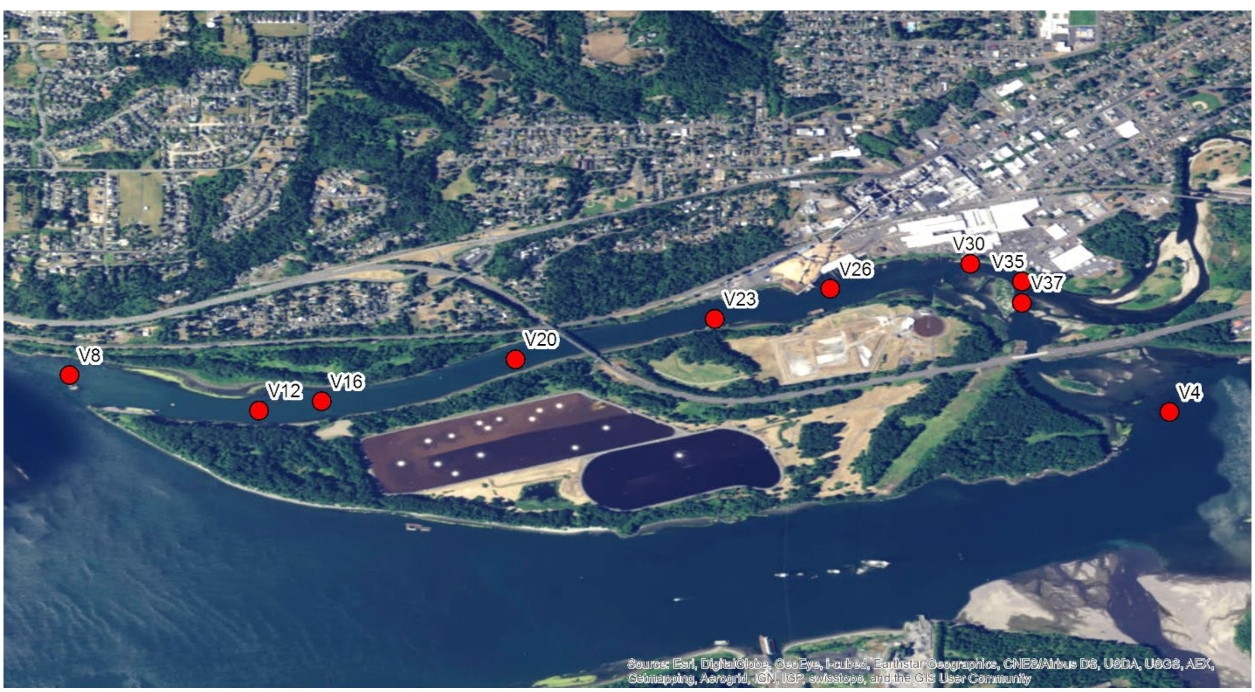
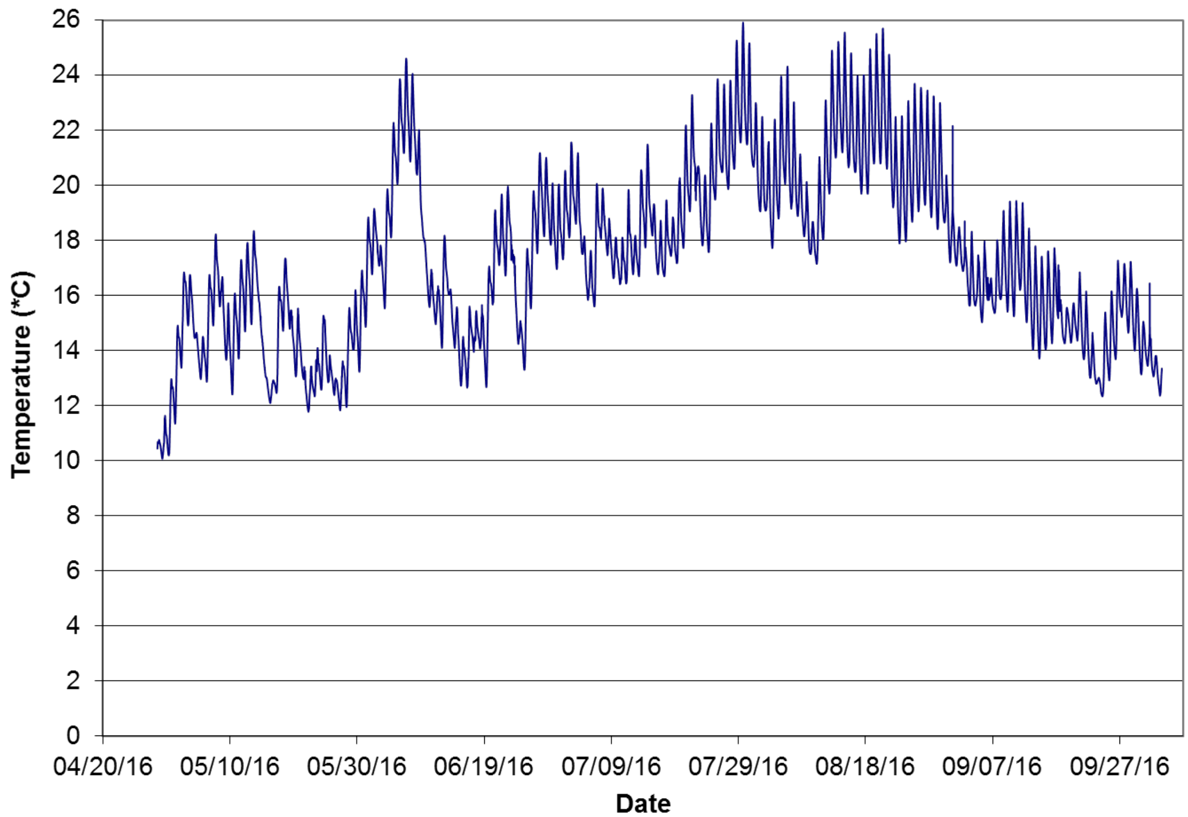


Figure 9. Measured Water Temperature Seasonal Profile the Washougal River near the mouth[2] during the summer of 2016



[2] Deployed at the 3rd Avenue Bridge (45.58702, -122.37237)

Figure 10. Measured Washougal River Discharge (cfs) – Water Year 2016

[Source - https://fortress.wa.gov/ecy/eap/flows/station.asp?sta=28B080#block2]

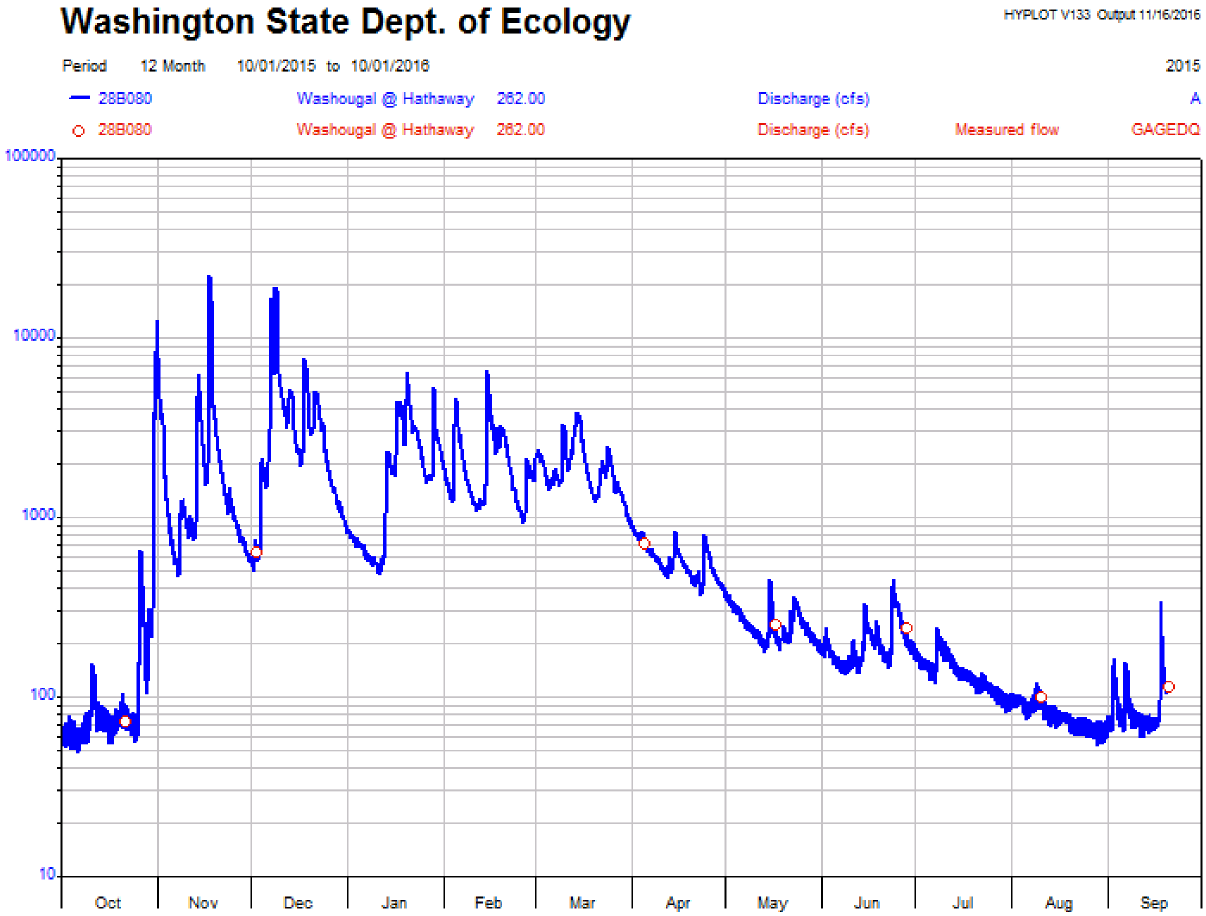
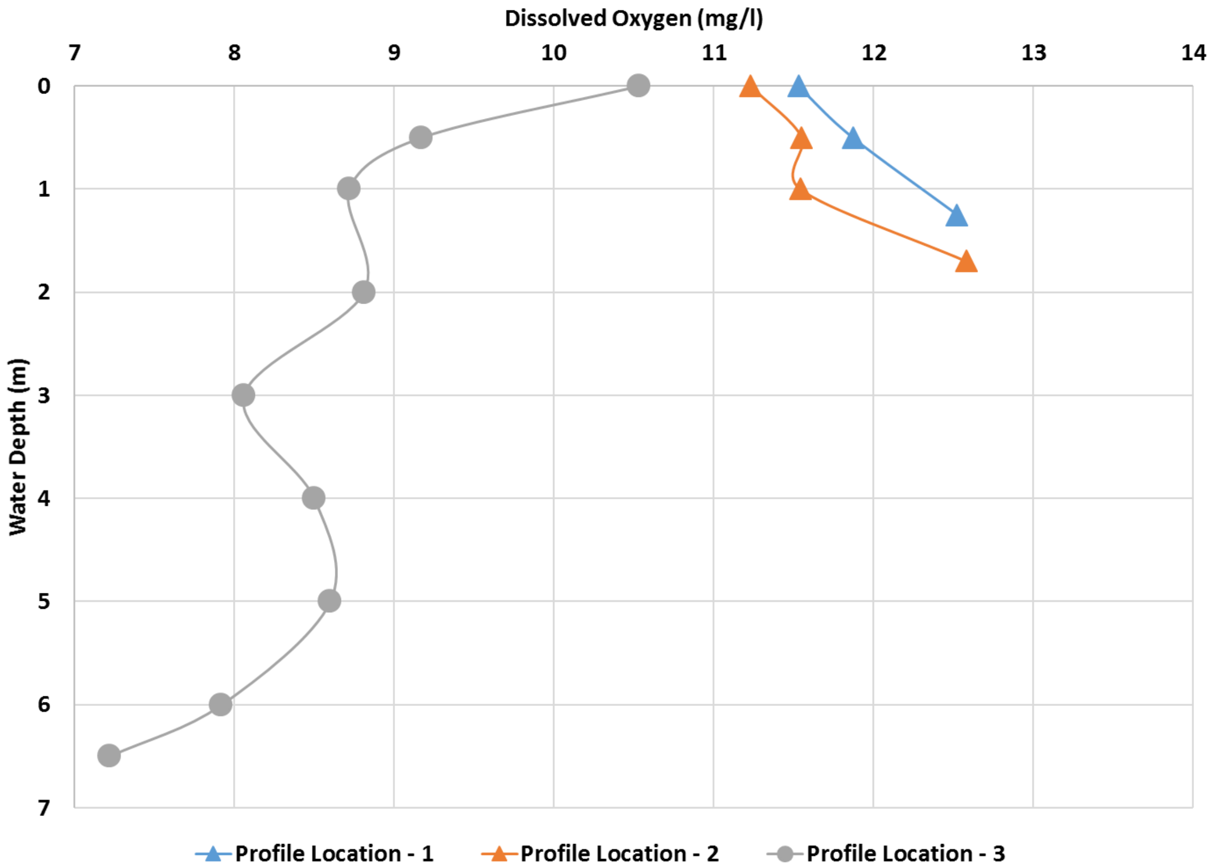


Figure 11. Measured Dissolved Oxygen at the Washougal and Columbia River Confluence on 8/16/16.



Results - Rock Creek (Washington)

Cold Water Plume Volume Results – Rock Creek

Results - The volume of the CWR plume at the Rock Creek confluence, for temperatures between 18*C and 20*C, is 8,845 m^3.

Methods – The cold water plume volume associated with Rock Creek discharge was estimated through the use of the following equation:

$$CWR\ Plume\ Volume = Plume\ Surface\ Area * Average\ Plume\ Depth$$

The cold water plume surface area was estimated based on the measured temperatures presented in **Figure 12**. Specifically, the approximate area associated with temperatures between 18*C and 20*C were estimated based on the measured temperatures: The measured area of the blue polygon in **Figure 12** was 8,845 m^2 (Calculated using Google Earth Pro).

It is important to note that water depths were extremely shallow within the confluence zone on the date of sampling: Sample points illustrated in **Figure 12** were collected at a 3-foot depth (1 m) while walking in the confluence zone. There were several pools within the confluence zone at greater depths, however there were about equal amount of area shallower than 3 feet. Accordingly, it is estimated that the average water depth is 3 ft (or 1 m) within the plume area indicated in **Figure 12**.

Field Sampling Results – Rock Creek

The confluence of the Rock Creek and Columbia River was monitored on August 16, 2016. The confluence zone is not tidally influenced: This tributary is located upstream of the Bonneville dam complex.

Measured water temperatures were slightly cooler within Rock Creek than temperatures observed in the Columbia River (**Figure 12**). The coldest water temperatures were measured in a deep pool zone within this confluence zone, indicating some limited effect of this pool on water temperatures.

Sampling efforts took place between 8 and 10am and as a result observed stream temperatures in Rock Creek were near the daily minimum (**Figure 13**). Accordingly, it could be expected the potential for Rock Creek to create CWR in the Columbia River would be reduced during other periods of the day.

Rock Creek temperatures were near annual maximum on the date of sampling (**Figure 14**). Measured stream flow in Rock Creek was only 7.1 cfs on the date of sampling. Both of these factors limit the potential magnitude and spatial extent of a CWR zone produced by Rock Creek discharge to the Columbia River.

Measured dissolve oxygen levels did not indicate a limiting condition on the date of sampling (**Figure 15**).

Figure 12. Measured Water Temperatures at a 1 meter depth in the Rock Creek and Columbia River Confluence on August 17, 2016.

[Estimated plume area designated by the blue polygon]

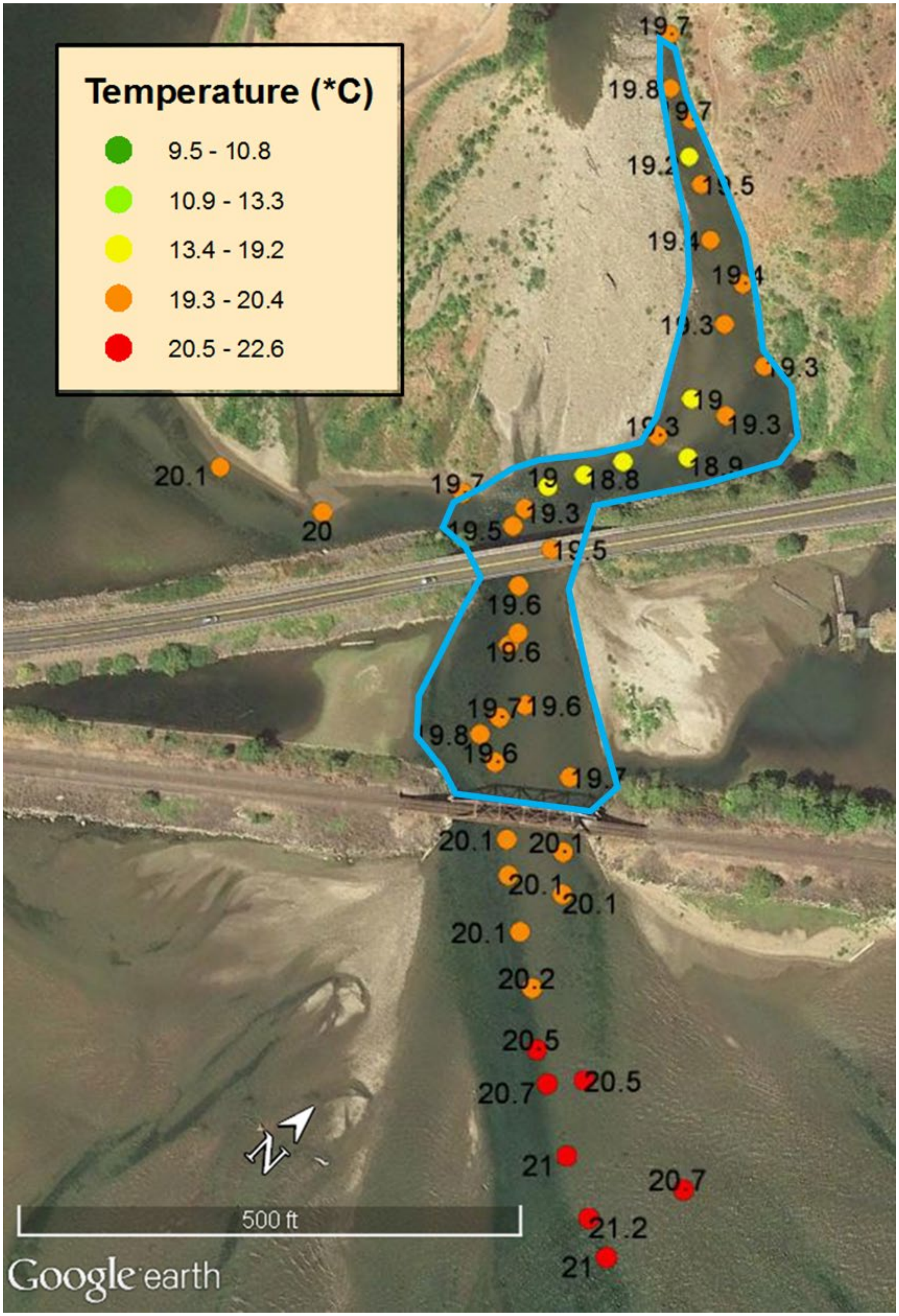


Figure 13. Measured Diurnal Water Temperature Profile for Rock Creek near the mouth[3] on the date of sampling (8/17/2016)

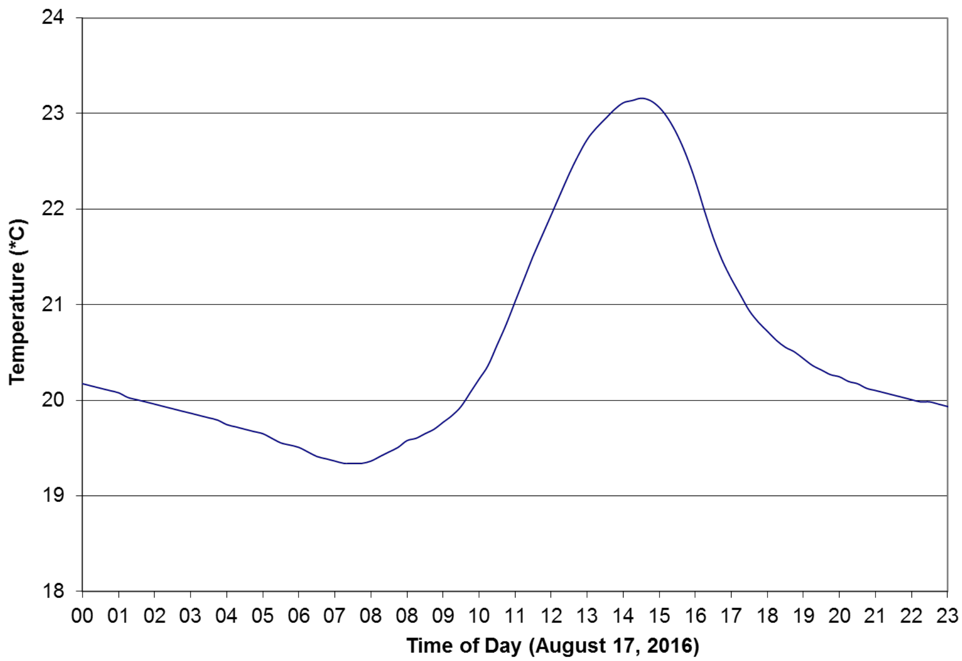
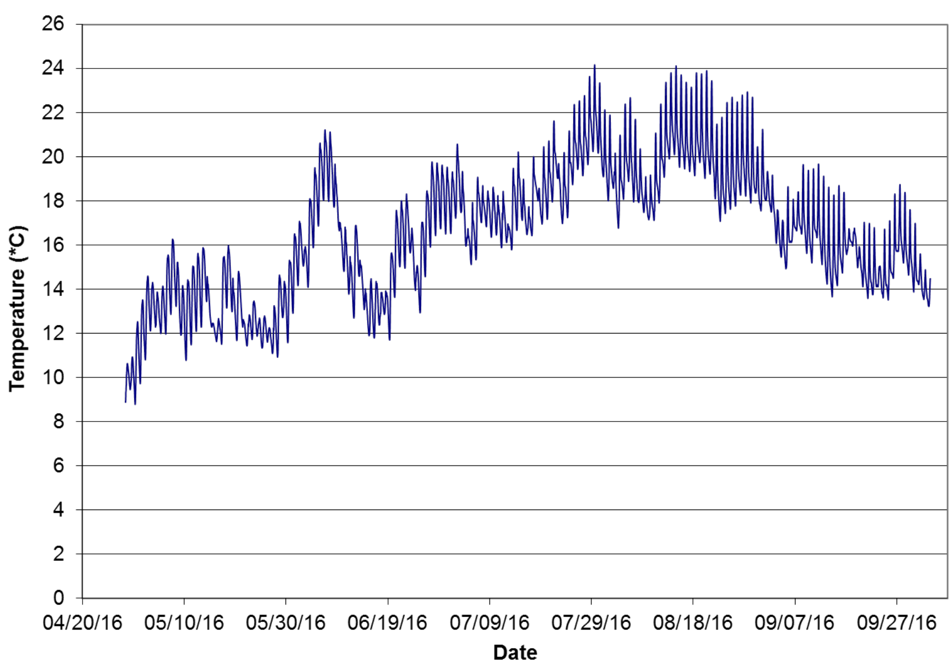
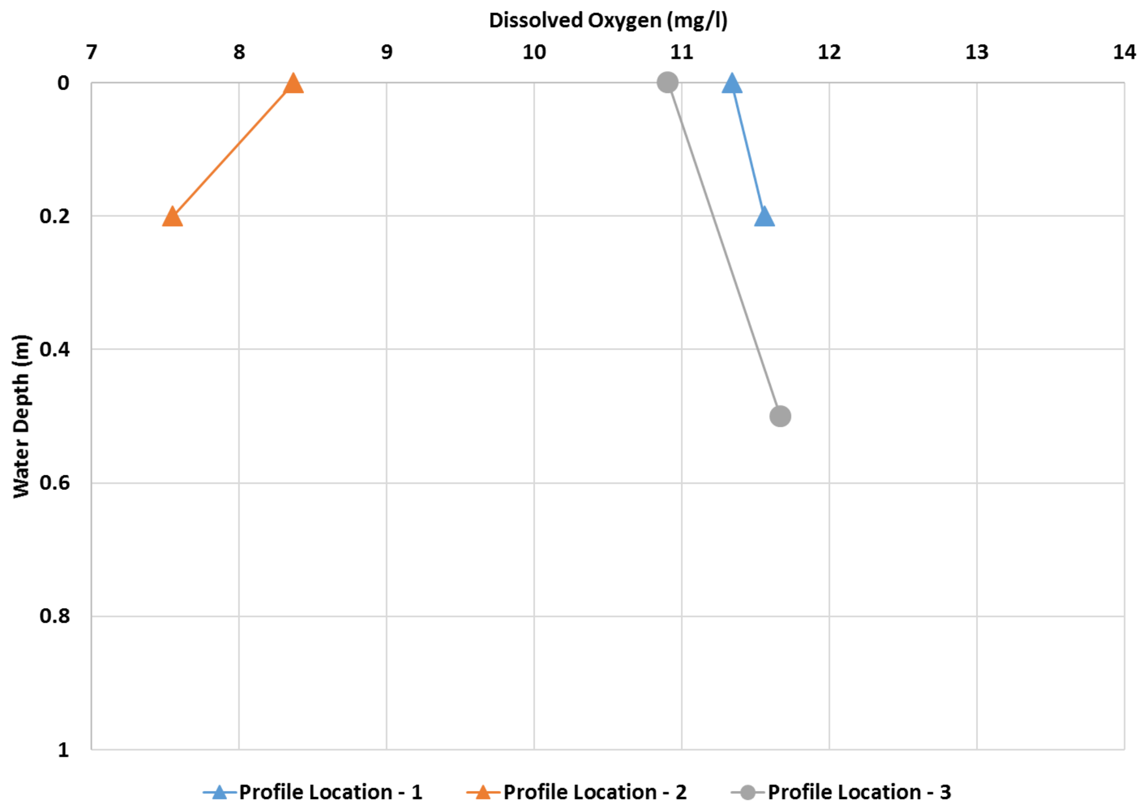


Figure 14. Measured Water Temperature Seasonal Profile Rock Creek near the mouth during the summer of 2016



[3] Deployed at the 3rd Avenue Bridge (45.58702, -122.37237)

Figure 15. Measured Dissolved Oxygen at the Rock Creek and Columbia River Confluence on 8/17/16.



Results - Wind River

Cold Water Plume Volume Results – Wind River

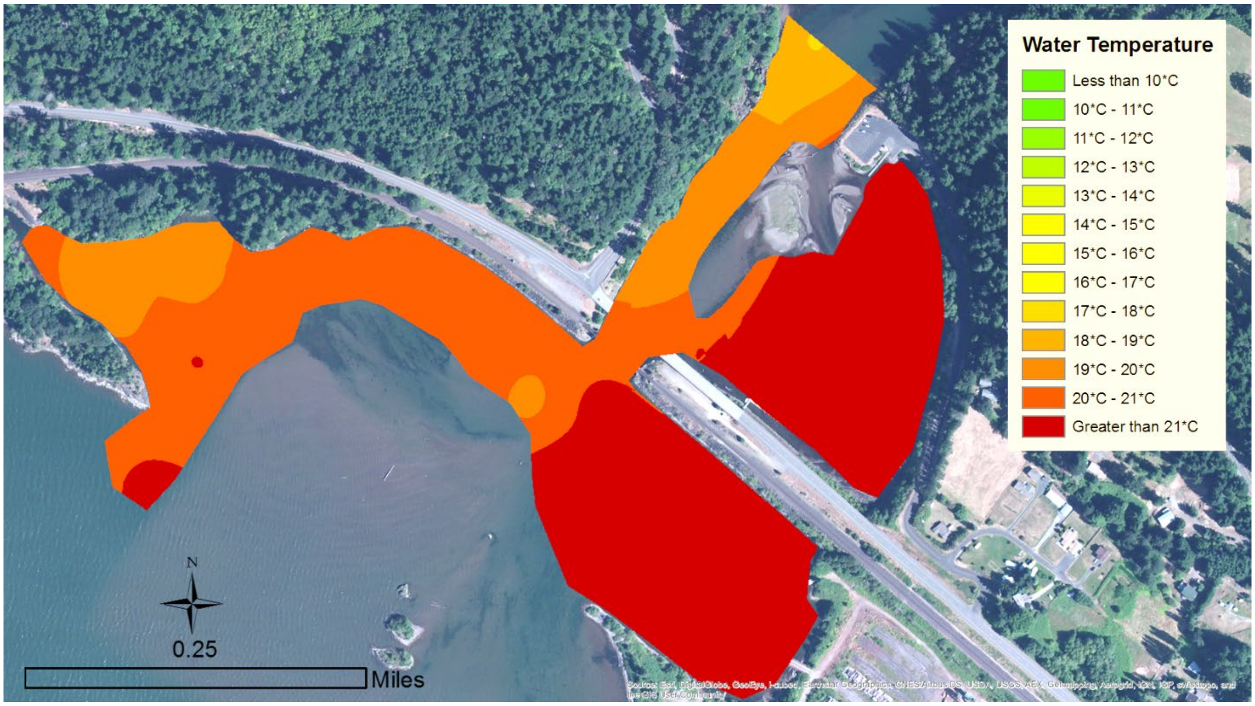
Results - Limited areas of “cold” water were observed at this confluence zone, with cooler water primarily located at depth (**Table 2** and **Figure 16**).

Table 2. Volume of water (m^3) within specific temperature ranges for the Wind and Columbia River Confluence on August 15, 2016

Depth	Less than 16*C	Between 16*C and 18*C	Between 18*C and 20*C
0.5 m	0	0	13,567
1.0 m	0	0	13,904
1.5 m	0	0	17,828
2.0 m	0	3,657	20,443
2.5 m	0	6,056	25,509
3.0 m	0	10,678	32,367
Sum	0	20,390	123,616

Figure 16. Wind River and Columbia River Confluence – Model Water Temperature at Various Depths for August, 15, 2016.

Depth - 0.5 m



Depth - 1 m

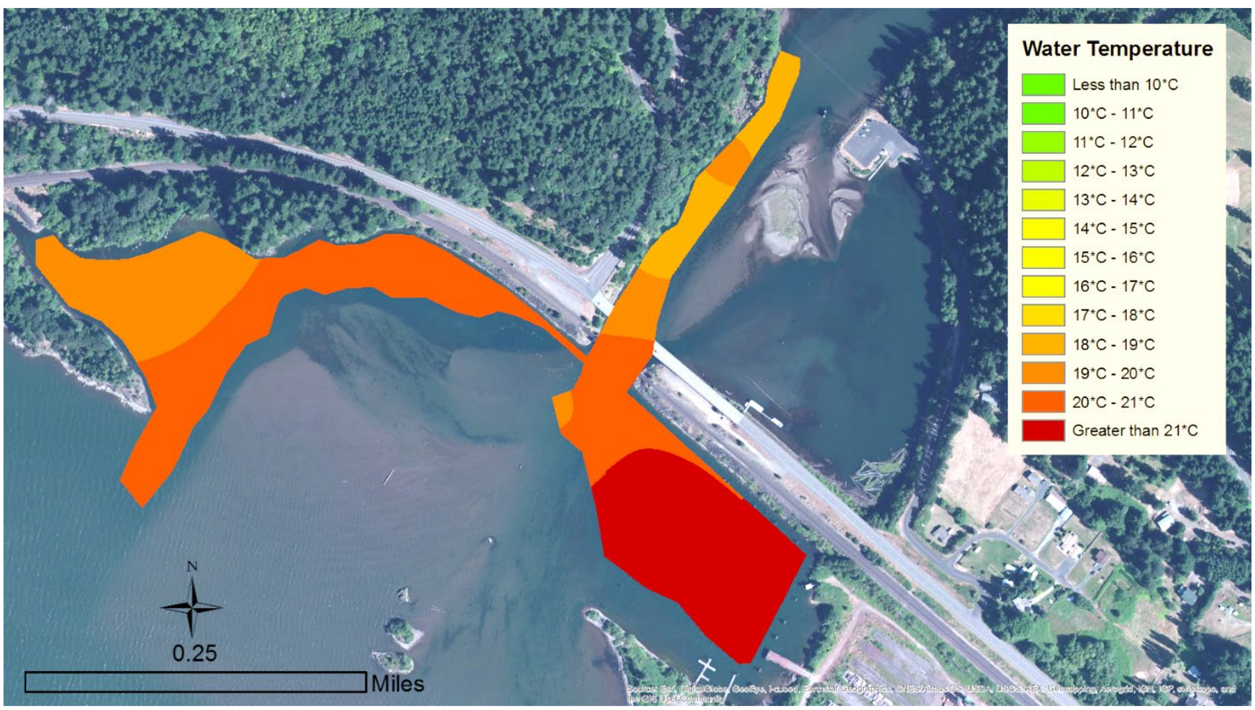
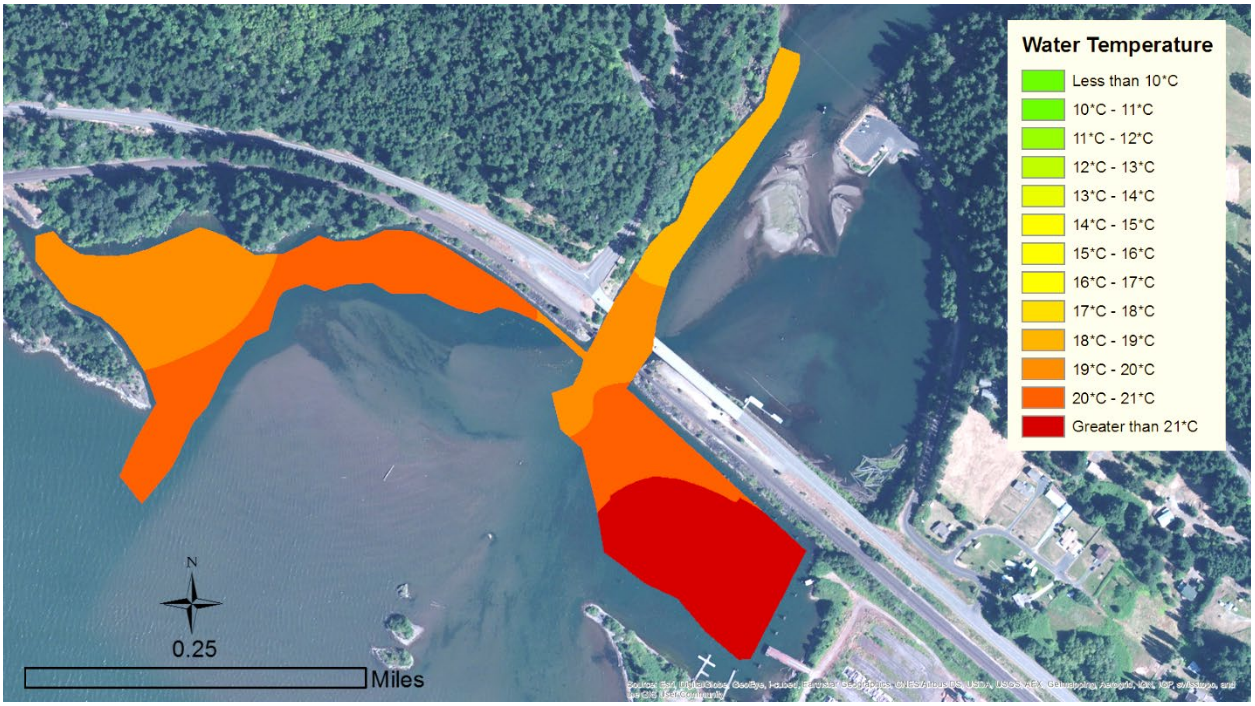


Figure 16 (Continued). Wind River and Columbia River Confluence – Model Water Temperature at Various Depths for August, 15, 2016.

Depth - 1.5 m



Depth - 2 m

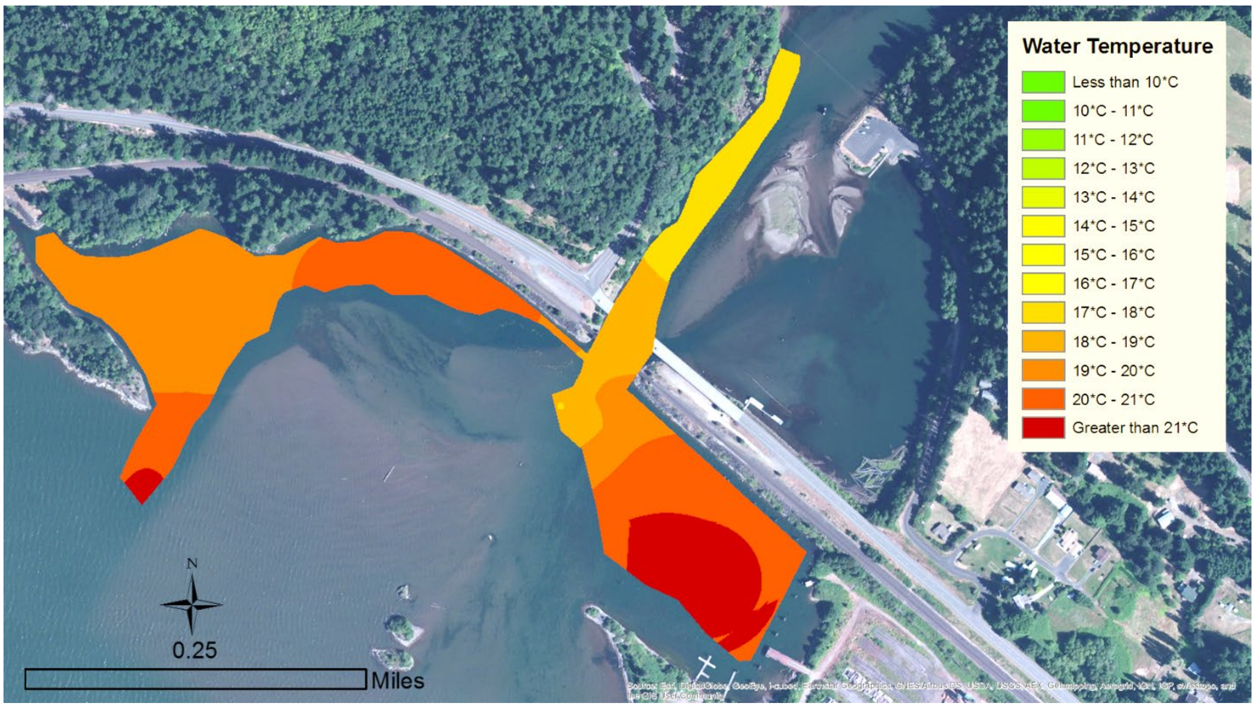
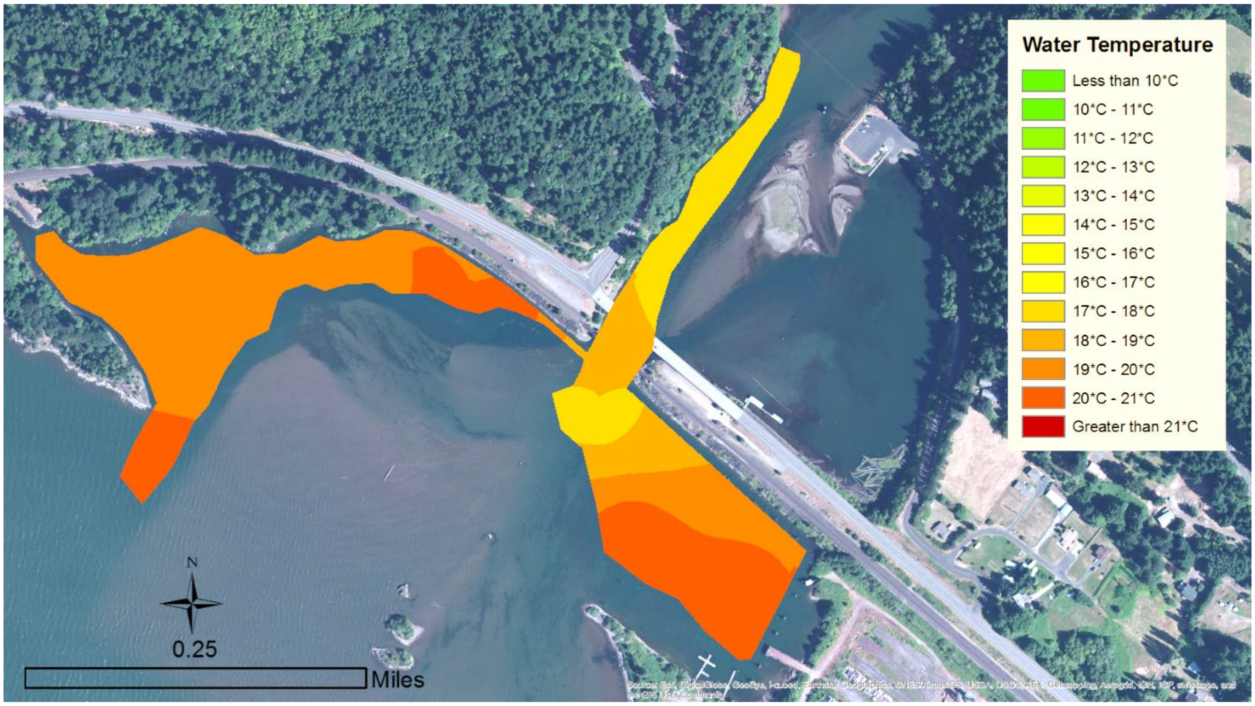
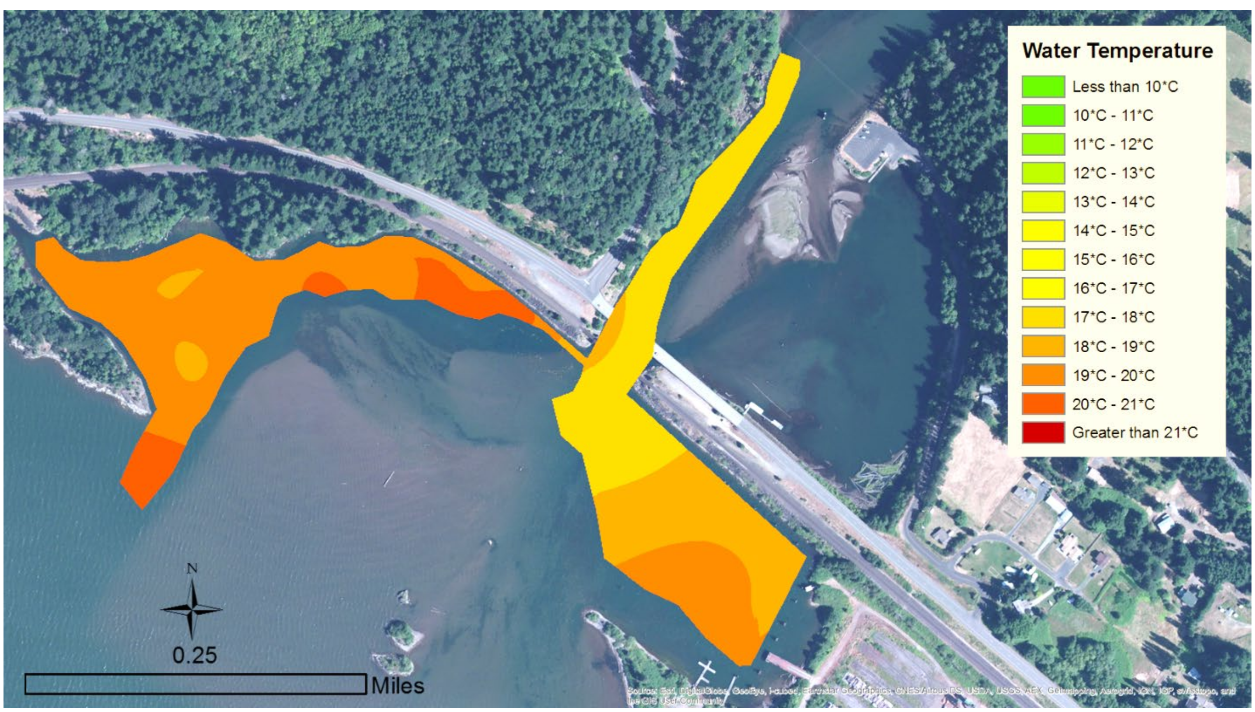


Figure 16 (Continued). Wind River and Columbia River Confluence – Model Water Temperature at Various Depths for August, 15, 2016.

Depth – 2.5 m



Depth – 3 m

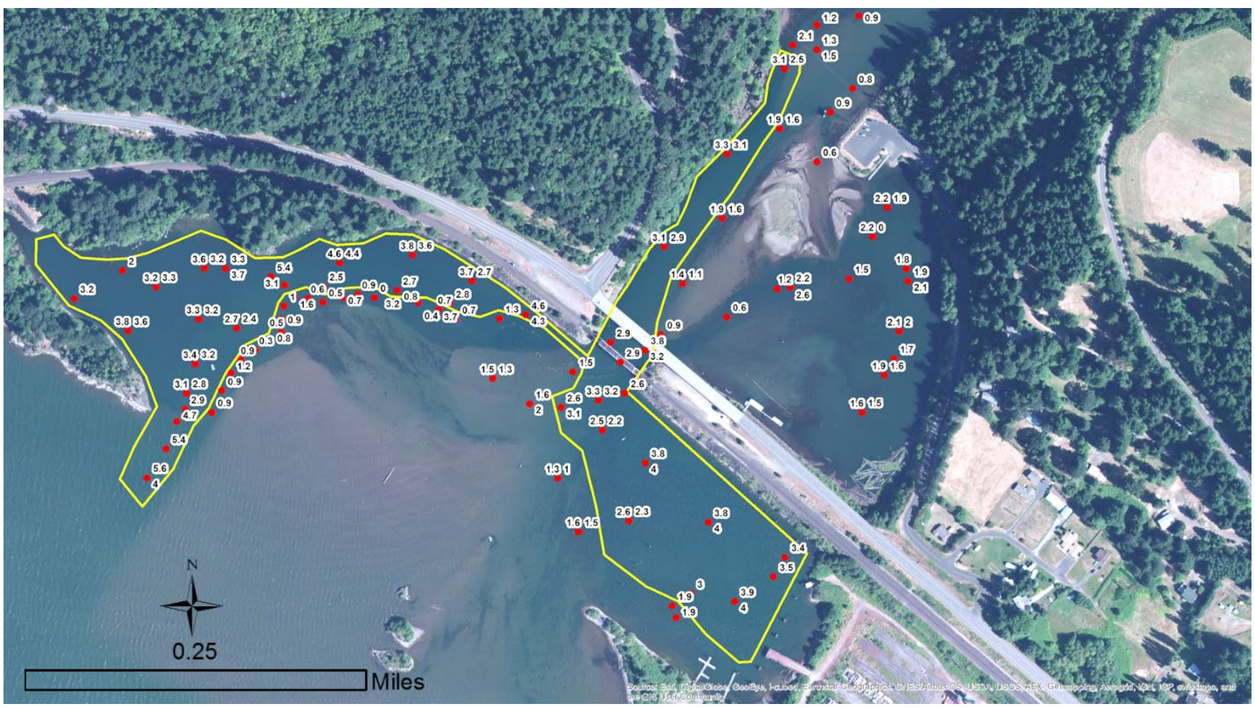


Methods – It was not possible to develop a detailed model of the water depths based on water depth data collected during the 8/15/16 monitoring event. However, it was possible to estimate general location of “pool” areas within this confluence zone based on this field data and general observations noted on the sampling date: The average depth of the pool area illustrated in **Figure 17** by the yellow polygon was estimated at 3 meters (Some areas are deeper, but other areas are shallower, but overall the depth of the pool areas was approximately 3 meters). The spatial extent of specific water temperatures conditions at each 0.5-meter depth was estimated from field data through the use of the Kriging tool in ArcGIS.

A comparison analysis indicated that there is a close relationship between modeled and measured temperatures at the various depth conditions (**Figure 18**).

Modeled surface (i.e., 0.5m depth) water temperatures (using the methods described above in this memorandum) were compared to surface water temperatures derived from Landsat 8 satellite imagery collected on August 25, 2016 (**Figure 19**) [4]. It appears these two methods show similar spatial surface temperature patterns.

Figure 17. Depth measurements (red dots) and estimated pool areas in the confluence zone - approximately 3.0m average depth (yellow polygon)



[4] Landsat 8 derived surface water temperature estimates were obtained on January 5, 2017 from Marcia Snyder at the USEPA ORD Laboratory in Corvallis Oregon.

Figure 18. Comparison between measured and modeled stream temperatures in the Wind River Confluence with the Columbia River.

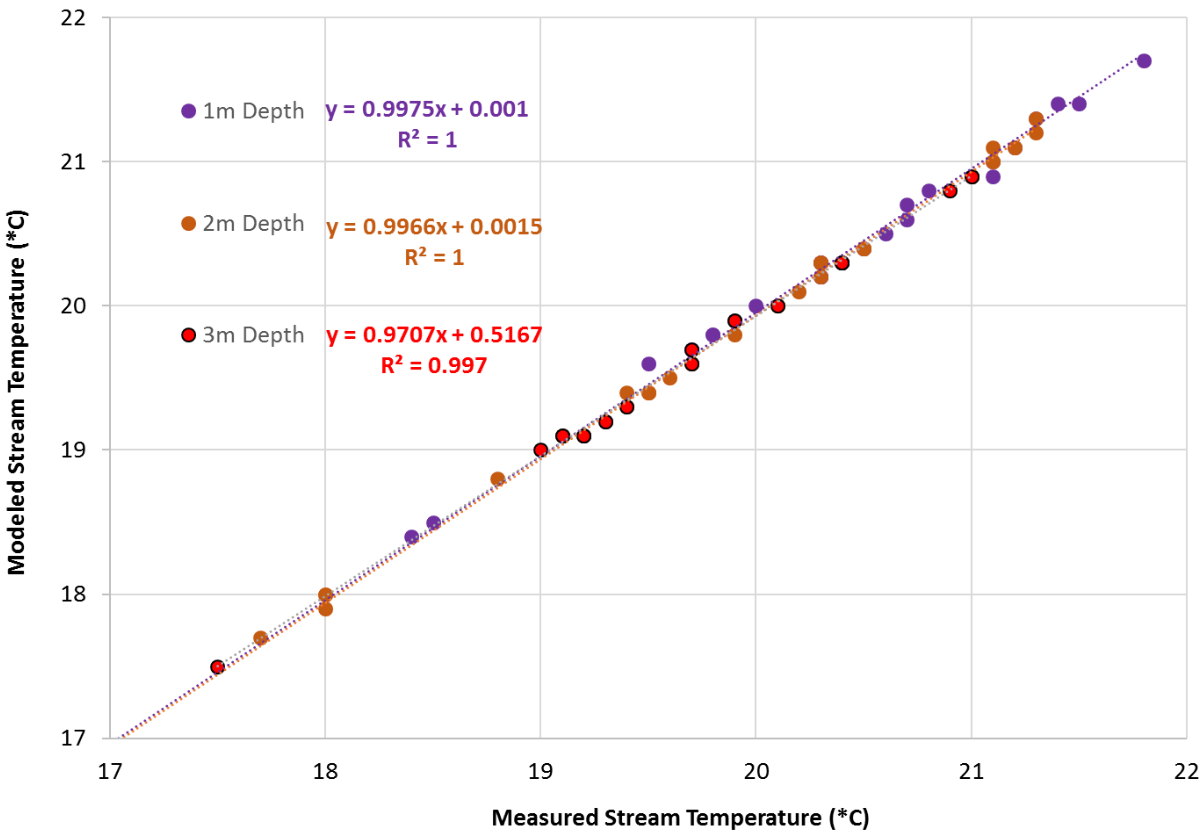
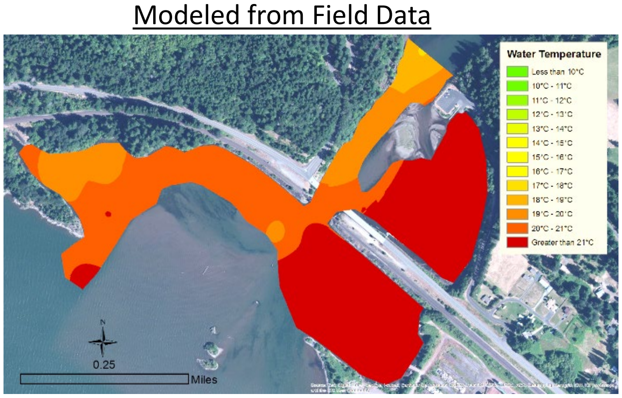
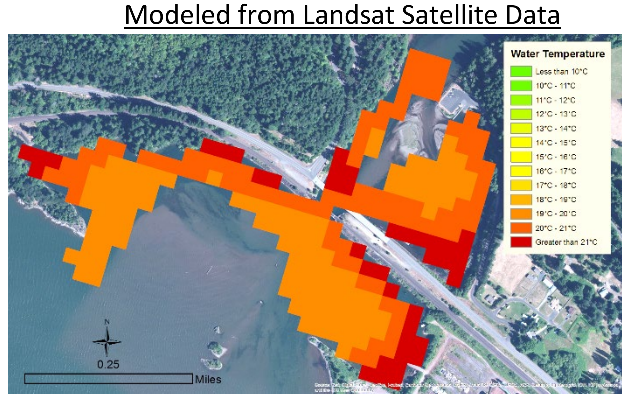


Figure 19. Comparison between modeled surface water temperatures derived from high resolution field data collected on August 15, 2016 and derived from Landsat 8 Satellite 25-meter resolution data collected on August 25, 2016.

Modeled from Field Data



Modeled from Landsat Satellite Data



Field Sampling Results – Wind River

The confluence of the Wind and Columbia rivers was sampled on August 15, 2016. The confluence zone is not tidally influenced: This confluence zone is located upstream of the Bonneville dam complex.

Water depths were shallow (<1m) at several locations within this confluence zone (**Figure 20**). In addition, a large proportion of the substrate within the eastern embayment, north of Highway 14, was covered by dense mats of aquatic vegetation that made boat navigation problematic within this region. Finally, there was a very large area of shallow waters located within the Columbia River: This shallow area appeared to be caused by dispositional sediment produced by Wind River sediment transport.

Water temperatures, measured at a depth of 1 m, indicated that there were limited areas of the "cold water" on the date of sampling (8/15/16) at this confluence area (**Figure 21**). The coldest water was observed in the most upstream location in Wind River and, based on the measured water temperatures, it appeared that this "cold" water discharged directly into the Columbia River (while mostly bypassing the eastern embayment region of the bay north of Highway 14.) There also appeared to be some limited areas of "cold" water within the Columbia River directly outside of the Wind River confluence.

It appears that this plume sampling effort occurred during one of the warmest water temperature periods of the summer (**Figure 22**), and during low Wind River flow conditions (i.e., 74 cfs) (**Figure 23**). Accordingly, this sampling event on 8/15/16 occurred at the period of lowest potential to produce "cold water refugia" at this confluence (i.e., low tributary discharge rates with warm tributary stream temperatures).

Vertical temperature profile measurements within the Wind River embayment (i.e., north of Highway 14 bridge) indicated that water temperature were colder at depth (**Figure 24**). This figure also showed a dramatic temperature difference between eastern and western parts of this embayment, indicating a potential hydrological separation of the eastern part of the embayment.

Temperature stratification was very large in a small bay within Columbia River located just outside of the mouth of the Wind River (**Figure 25**). It also appeared that surface temperature became warmer further away from the confluence location.

Temperature stratification was much less prominent at Columbia River locations further away from the confluence (**Figure 26**): There were warmer temperatures at depth in this zone than observed at depth directly at the confluence location (**see Figure 25**). However, temperature stratification was slightly greater within the western portion of this reach, a segment protected by the dominant wind direct on the day of sampling (i.e., east) (**see green lines in Figure 26**).

Measured dissolve oxygen levels did not indicate a limiting condition on the date of sampling (**Figure 27**).

Figure 20. Measured Water Depths at the Wind and Columbia River Confluence (8/15/16)

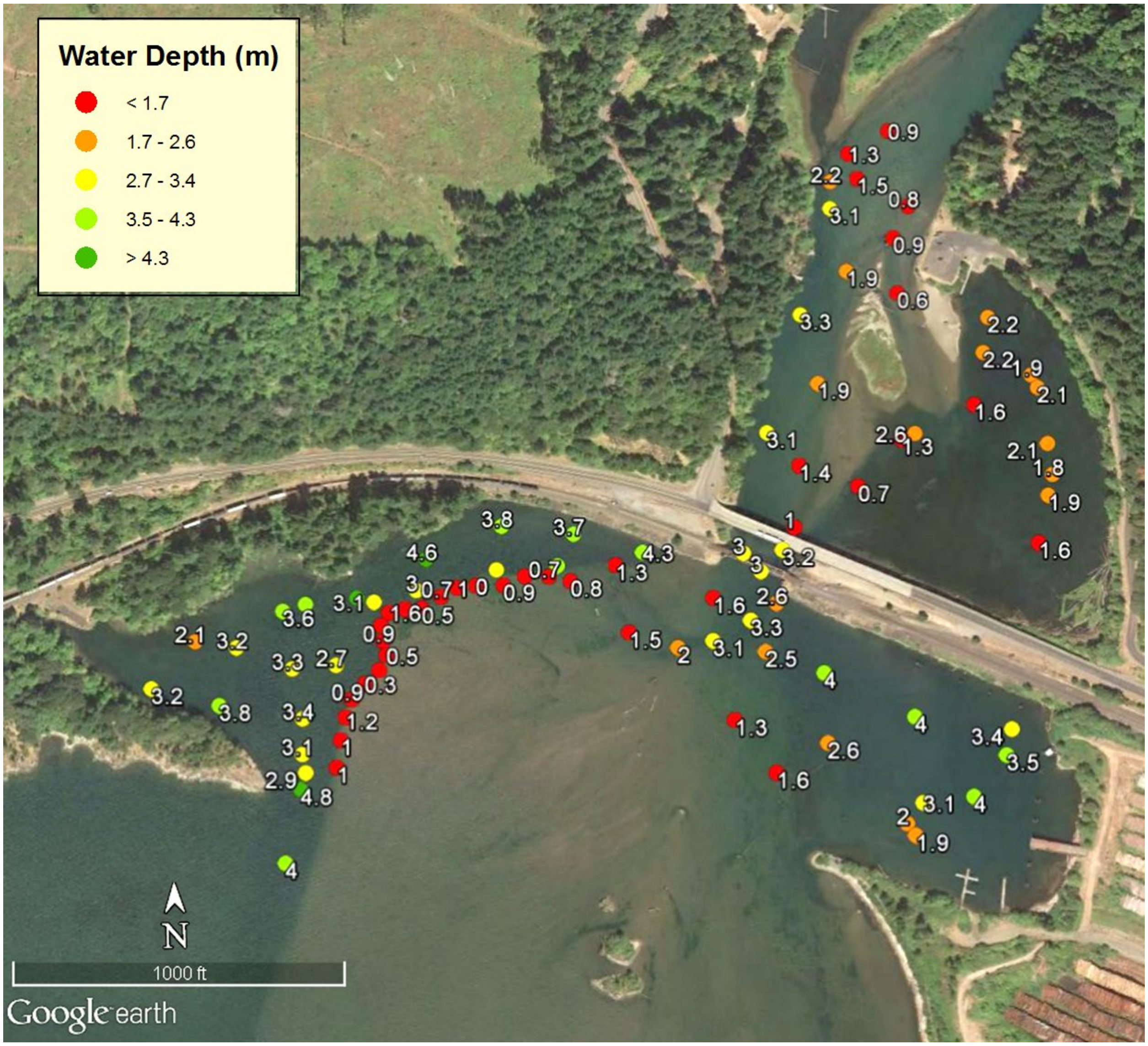


Figure 21. Water Temperature at a 1 meter depth at the Wind and Columbia River Confluence (8/15/16)

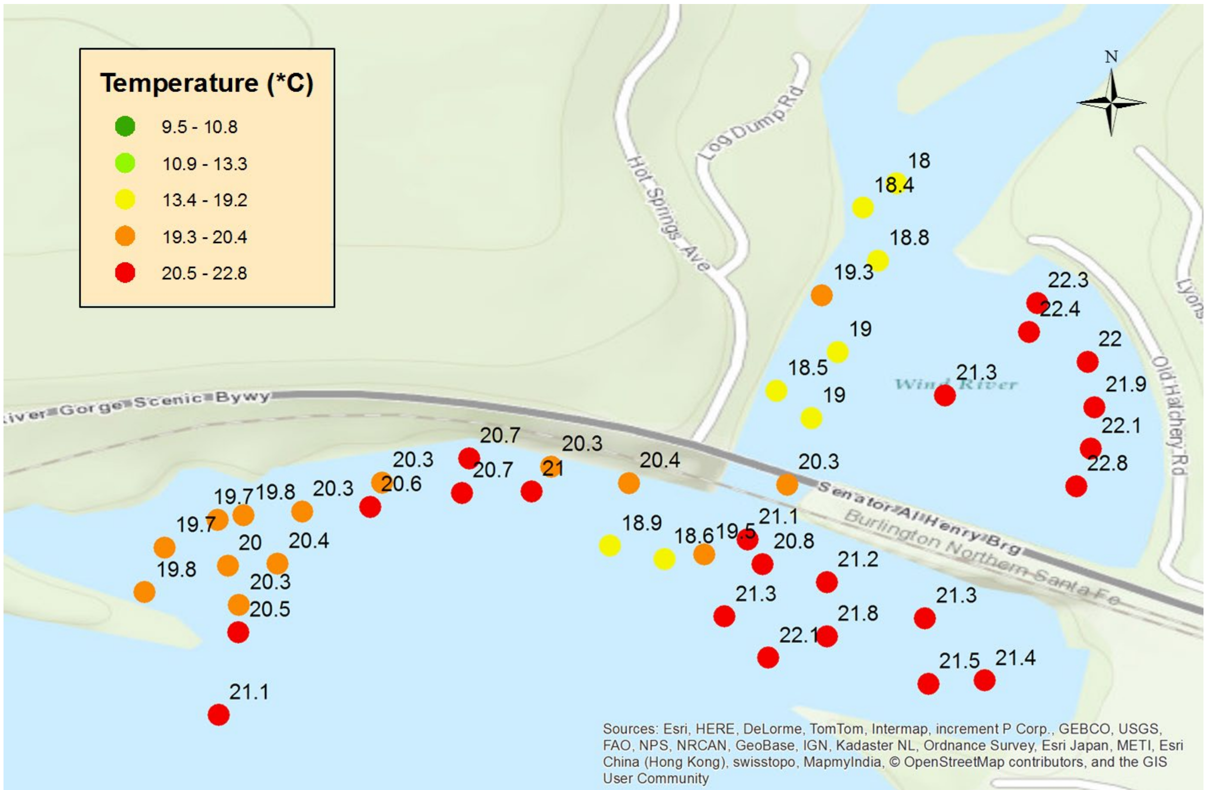


Figure 22. Measured Water Temperature Seasonal Profile at the mouth of the Wind River during the summer of 2016

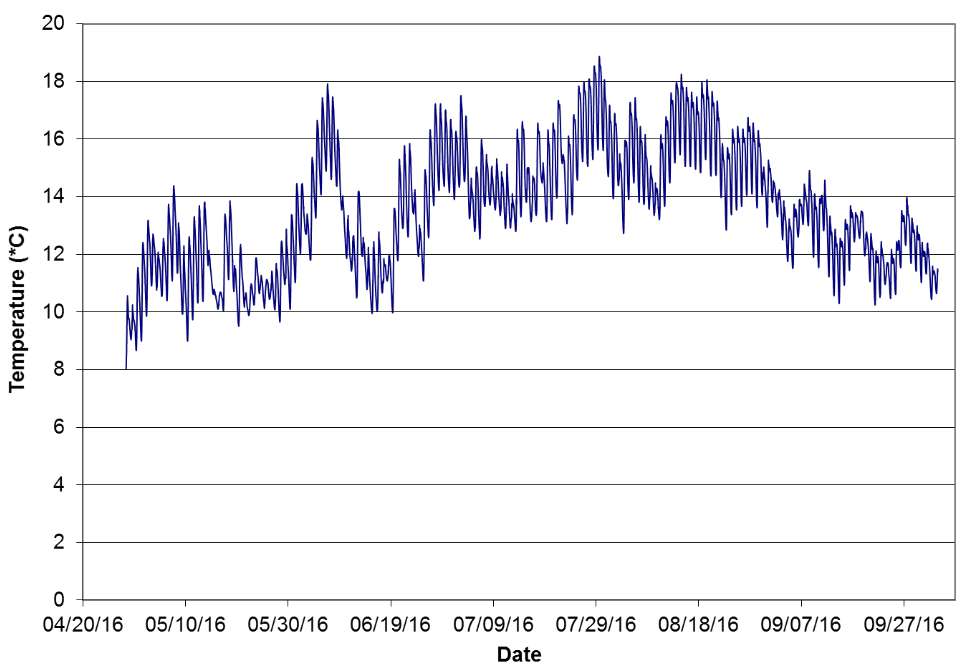


Figure 23. Measured Wind River discharge (cfs) – 2016

[Source -https://fortress.wa.gov/ecy/eap/flows/station.asp?wria=29#block2]

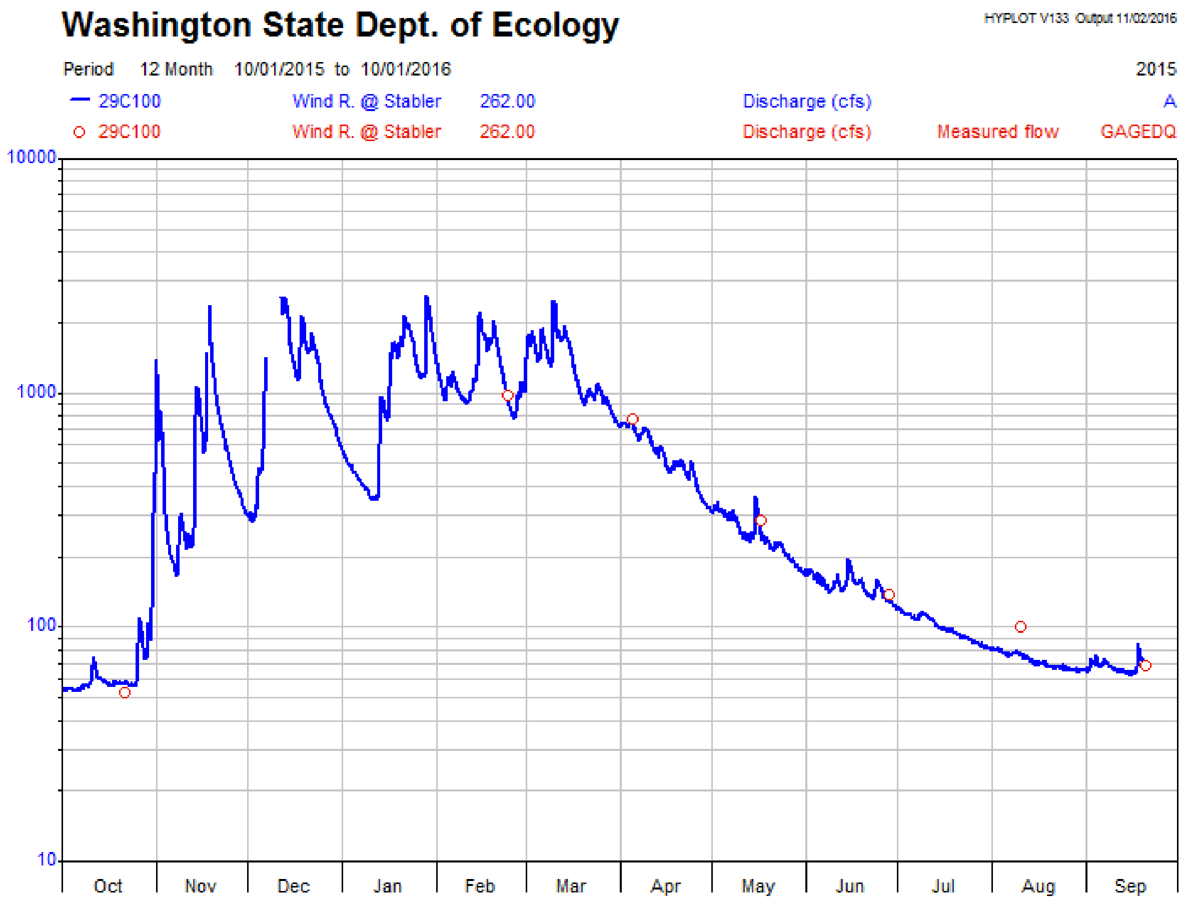


Figure 24. Measured Water Temperature Profile at Selected Embayment Locations at the Wind and Columbia River Confluence on August 15, 2016

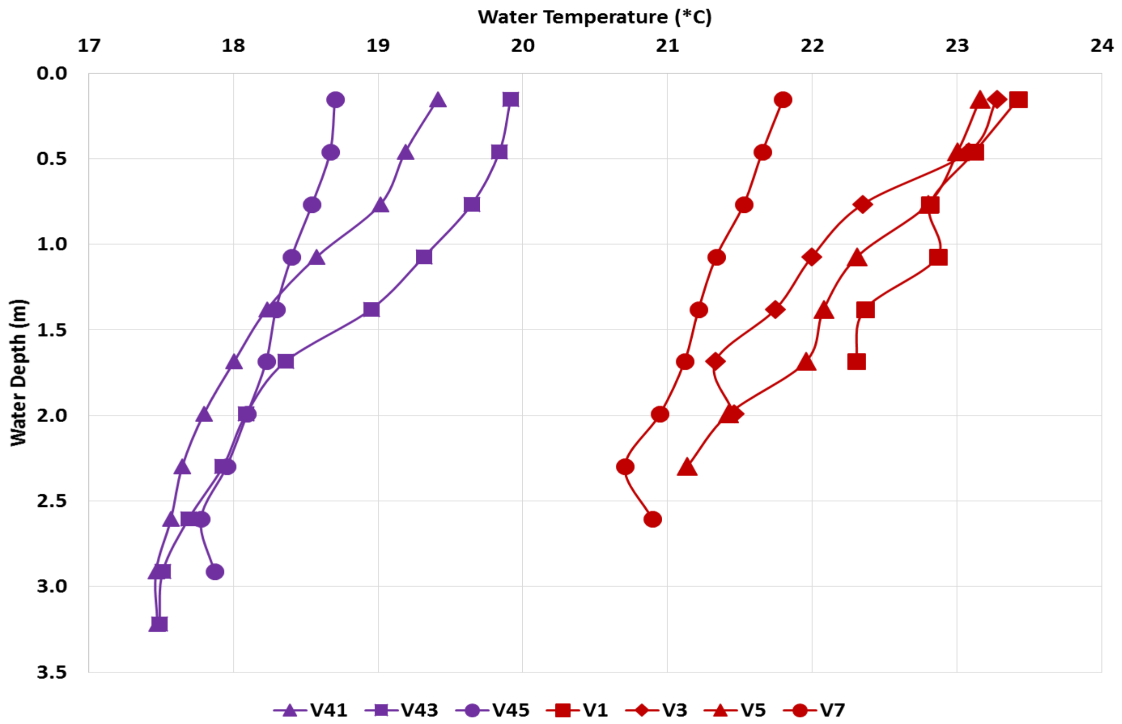


Figure 25. Measured Water Temperature Profile at Selected Wind and Columbia River Confluence Locations on August 15, 2016

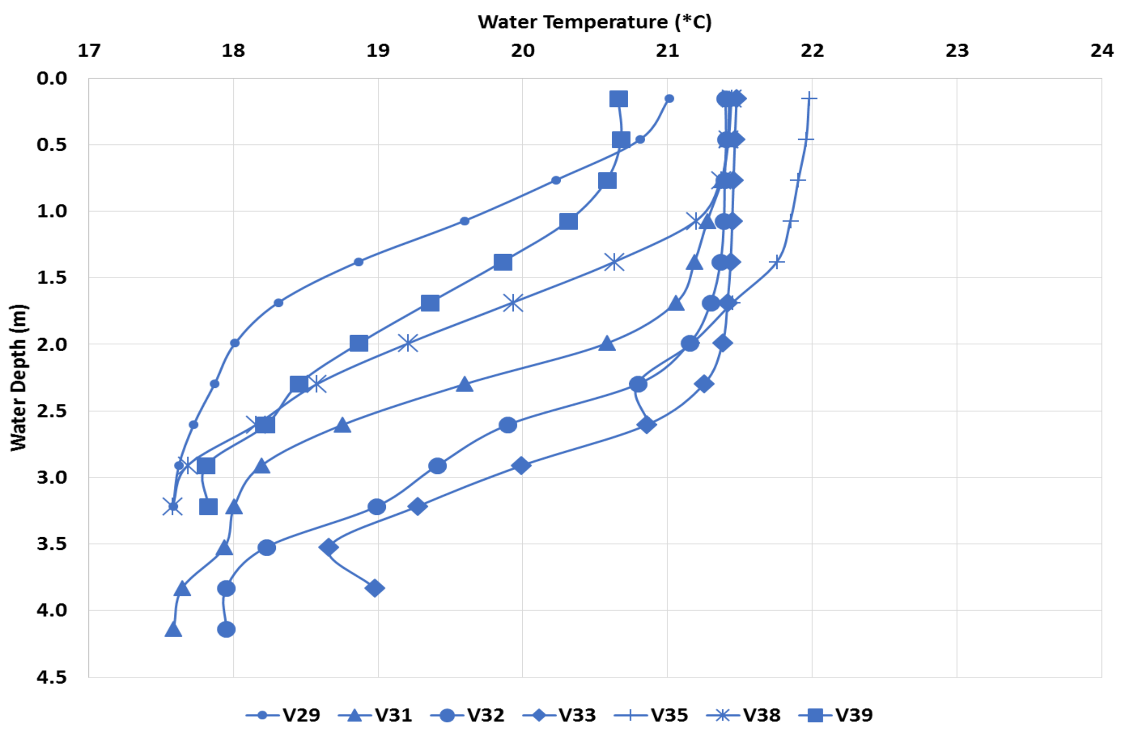


Figure 26. Measured Water Temperature Profile at Selected Wind and Columbia River Confluence Locations on August 15, 2016

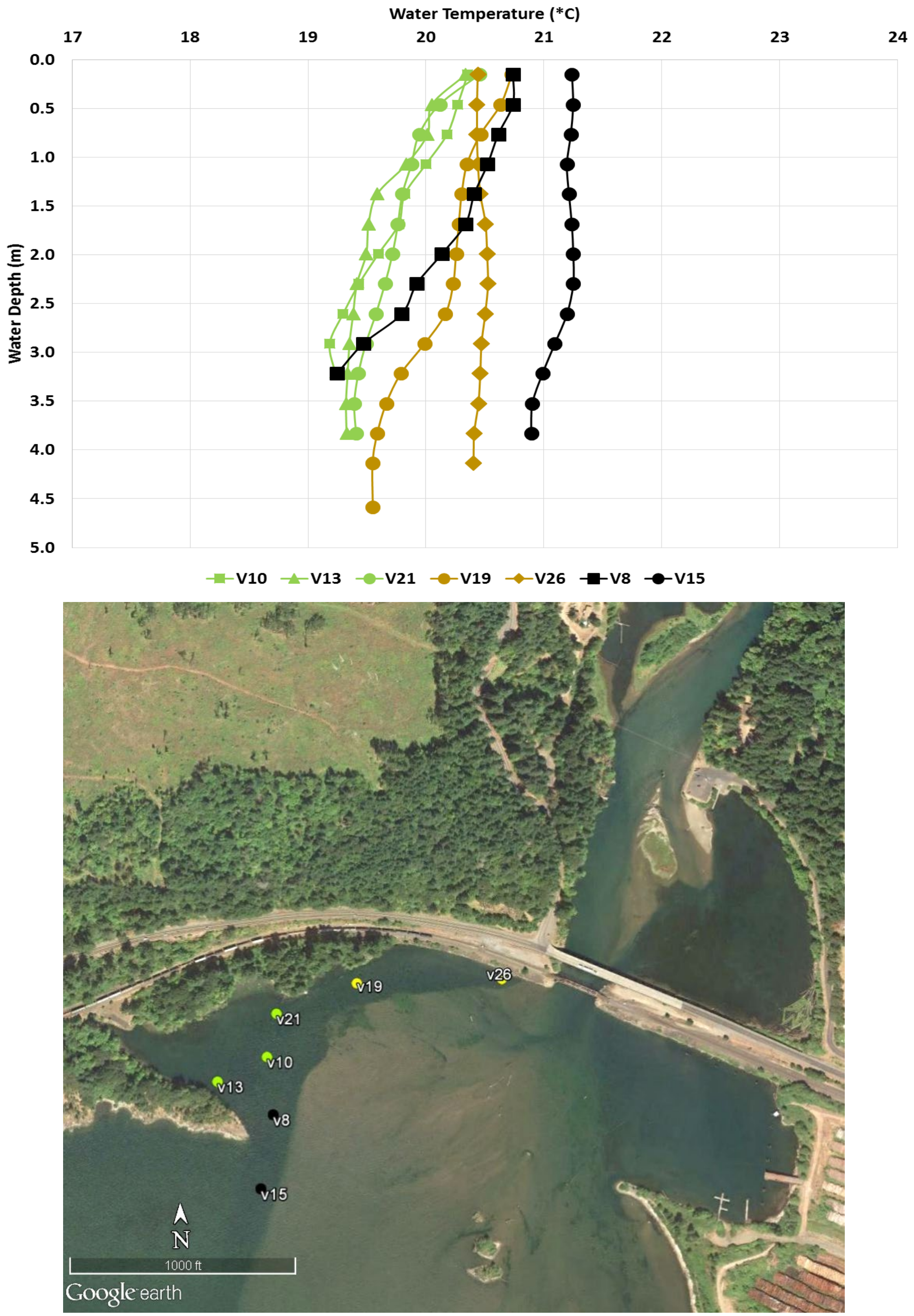
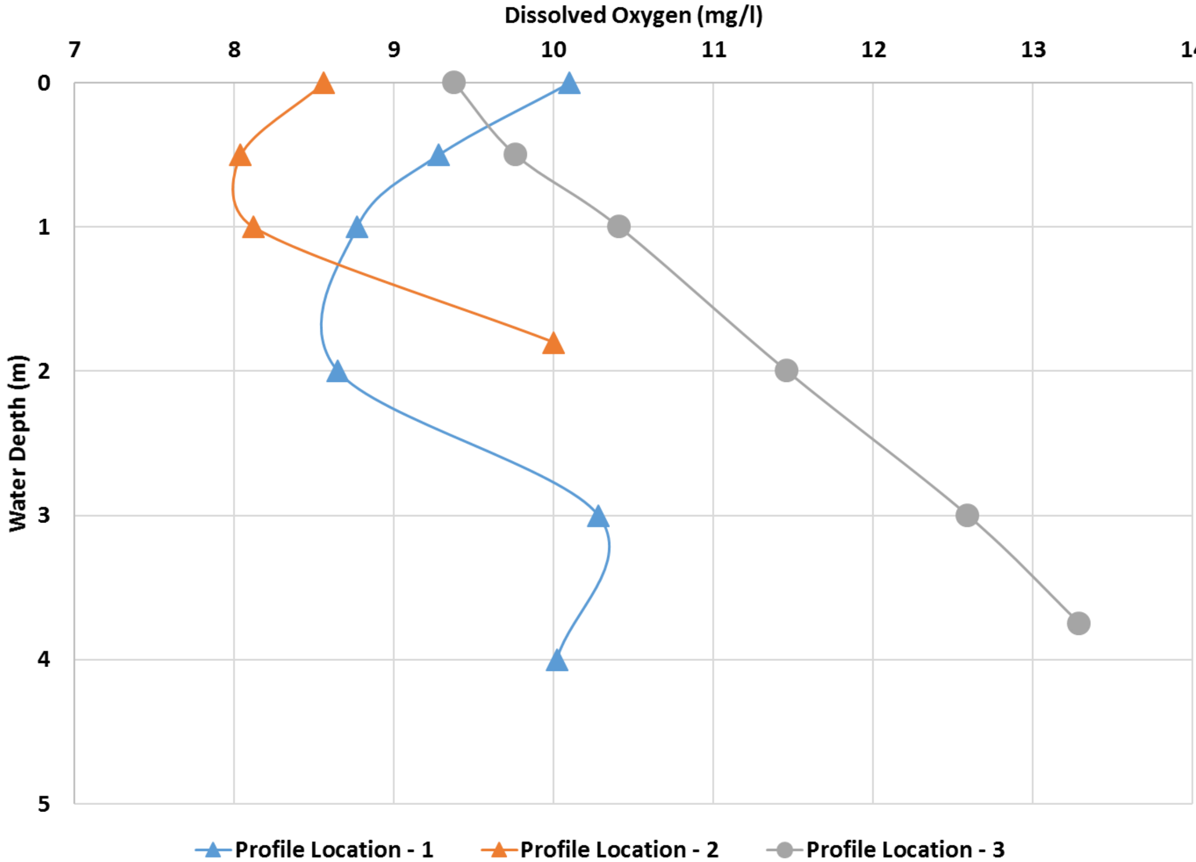


Figure 27. Measured Dissolve Oxygen Profile at Selected Wind and Columbia River Confluence Locations on August 15, 2016



Results – Little White Salmon River

Cold Water Plume Volume Results – Little White Salmon River

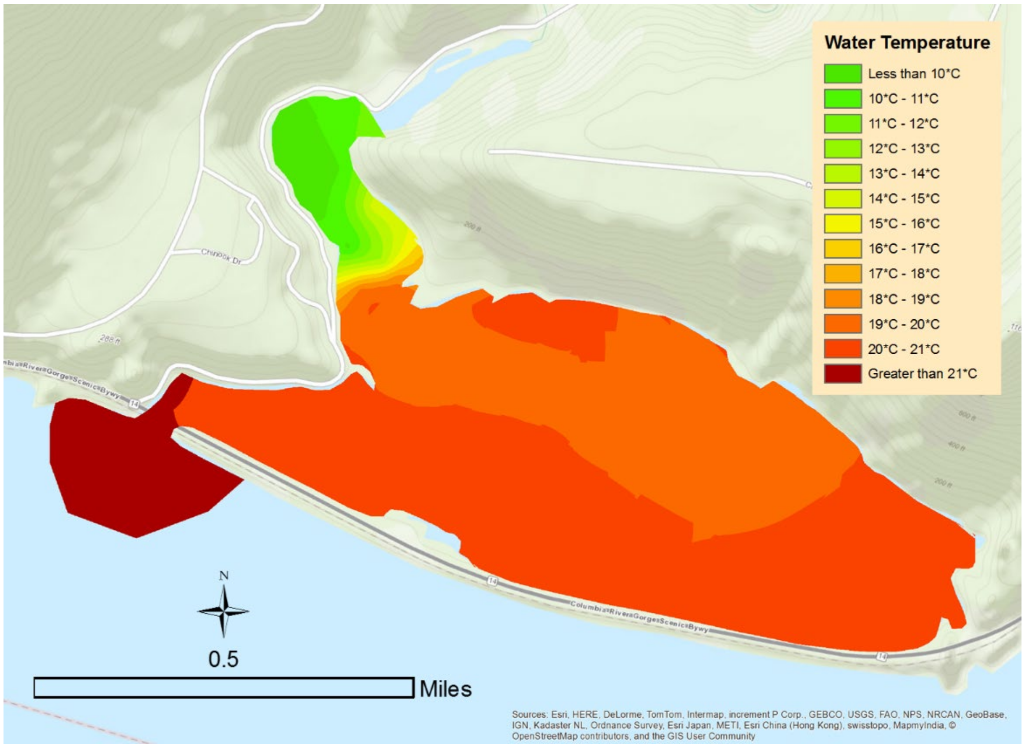
Results - Areas of "cold" water were observed at this confluence zone, with cooler water primarily located within the surface waters near the inlet of the Little White Salmon River into Drano lake and within bottom waters of Drano Lake (**Table 3** and **Figure 28**).

Table 3. Volume of water (m^3) within specific temperature ranges for the Little White Salmon and Columbia River Confluence on August 17, 2016

Depth	Less than 16*C	Between 16*C and 18*C	Between 18*C and 20*C
0.5 m	36,849	2,748	30,044
1.0 m	11,199	1,671	37,719
1.5 m	0	0	41,995
2.0 m	2,312	5,051	28,856
2.5 m	3,391	2,793	26,928
3.0 m	0	0	59,443
3.5 m	0	1	114,250
4.0 m	0	0	170,418
4.5 m	0	0	167,974
5.0 m	0	0	165,867
5.5 m	0	0	157,729
6.0 m	0	32,826	129,004
6.5 m	0	7,8174	77,720
7.0 m	0	96,662	43,421
7.5 m	0	103,419	16,511
8.0 m	0	93,451	0
8.5 m	33,787	24,006	0
9.0 m	3,186	0	0
Sum	90,723	440,801	1,267,874

Figure 28. Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth - 0.5 m



Depth - 1 m

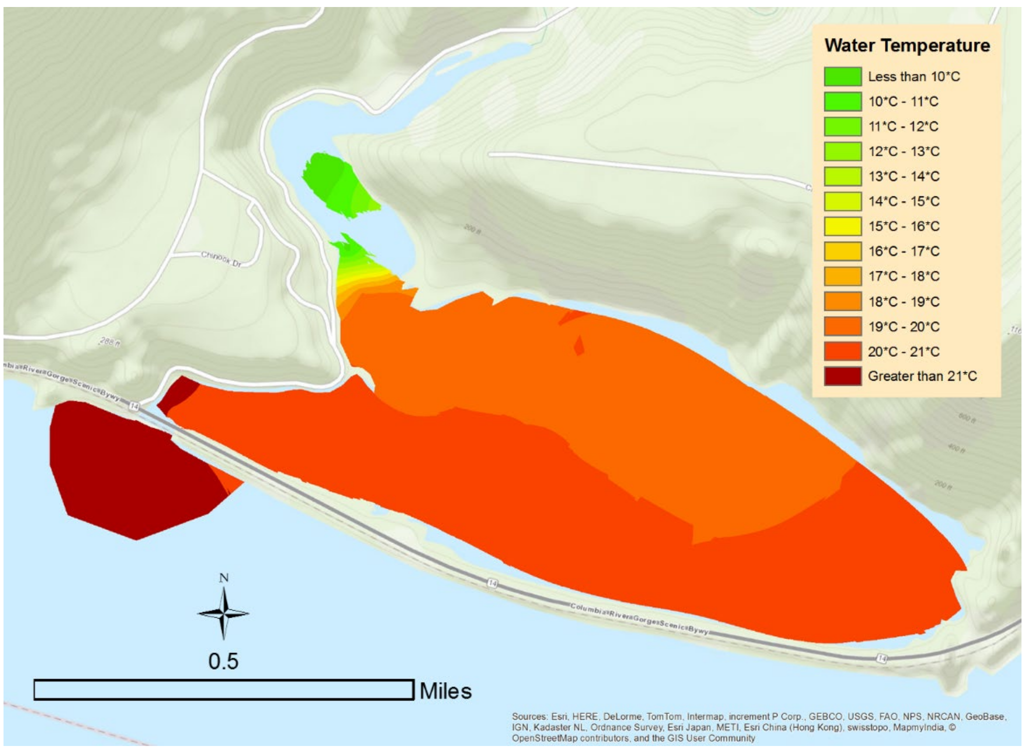
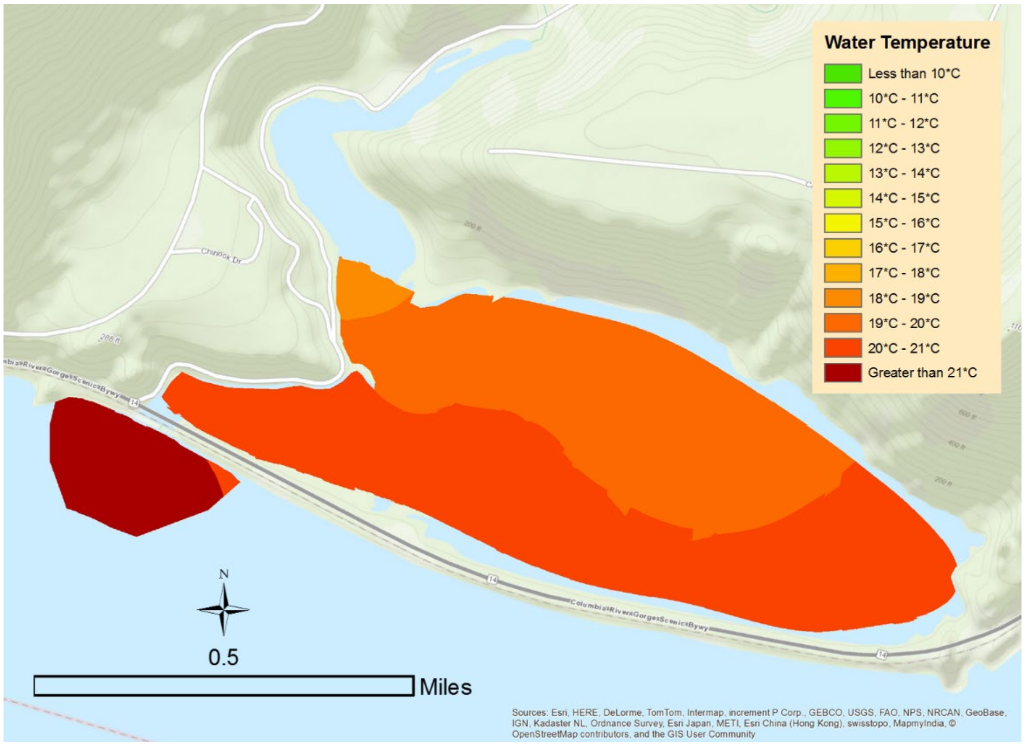


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth - 1.5 m



Depth - 2 m

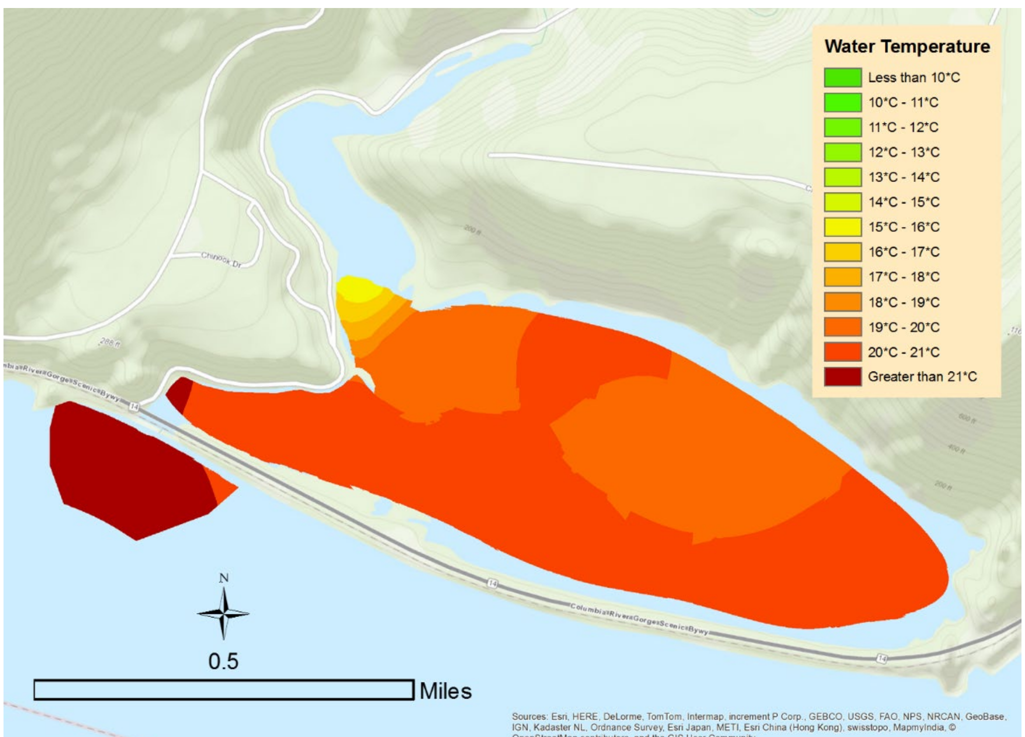
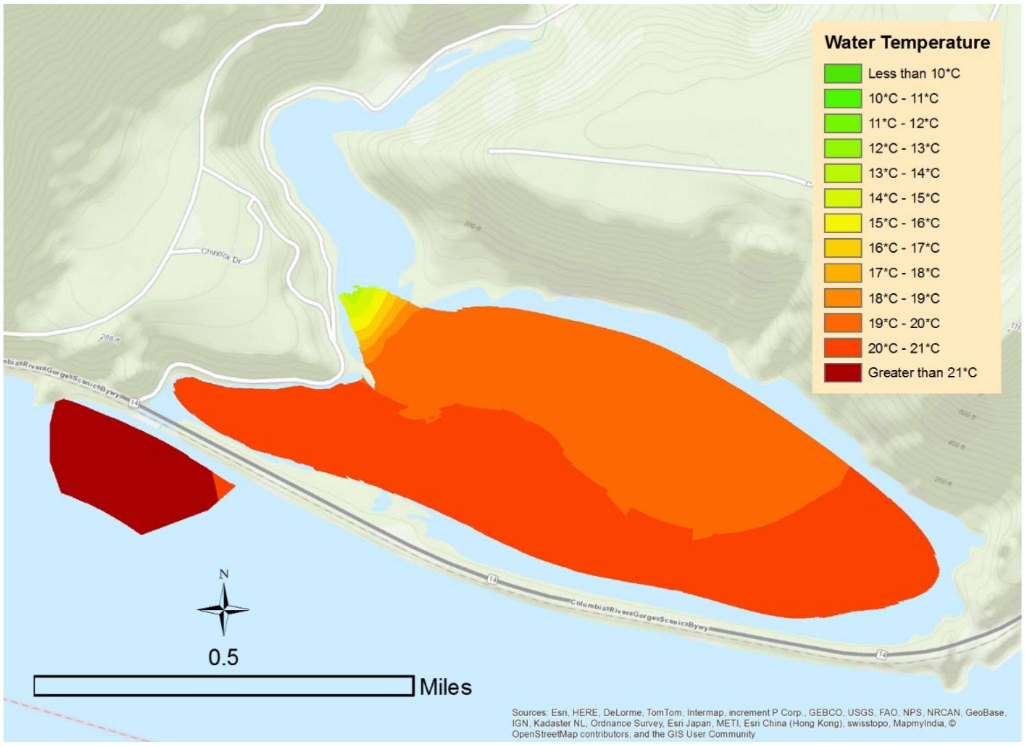


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 2.5 m



Depth – 3 m

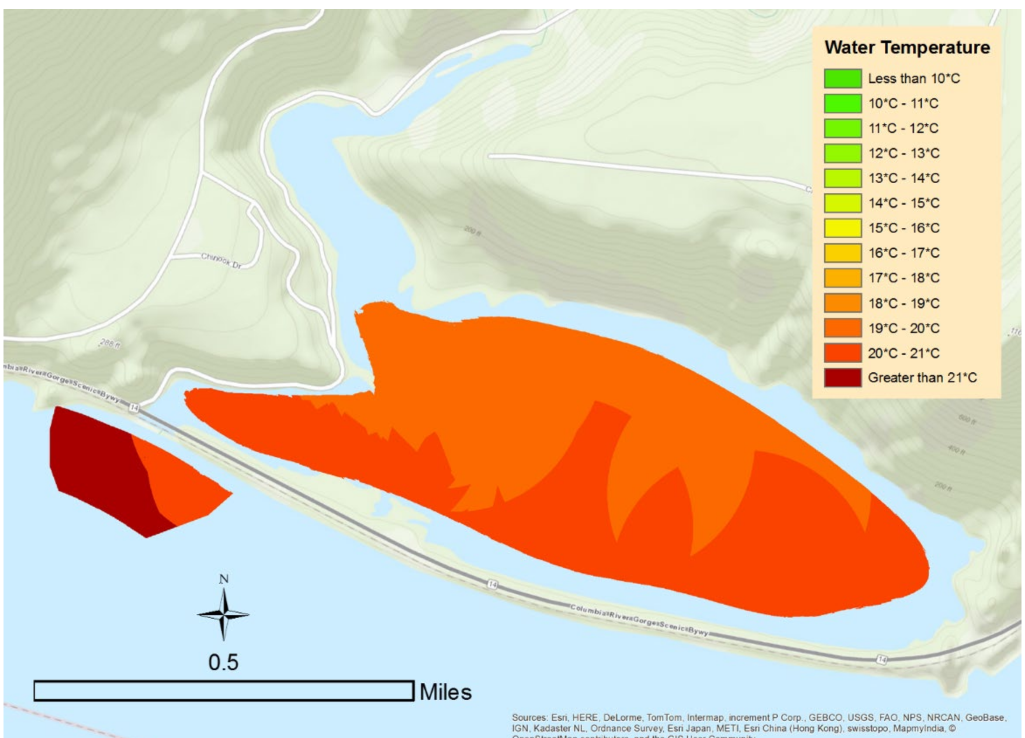
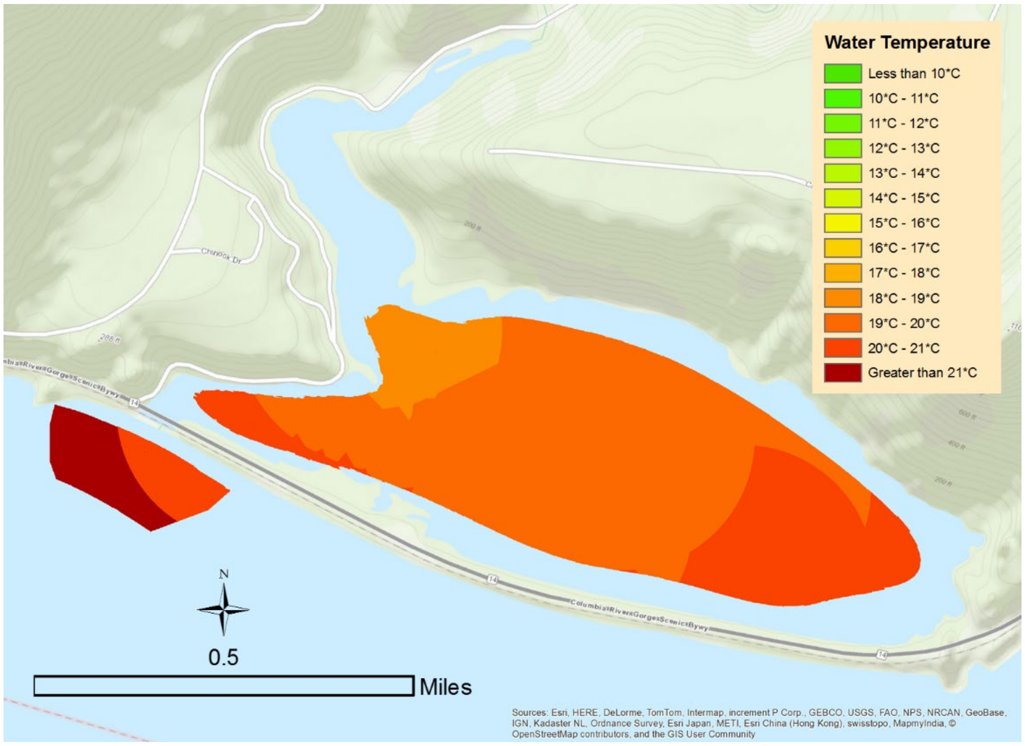


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 3.5 m



Depth – 4 m

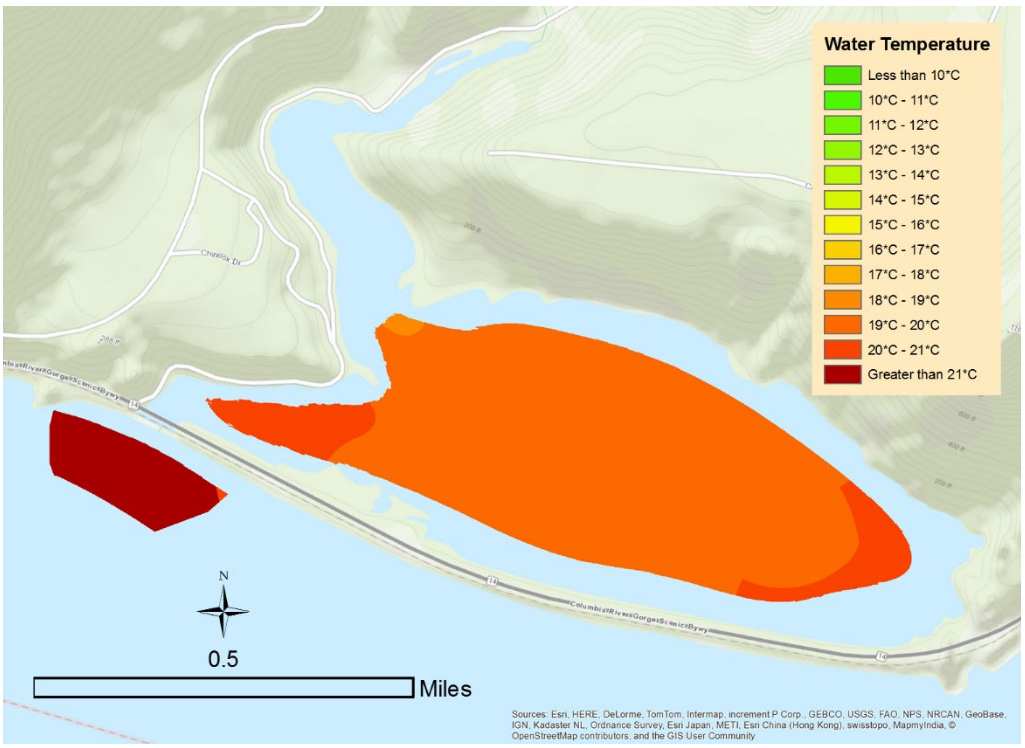
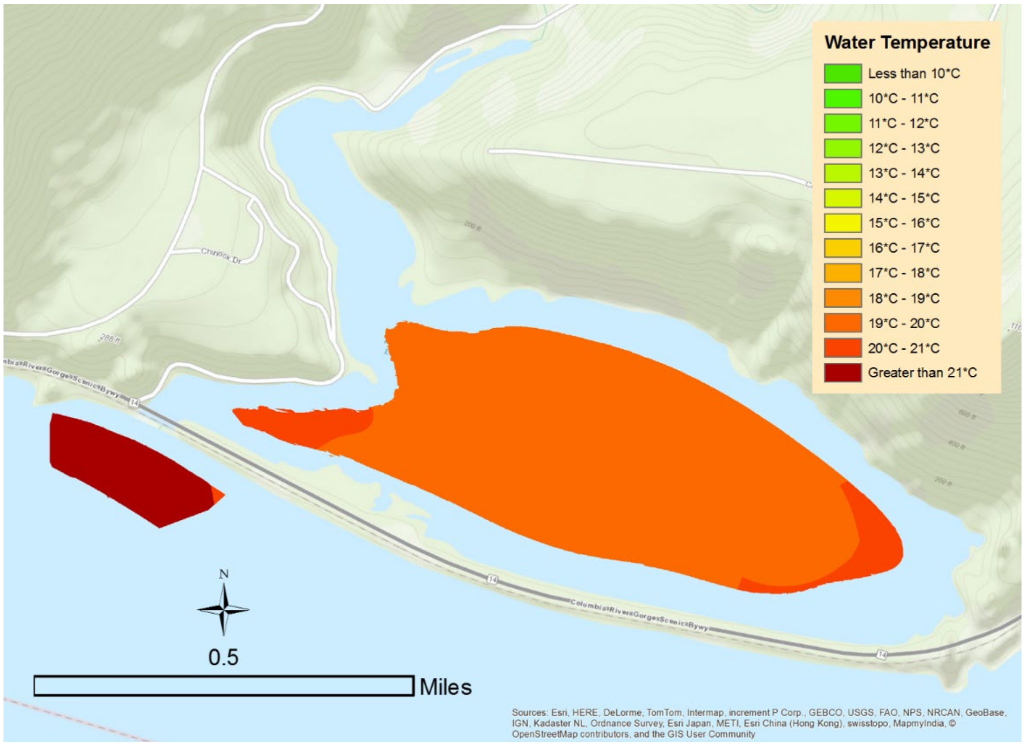


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 4.5 m



Depth – 5 m

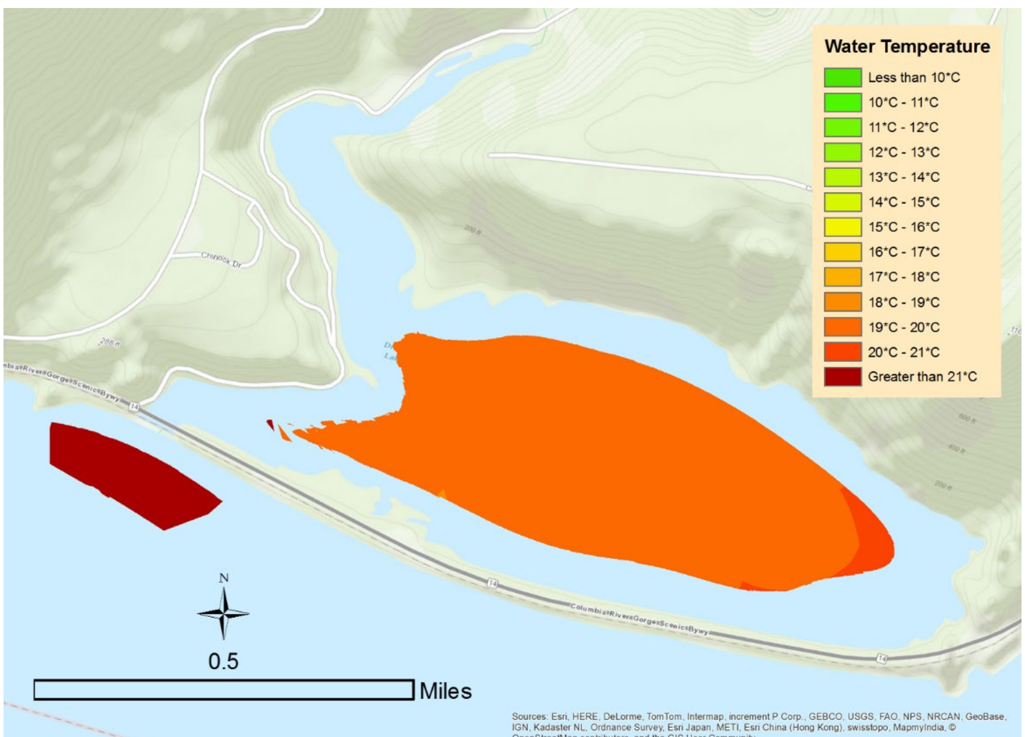
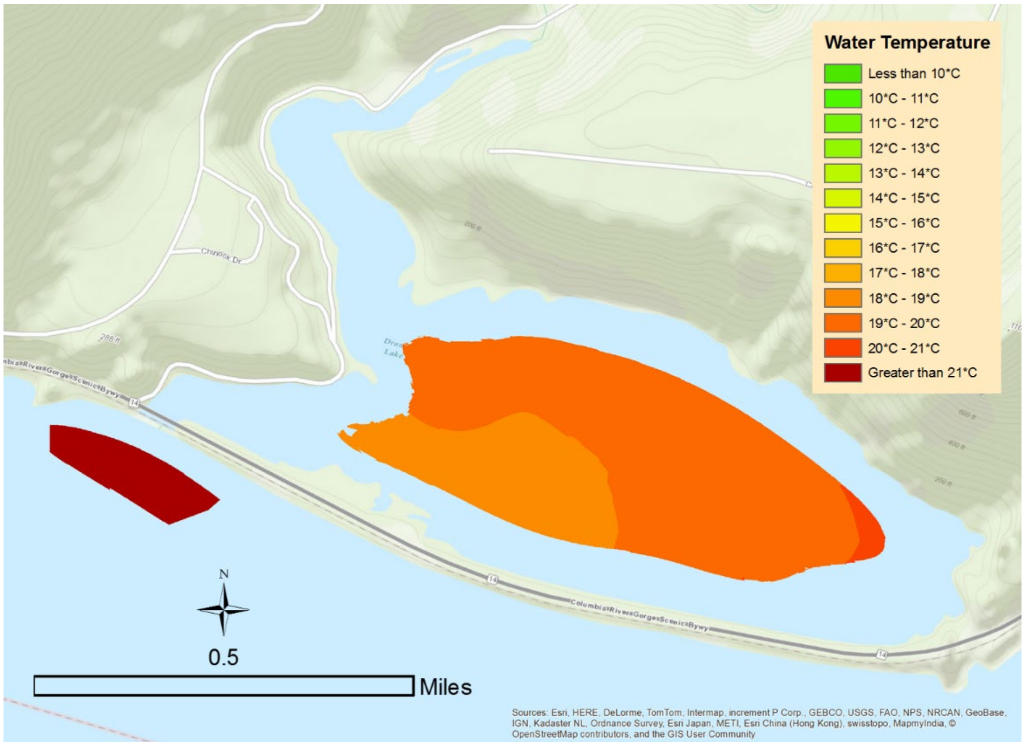


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 5.5 m



Depth – 6 m

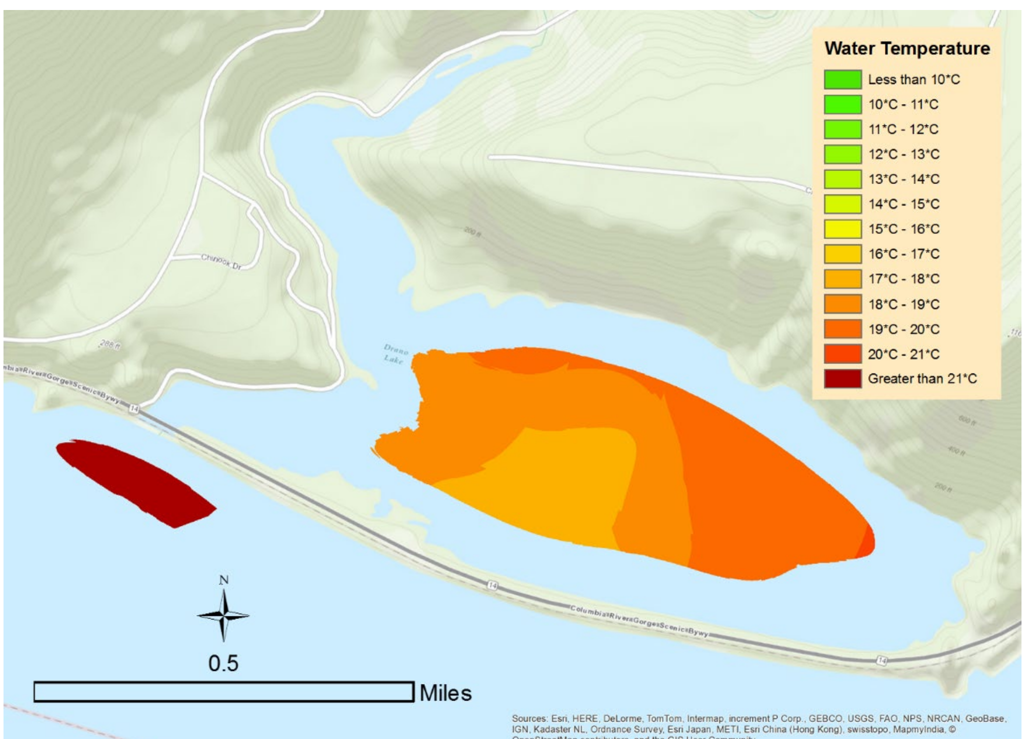
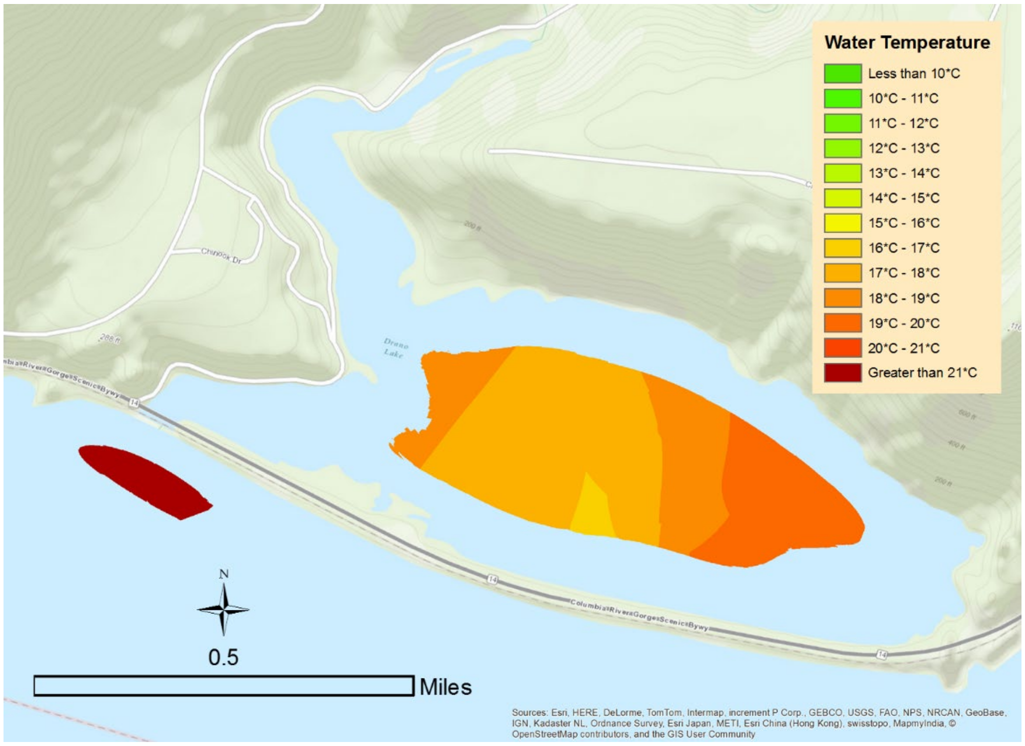


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 6.5 m



Depth – 7 m

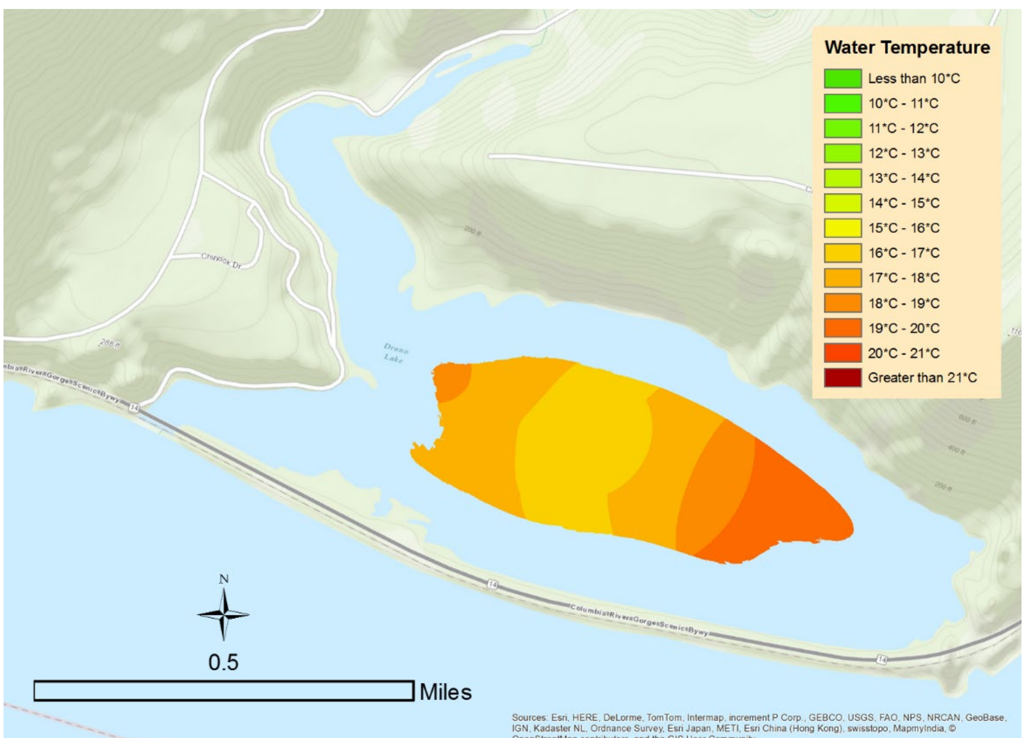
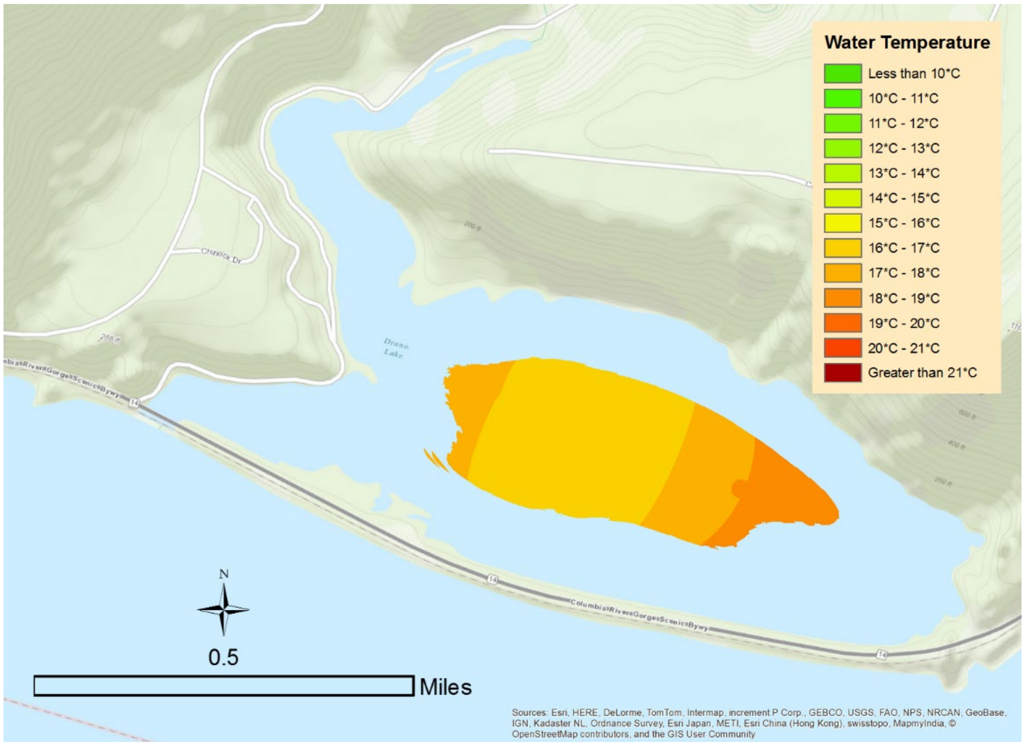


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 7.5 m



Depth – 8 m

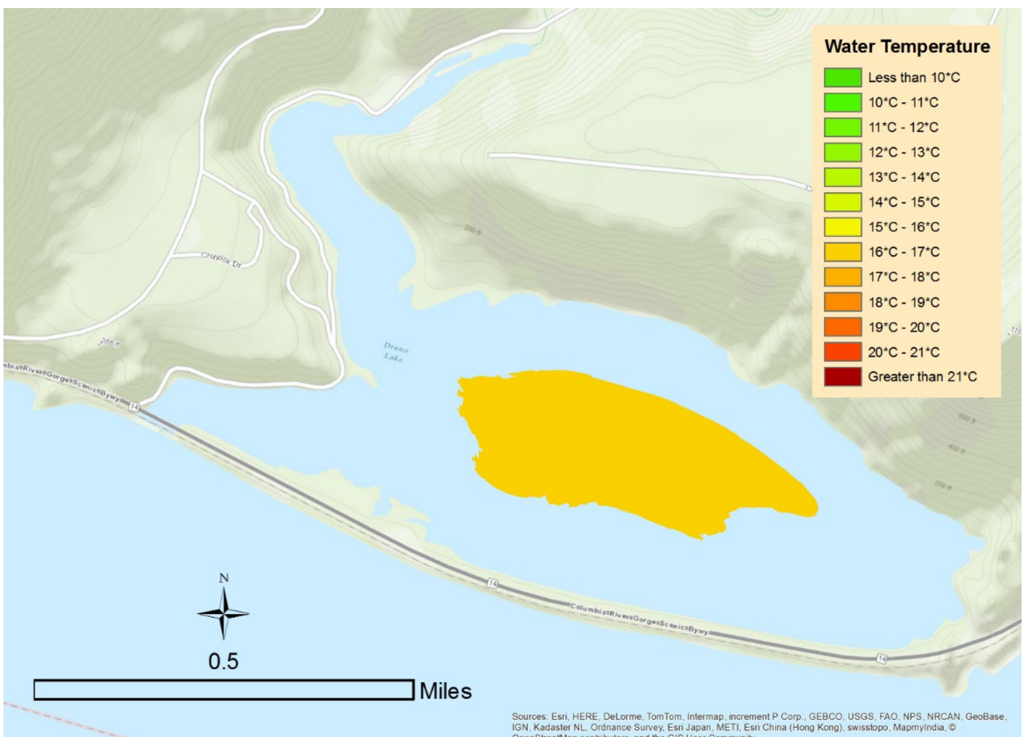
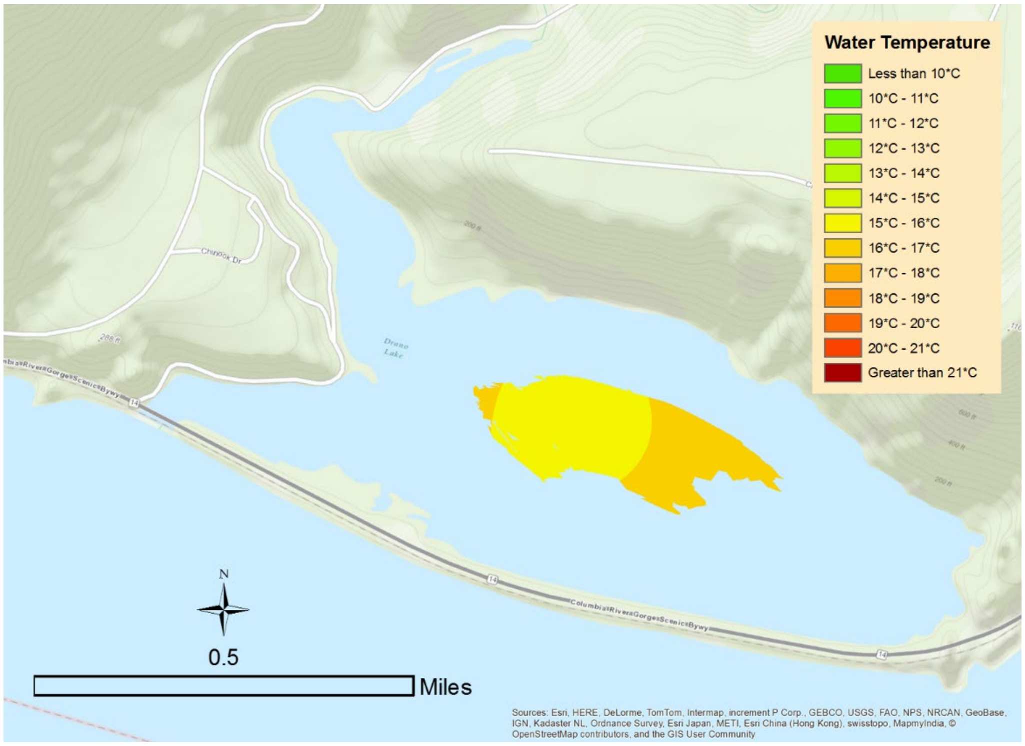
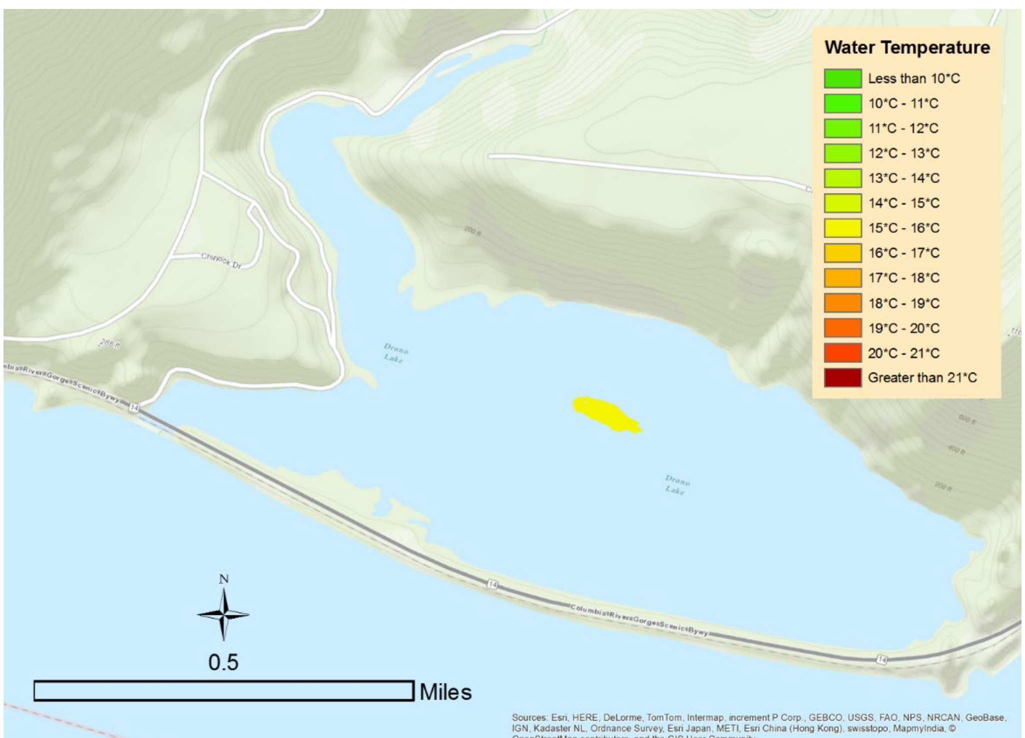


Figure 28 (Continued). Little White Salmon River and Columbia River Confluence – Model Water Temperature at Various Depths for August 17, 2016

Depth – 8.5 m



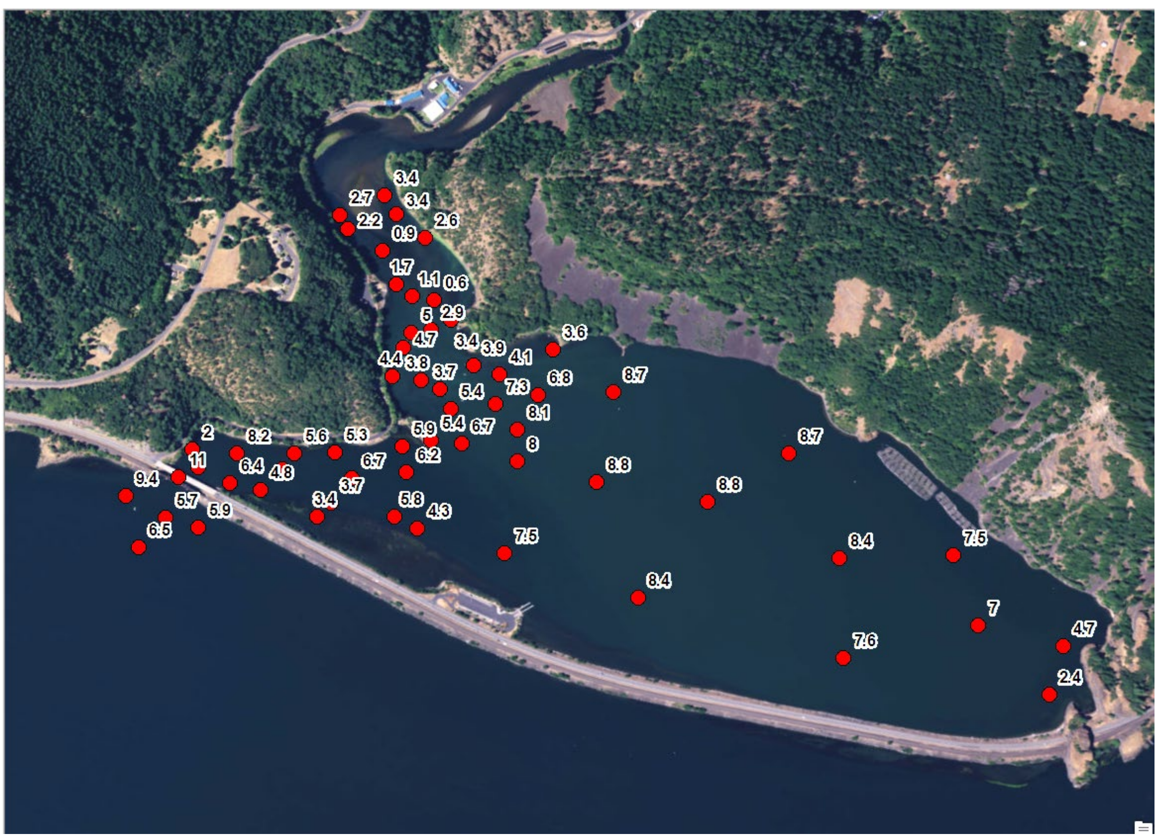
Depth – 9 m



Methods – The volume of cold water at the Little White Salmon/Columbia River confluence was estimated from field data through a two-step process: The first step was to use depth measurements to estimate the bathometry of this confluence zone, and the second step was to use temperature measurements to estimate the spatial extent of water temperatures along the vertical depth profile.

Modeling Little White Salmon/Drano Lake Bathometry - Depth measurements (along with temperature measurements at depth) were collected within Drano Lake and the Little Salmon River on August 17, 2016 (**Figure 29**). The average distance between each sampling location was calculated as 77 meters. This distance was used to calculate the distance of shore sampling nodes (i.e., zero depth) within this analysis area (**Figure 30**). There were two locations at the confluence of the Little White Salmon River/Drano Lake which were too shallow for the boat to collected samples on the date of sampling (Indicated by the blue and purple polygons in **Figure 31**). Based on field observations, these two locations were estimated to be approximately 0.5-meter deep, and the sampling node distance for these two areas were also set at 77 meters. Using the measured depth values, along with shallow and shoreline areas described above, the bathometric elevation was calculated for Drano Lake/Little White Salmon confluence through using the "Kriging" Geostatistical tool in ArcGIS (**Figure 32**)[5].

Figure 29. Little White Salmon River and Columbia River Confluence – Measured water depths on August 17, 2016



[5] The measured depth data was shown to have a 2^{nd} order polynomial trend, and therefore was removed by the Kriging tool. In addition, local directional influences (anisotropy) in the semivariogram were accounted for during bathometry modeling.

Figure 30. Little White Salmon River and Columbia River Confluence – Plume/Shoreline Boundary

Figure 31. Little White Salmon River and Columbia River Confluence – Shallow Zones

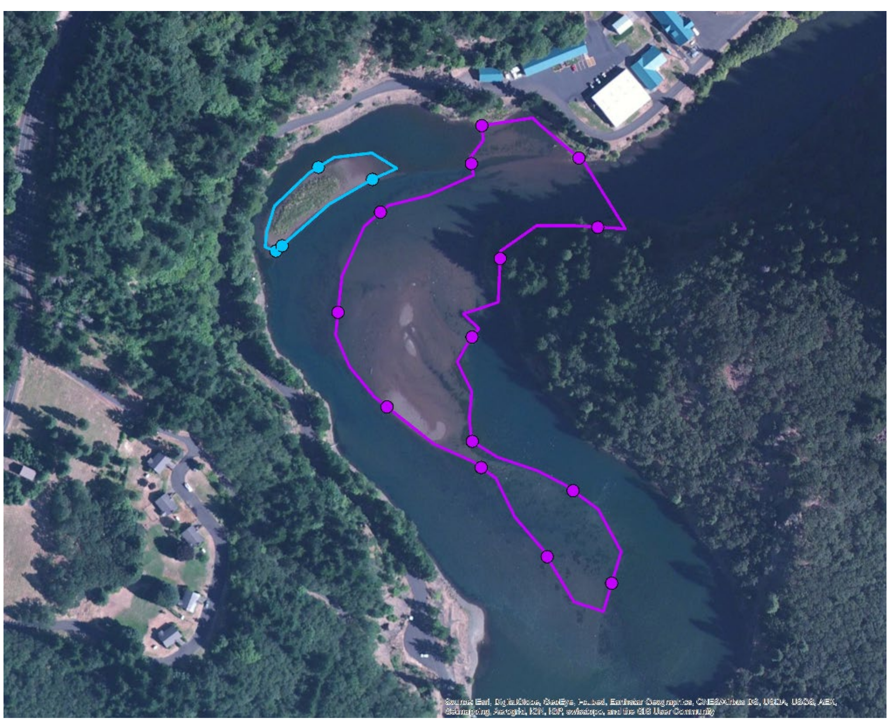
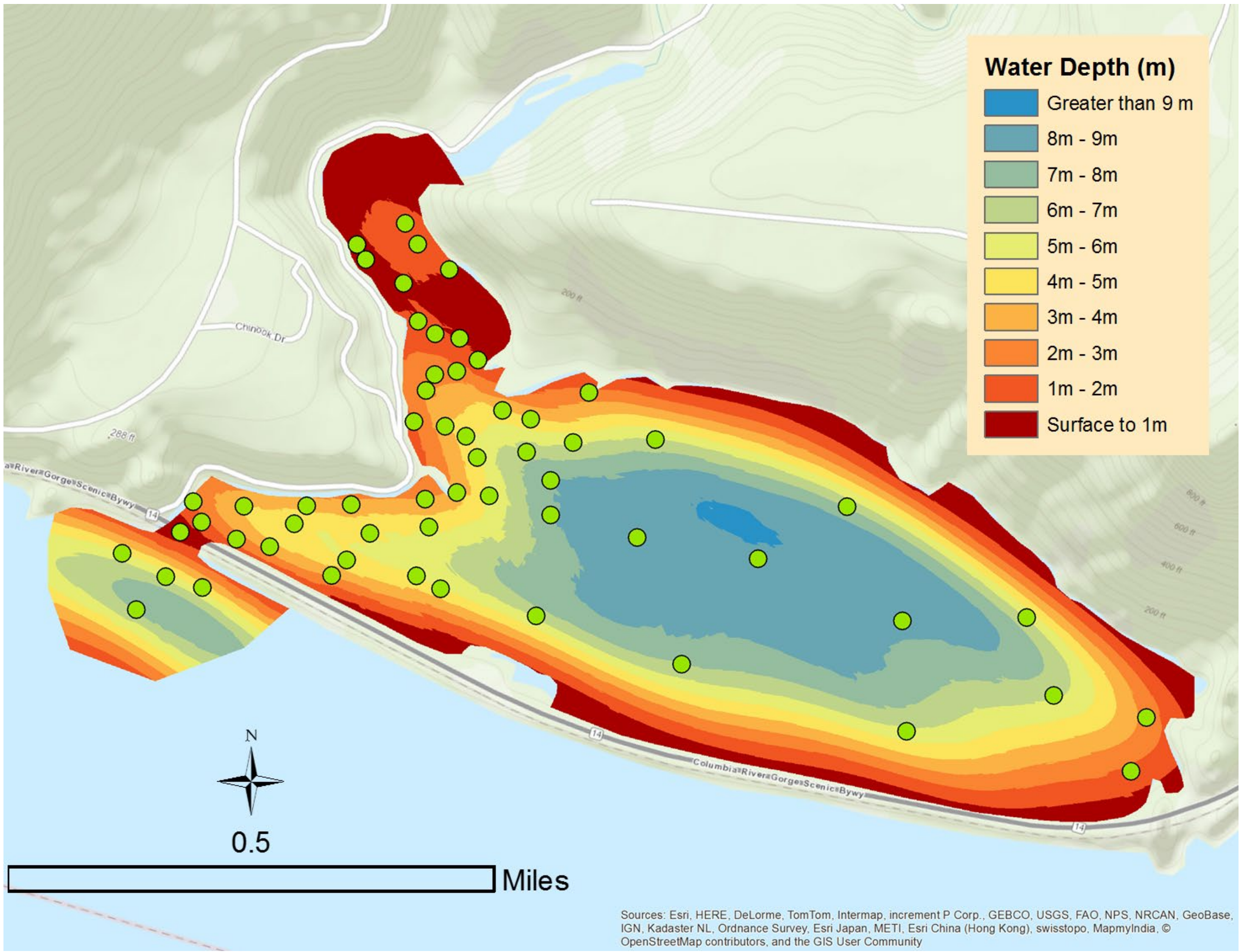


Figure 32. Little White Salmon River and Columbia River Confluence – Modeled Water Depths and Temperature Monitoring Locations (Green Dots)



Modeling Little White Salmon/Drano Lake Water Temperatures - Water temperature profiles were collected at numerous locations within the Little White Salmon River/Drano Lake and Columbia River confluence on August 17, 2016 (see image above). Based on this field data, and the bathometric data, water temperatures were spatially modeled for different depths of this confluence zone through using the Spatial Kriging Geostatistical modeling tool in ArcGIS. A comparison analysis indicated that there is a close relationship between modeled and measured temperatures at the various depth conditions (**Figure 33**).

Modeled surface (i.e., 0.5m depth) water temperatures (using the methods described in this memorandum) were compared to surface water temperatures derived from Landsat 8 satellite imagery collected on August 25, 2016 (**Figure 34**) [6]. It appears these two methods show similar spatial surface temperature patterns, with the coolest surface water temperatures located right at the confluence of the Little White Salmon and Drano Lake and fairly similar temperature observed in the main body of Drano Lake.

[6] Landsat 8 derived surface water temperature estimates were obtained on January 5, 2017 from Marcia Snyder at the USEPA ORD Laboratory in Corvallis Oregon.

Figure 33. Comparison between measured and modeled stream temperatures in the Little White Salmon River Confluence with the Columbia River.

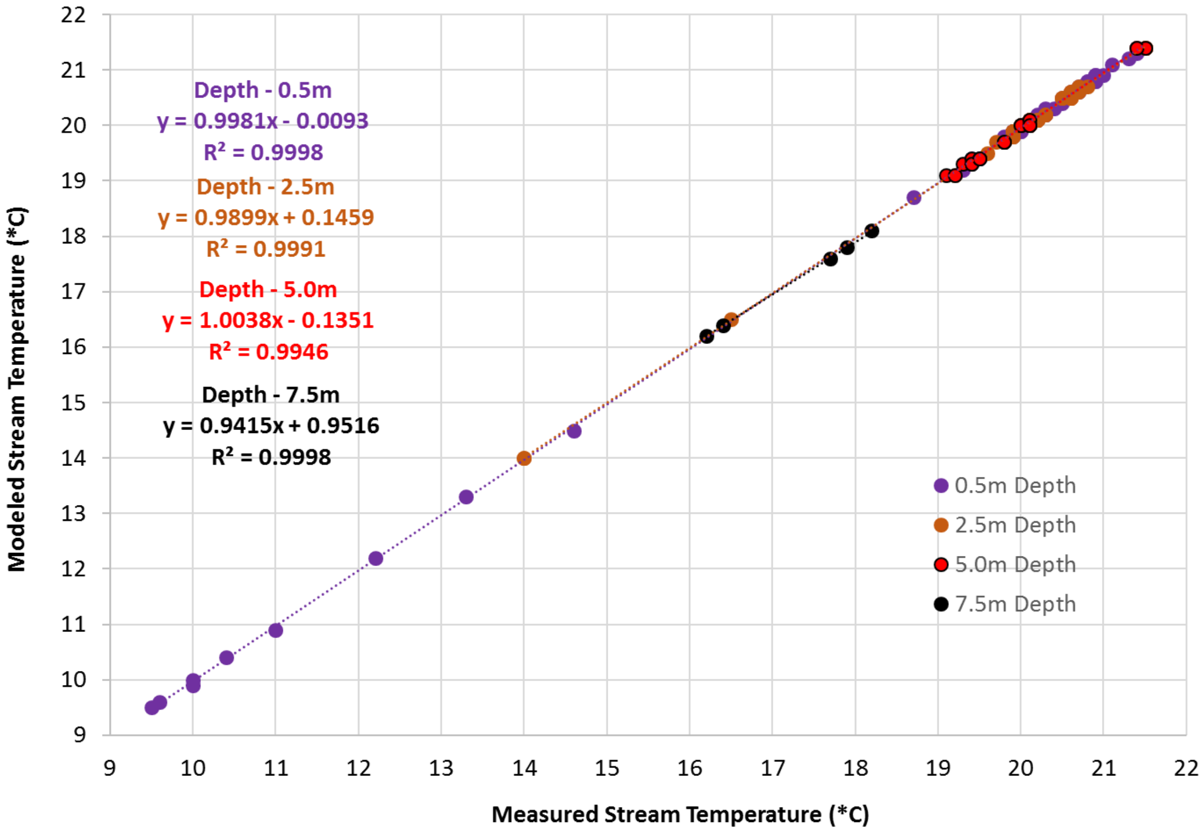
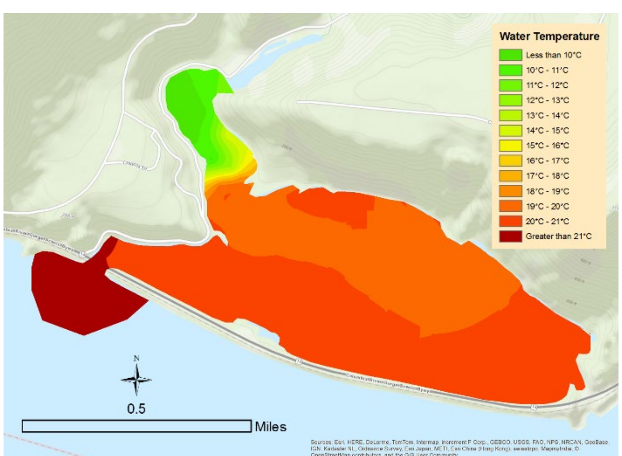
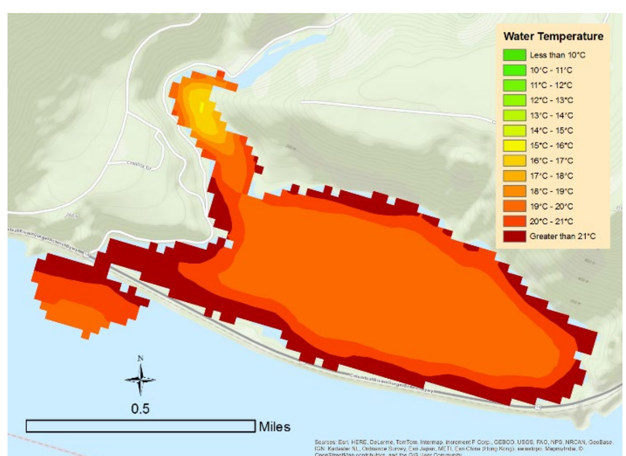


Figure 34. Comparison between modeled surface water temperatures derived from high resolution field data collected on August 17, 2016 and derived from Landsat 8 Satellite 25-meter resolution data collected on August 25, 2016.

<u>Modeled from Field Data</u>



<u>Modeled from Satellite Data</u>



Because the relatively coarse (i.e., 25m) spatial resolution of the satellite data, water temperatures estimated at near shore areas will include residual effects of surface temperatures on the shore areas: Pixel temperature will include the effects of the “hot” shore region and thus resulting in “high” estimates of water temperature in these near shore pixels. This phenomenon may be responsible for the difference in modeled water temperatures at the narrow areas of the Little White Salmon River and Drano Lake confluence. Another reason for the difference may be a result of the different data collection dates: It is possible that different climate and environmental conditions on the two dates could account for some of the difference of results between the two methods. Finally, Landsat imagery only measures the temperature at the absolute surface of the water, while field measured water temperatures were collected at a depth of 0.5 meters under the surface: This may have resulted in some of these observed difference. Regardless of the reason for the slight difference in the estimated absolute temperatures, once again, it appears that the spatial patterns of modeled stream temperature were similar between the two methods and that modeled stream temperatures in open water regions were also similar between the two methods.

Field Sampling Results – Little White Salmon River

The confluence of the Little White Salmon (LWS) and Columbia rivers was sampled on August 17, 2016. The confluence zone is not tidally influenced: This confluence is located upstream of the Bonneville dam complex.

Measured water temperatures (observed at a one-meter depth) showed that the coldest temperatures were located near the mouth of LWS River and were warmer at distance from this location within Drano Lake (**Figure 35**). The temperature of the LWS River, before entering Drano Lake, is cold throughout the summer (**Figure 36**).

The observed flow of the LWS River on the date of sampling activities was 206.4 cfs.

The greatest thermal stratification was observed near the confluence of the LWS River and Drano Lake **(Figure 37)**. There is some thermal stratification in the middle of Drano Lake, however cooler water temperatures are relatively deep at this location.

Dissolved oxygen concentrations were relatively high throughout this confluence area (**Figure 38**).

Figure 35. Measured Water Temperatures at a 1-meter depth in the Little White Salmon and Columbia River Confluence on August 17, 2016.

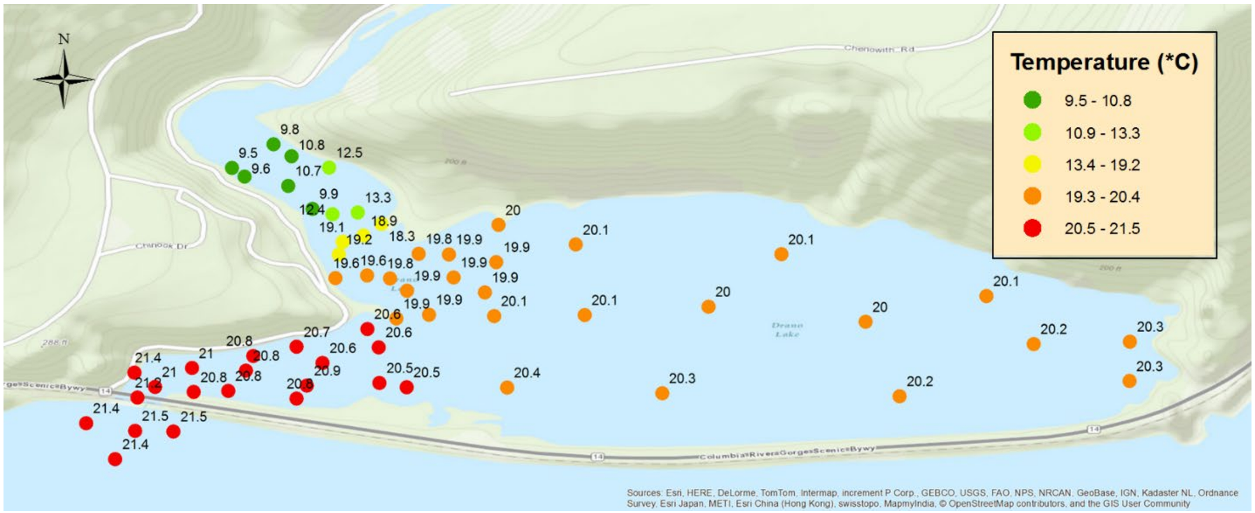
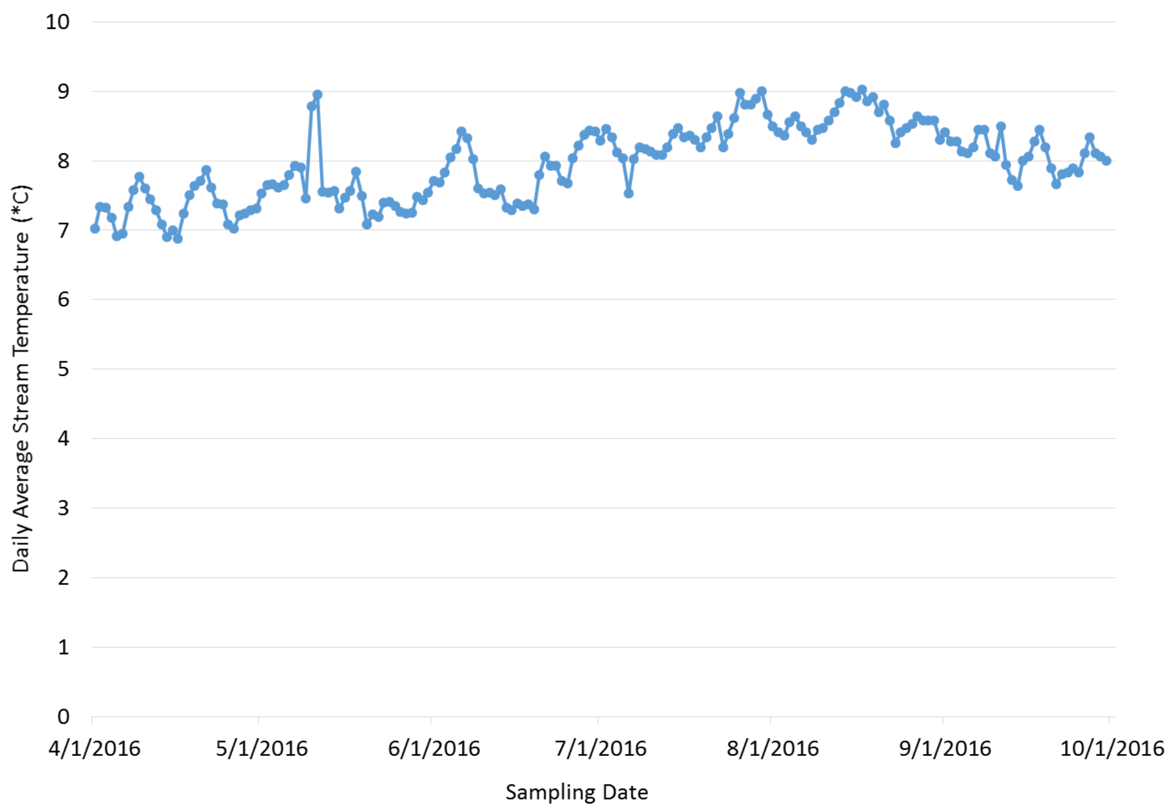
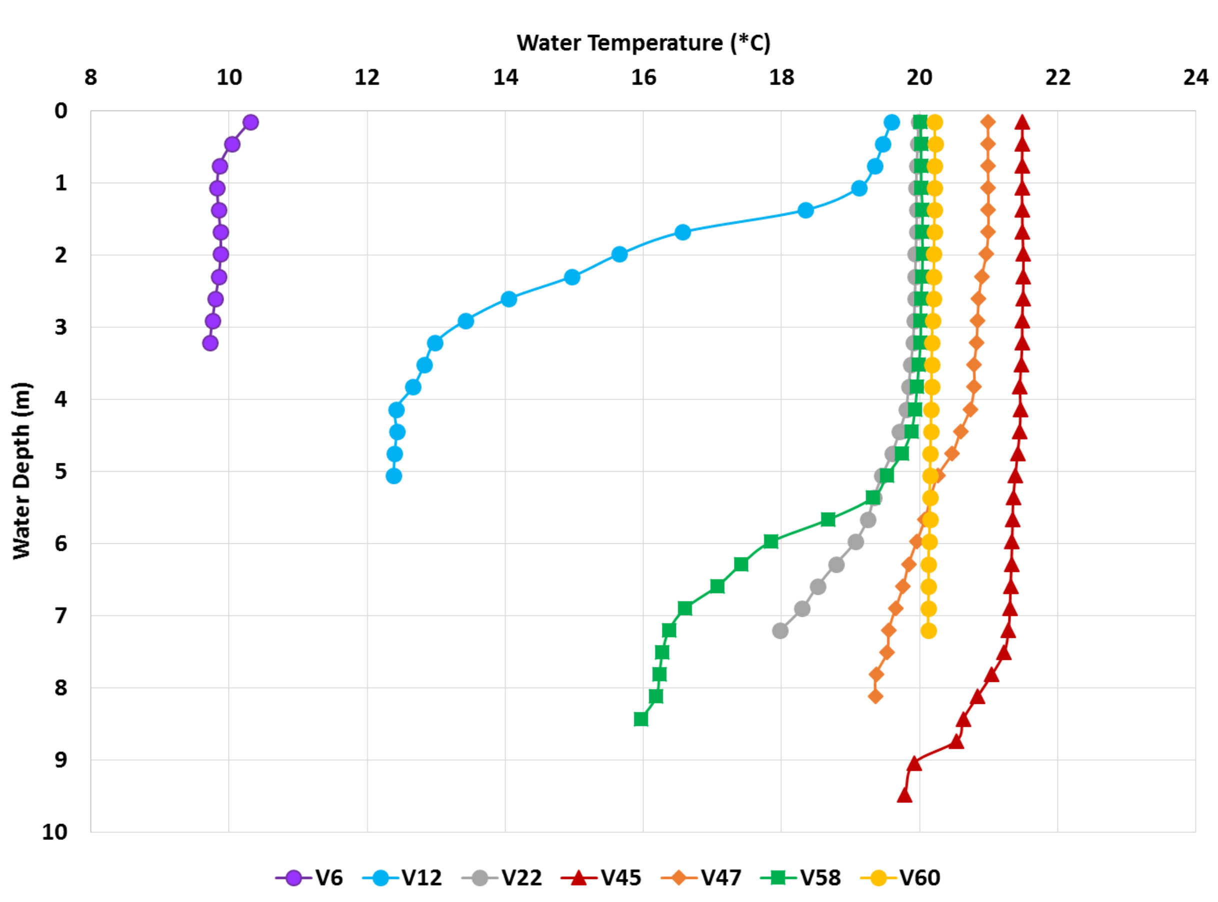


Figure 36. Measured Water Temperature Seasonal Profile at the mouth of the Little White Salmon (i.e., Fish Hatchery Intake) during the summer 2016.[7]



[7] Source – Little White Salmon Hatchery Daily Record Sheets

Figure 37. Measured Water Temperature Profile at Selected Locations at the Little White Salmon and Columbia River Confluence on August 17, 2016.



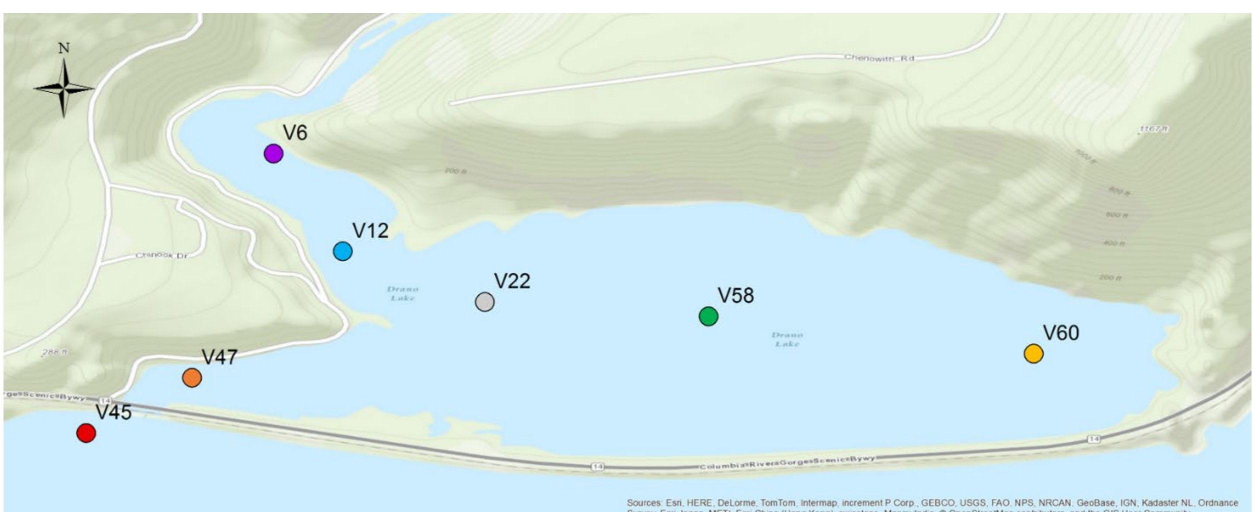


Figure 38. Measured Dissolved Oxygen Profile at the Little White Salmon and Columbia River Confluence on August 17, 2016.