

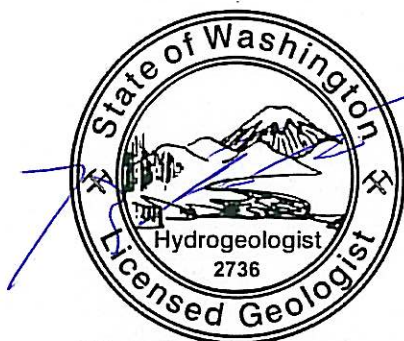
MEMORANDUM

Project No.: 110163-04

May 21, 2013

To: Keith Kistler – Colville Tribes Anadromous Fish Division

cc: Ed Zapel – Pacific Hydraulic Engineers and Scientists



William M. Sullivan

5/21/13

From: William M. Sullivan, LHG
Project HydrogeologistErick W. Miller, LHG
Senior Associate Hydrogeologist

Re: Aeneas Creek Hydrologic Monitoring

Executive Summary

Aspect Consulting, LLC (Aspect) performed hydrologic monitoring of the lower reach of the Aeneas Creek (Creek) near Tonasket, Washington in the summer and fall of 2012 to assess suitability of the Creek as habitat for Endangered Species Act (ESA)-listed Okanogan Steelhead, and to characterize the thermal influence of the Creek on the Okanogan River (River) for providing thermal refugia to fish in the River.

Based on water quality parameters measured in the course of this study, the water quality of Aeneas Creek appears to be generally suitable for the targeted species as established by Bell (1991). Monitoring results indicate the effectiveness of cool water from the Creek for providing thermal refugia in the mainstem River is small. The volume of water entering the River from the Creek is relatively small and Creek temperatures are not substantially cooler than the River during the warmest months. Thus, the Creek's thermal benefit to the River extends only about 50 feet from the mouth of the Creek.

Precipitation of calcium carbonate from the calcite-supersaturated water in the Creek is responsible for cementation of the substrate and is expected to continue under existing hydrogeochemical conditions given the Creek's observed temperature and pH range. Calcite is more likely to precipitate at higher temperatures, thus habitat enhancement measures to decrease water temperature such as beaver dam removal will decrease the potential for substrate cementation.

May 21, 2013

1 Introduction

This memorandum summarizes work accomplished to support enhancement of aquatic habitat in the lower reach of Aeneas Creek (Creek) near Tonasket, Washington.

The Colville Confederated Tribes (Tribes) Anadromous Fish Division (CCT AFD) identified the lower 0.25 miles of Aeneas Creek (lower reach) as having potential for quality habitat benefitting ESA-listed Okanogan Steelhead (Figure 1). Aeneas Creek is one of the only Okanogan River (River) tributaries providing year-around cool (spring fed) water flowing all the way to the River. However, habitat in the Creek is impeded by beaver dams and hydraulic jumps that block passage of juvenile and adult fish from the River. Additionally, substantial mineral cementation of the substrate accumulated behind beaver dams impedes spawning habitat.

2 Objectives

CCT AFD's primary objective for the Creek is establishing access to the lower reach for rearing and thermal refugia of juvenile Okanogan Steelhead. CCT AFD is taking a phased approach to accomplish this objective by removing several of the lowest barriers and then monitoring project success before committing to development of subsequent phases. Secondary and tertiary objectives are maximizing thermal benefits of the Creek to the mainstem River and establishing spawning habitat for adult steelhead in the lower reach of the Creek, respectively.

3 Purpose and Scope

The Aeneas Creek Fish Habitat Enhancement Project was initiated by CCT AFD to address the aforementioned habitat objectives with emphasis on the first and second priorities of establishing fish passage to the Creek and enhancing thermal refugia in the mainstem River.

Aspect and CCT AFD began initial work to enhance habitat in Aeneas Creek in spring 2012. Aspect's scope of work consisted of six tasks addressing habitat improvements in three phases with hydrologic monitoring taking place throughout. Hydrologic monitoring of the Creek and River adjacent to the Creek mouth is intended to establish baseline conditions and to determine project success between phases.

Under Task 1, Aspect provided a site topographic survey and a kickoff meeting and initial consultation to CCT AFD for removing fish passage barriers (beaver dams) in the lower reach of the Creek. Exhibits from the topographic survey including stationing are contained in Appendix A. CCT AFD subsequently removed several of these barriers in Spring 2012 providing passage to approximately Station 4+50 and implemented performance monitoring to observe how the Creek responds, including noting hydraulic changes, and whether the newly opened reach will be used by targeted species.

Under Task 4, Aspect implemented hydrologic monitoring consisting of stream flow and water quality monitoring in summer and fall 2012 to characterize existing conditions and support CCT AFD in determining the likelihood that targeted species will use the newly opened channel.

The phased nature of the project resulted in CCT AFD initiating changes to Aspect's scope of work. Following removal of fish passage barriers in the lowermost reach of the Creek in spring 2012, CCT AFD resolved to continue with additional beaver dam removal and reach performance monitoring for a period of 1 year before proceeding with subsequent phases.

May 21, 2013

This memorandum documents the results of Aspect's monitoring under Task 4 so that it can be used to benefit subsequent project phases.

4 Methodology

Data were collected during Creek and River monitoring to characterize existing flow and water quality conditions in the lower reach of the Creek and adjacent River for supporting development of alternatives to achieve CCT AFD's primary objective of enhancing steelhead habitat in the Creek and its secondary objective of providing thermal refugia in the main stem Okanogan River. Water chemistry data also informed CCT AFD regarding substrate cementation supporting the tertiary objective of enhancing spawning habitat. Hydrologic data collection and analysis conducted under Task 4 consisted of:

- Stream flow monitoring and rating curve development to improve the understanding of discharge conditions in the Creek. These data support development of designs for habitat improvements to the Creek, and support predicting how the Creek might be used by targeted species.
- Water temperature monitoring to verify the Creek is suitable for targeted species and to characterize the thermal impacts of the Creek on the River.
- Water chemistry parameters, including major ions present to support CCT AFD in predicting whether the Creek will be used by targeted species and characterization of the chemical makeup of substrate cementation observed in the Creek bed.

Stream flow, temperature, and water chemistry data were collected in two events: A 1-day initial area-wide survey and subsequent continuous-recording data logging. The start of hydrologic monitoring was performed in mid-August after flows in the River had receded. Aspect performed an initial area-wide survey of the Creek and River on August 14, 2012. This consisted of measuring temperature and other water quality parameters in the Creek and River, deploying temperature dataloggers in the River upstream and downstream of the Creek confluence, measuring flows in the Creek and installing a stream gauge in the Creek. Discharge recorded at the River gauge near Tonasket was 1,750 cubic feet per second (cfs) on August 14th and flows remained below 2,000 cfs during the monitoring period ending October 31, 2012.

4.1 Stream Flow

A staff gauge outfitted with a continuous recording temperature/pressure datalogger (Instrumentation Northwest PT2X) was installed in the Creek 0.5 miles above the mouth (Staff Gauge AC-1). Data was collected from August 14 through October 31, 2012 to examine stream flow patterns. Prior to this study, there were no stream gauges on the Creek and no record of continuous flow measurements. No existing spot flow measurements were identified.

The location of the Staff Gauge AC-1 is shown in Figure 1. Although not an optimal location (the Creek is wide here), this location was preferred over alternate sites and was selected based on the following criteria:

1. **Access and Location** – It is the first accessible private property lying upstream of the lower reach of the Creek proposed for rehabilitation.
2. **Hydraulic Control** – The presence of a relatively stable hydraulic control comprised of a cemented beaver dam.

May 21, 2013

Stage height and flow data were collected to support developing a rating curve for Staff Gauge AC-1. Discharge was measured on three occasions using a flow velocity meter near the mouth of the Creek at Station 2+50. Development of the rating curve is ongoing, awaiting spring runoff when flows are expected to vary from those observed in the fall. Approximately 4 to 6 additional measurements taken at different stages are required to complete the rating curve.

4.2 Area-Wide Hydrologic Survey

An area-wide hydrologic survey of the Creek and the River was conducted on August 14, 2012. A pontoon boat was used to survey the River upstream and downstream of the confluence with the Creek. A YSI-85 multimeter was used to measure temperature, specific conductance, dissolved oxygen, pH, and oxidation/reduction potential (ORP). The meter was calibrated the day prior to use. Measurements were taken at depths of 1-foot below the water surface and 1-foot above the bottom at 23 locations in water up to 15 feet deep. A handheld (map grade) GPS was used to mark the locations that are shown in Figure 2.

Water quality parameters other than temperature were used to provide multiple lines of evidence for the mixing zone characteristics. Parameters, including pH and dissolved oxygen, were measured to characterize the habitat suitability of the Creek and River waters for targeted species. A grab sample was taken from the Creek near its mouth and submitted to Cascade Analytical Laboratory in Wenatchee, Washington for analysis of major ions to characterize the chemical composition of the Creek water.

4.3 August 14 – October 31 Continuous Temperature Monitoring

Continuous temperature monitoring was performed from August 14 through October 31, 2012 for the River and Creek. Monitoring continues to be ongoing in the Creek. Five strings each, containing two continuous recording temperature dataloggers (10 total Hobo Pendants), were deployed in the River (Figure 1). Hobo loggers were connected to a ¼-inch rope affixed on one end to a cinder block lying on the River bottom and on the other end to a float at the water surface. Loggers were set 1-foot below the surface and 1-foot above the bottom.

Dataloggers were deployed in the River at the following locations shown in Figure 1:

- **OR-1:** Located upstream of the confluence with the Creek to establish background temperatures;
- **OR-2 and OR-5:** Located in a relatively deep pool adjacent to mouth of the Creek and at the River thalweg near the Creek mouth to characterize thermal impacts to the River from the Creek; and
- **OR-3 and OR-4:** Located downstream of the pool to characterize the impacts of mixing.

Continuous temperature monitoring of the Creek was accomplished using the datalogger at Staff Gauge AC-1.

Raw data from continuous temperature monitoring in the River and Creek are contained in Appendix B.

May 21, 2013

5 Results

Results of monitoring for stream flow, temperature, and water chemistry are presented below.

5.1 Stream Flow

The Creek stream flow remained relatively constant during the monitoring period from August 14 to October 31, 2012 (Figure 3). During this period, discharge in the Creek was measured at 1.42 cfs on August 14, 1.67 cfs on August 25, and 1.68 cfs on October 31. At the time this memorandum was drafted, stream flow data were too limited to develop a rating curve. Therefore, the hydrograph in Figure 3 shows the Creek stage as measured by the pressure transducer datalogger. Stage height apparently increased by about 0.1 foot over the monitoring period. Additional monitoring is required to determine whether this stage increase represents actual increased discharge or instrument offset drift. The period shown on the hydrograph between August 25 and ending September 14 represents a period when water level data are unavailable due to equipment malfunction. Diurnal water level fluctuations that are most apparent in August and diminish through September are attributed to evapotranspiration from riparian vegetation.

River discharge generally decreased during the monitoring period from about 1,700 cfs in mid-August to about 1,100 cfs in late October with the lowest flows of 600 cfs occurred on about October 3 (Figure 4). River discharge began to increase significantly beginning October 31 on the same day the dataloggers were retrieved.

5.2 Temperature

Four of five datalogger strings, including six dataloggers, were recovered on October 31. The entire OR-3 string could not be located. The bottom logger on OR-1 (deployed at 5.5 feet) and the surface logger on OR-5 (deployed at 1.0 feet) were missing. The OR-2 string had moved downstream about 30 feet. The cause of missing and displaced loggers is not known. Debris was hung up and holding the float at OR-1 below the surface. The River at this location is frequented by fishermen. River flows decreased during the entire continuous monitoring period, minimizing the possibility of the strings being swept downstream by the River.

Figure 4 shows continuously recorded water temperatures in the River and Creek, River temperatures and discharge at the United States Geological Survey (USGS) Tonasket Gauge located upstream from the Site, and air temperatures at Omak for the monitoring period from August 14 through October 31, 2012.

The River and Creek temperatures are discussed in greater detail below.

5.2.1 Okanogan River Temperatures

River temperatures generally mimic air temperature and decreased through the August 14 – October 31 continuous monitoring period. .

Temperature measured by dataloggers in the River at the Creek during the monitoring period ranged from 7.7° C to 25.5° C, and averaged 16.7° C, with the overall temperature decreasing during the monitoring period from mid-August through late October (Figure 4).

Changes in the River water temperature mimicked changes in air temperature with the highest water temperatures occurring at mid-day as air temperatures peaked on August 19. Loggers recorded sharp declines in water temperature on September 11, October 3, and again on about

May 21, 2013

October 16, when air temperatures dropped substantially (10° C or more). Distinct diurnal water temperature fluctuations of about 2° C persisted until mid-October.

River temperatures at the USGS gauge upstream near Tonasket generally followed the same trends as the River at the Creek. However, temperatures at the USGS gauge were generally 1-2° C cooler than the River at the Creek until October 3 when River temperature at the Creek declined faster than at the USGS gauge. Diurnal fluctuations in the River at the USGS gauge were generally smaller and diminished sooner than at the Creek.

No long-term difference in average temperature was observed among loggers during the monitoring period. Temperatures over the monitoring period were within 0.1° C among all loggers, indicating the River temperature was essentially the same at all locations. However, temperature plots in Figure 4 showed that short-term (daily) variation among loggers was common, especially during the heat of the day with shallow loggers displaying higher temperatures than deeper ones. For example, daily mid-day temperatures at OR-2 (1.0 feet) were about 0.3° C higher than other locations until mid-September when cooler weather produced less solar heating at the River surface. No logger (including deep ones) displayed consistently lower temperatures than the others.

5.2.1.1 Influence of Aeneas Creek on the Okanogan River

A snapshot of water temperature collected on the August 14 area-wide survey indicates the Creek presents a limited thermal influence to the River. Shallow temperatures measured 1-foot below the surface are shown in Figure 5, and deep temperatures measured 1-foot off the bottom are shown in Figure 6. The shallow water temperature map shows the influence of the Creek on the River is relatively distinct (shown in blue on Figure 6), where the Creek depresses the River temperature by 2-3° C to about 21° C in a plume extending about 50 feet from the mouth. The Creek's influence on deeper water extends about as far from the mouth but is less distinct.

Figures 5 and 6 also show that shallow and deep River temperatures measured on August 14 increased up to 1° C over a distance of 700 feet from upstream to downstream of the Creek mouth.

5.2.2 Aeneas Creek Temperatures

Creek temperatures follow air temperature and remained cooler than the River for most of the monitoring period. Water temperature data collected during the August 14 area-wide survey are shown in Table 1 along with other water quality parameters.

Temperatures measured in the Creek at Staff Gauge AC-1 ranged from 6.9° C to 19.1° C, and averaged 12.7° C during the monitoring period. Figure 4 shows that water temperatures in the Creek decreased through the monitoring period and mimicked air temperature with the highest water temperatures occurring on about August 19. Creek temperatures exceeded the maximum for salmonid rearing (17° C) as established by Bell (1991) for 11 days, ending August 27. Temperatures dipped below the minimum for salmonid rearing (7° C) on 1 day. Diurnal temperature fluctuations of about 3° C to 4° C were greater than those observed in the River consistent with the shallower depth, lower creek flows, and numerous beaver dams.

Creek temperatures increased with distance downstream. Temperature measured on August 14 varied from 16° C at the Staff Gauge AC-1 to 20° C near the mouth of the Creek (a distance of 0.5 miles). River temperatures measured on the same day ranged from 23° C to 24° C.

May 21, 2013

Creek temperatures were lower than the River for most of the monitoring period until October 19, when a sharp decline in air temperature depressed River temperatures below that of the Creek.

5.3 Water Quality and Chemistry

5.3.1 Water Quality

Water quality parameters collected in addition to temperature on August 14 are shown in Table 1. Parameters in the Creek and River for dissolved oxygen and pH were generally within ranges established as tolerable for targeted species (Bell, 1991). Dissolved oxygen was measured at 9.5 milligrams per liter (mg/L) to 9.8mg/L in the Creek and ranged from 8.9 mg/L to 9.4 mg/L in the River. No appreciable correlation was observed between dissolved oxygen and depth in the River. An exception is pH that was measured at 8.7 in the Creek, which is higher than the maximum for this parameter of 8.3 pH (Bell, 1991). The pH ranged from 8.4 to 8.5 in the River. No relation between pH and depth was observed.

Specific conductance measurements (collected to examine mixing of the Creek waters with the River) are shown mapped in Figure 7. Specific conductance was measured at 584 $\mu\text{S}/\text{cm}$ in Aeneas Creek and averaged about 192 $\mu\text{S}/\text{cm}$ in the Okanogan River. No relation between specific conductance and depth was observed. Similar to water temperature, Figure 7 shows the Creek projects a plume of higher specific conductance water extending about 50 feet into the River from the mouth of the Creek.

5.3.2 Laboratory Analysis

Analytical results for major ions from the Creek collected on August 14, 2012 (Appendix C) were plotted on a trilinear diagram (Figure 8). The diagram indicates that this is a calcium-magnesium-bicarbonate-sulfate type water with minor contributions of sodium, potassium, and chloride. Major ion concentrations in addition to temperature and pH data collected at the time of sampling were evaluated using a hydrogeochemical model, PHREEQC Version 3.0.0.7430 (Parkhurst and Appelo, 2013). The hydrogeochemical analysis indicates water in the Creek is supersaturated with calcium carbonate minerals, calcite and aragonite, suggesting the source of cementation observed on the Creek substrate is calcium carbonate. Given the concentrations of dissolved calcium, alkalinity, and pH measured at 8.6, precipitation of the calcium carbonate is likely to continue under the temperature range observed in the Creek. Given the observed major ion chemistry, calcium carbonate precipitation would be expected to decrease if the pH decreases to approximately 7.4.

6 Conclusions

The following conclusions are drawn from results of hydrologic monitoring taking place in the summer and fall of 2012.

A. *Measured water quality parameters of Aeneas Creek are within acceptable range for the targeted species:*

Water quality within the Creek is an important factor in determining the extent the water body will be used following fish passage restoration. Temperature, dissolved oxygen, and pH were generally observed within established parameters (Bell, 1991).

Achieving the Tribe's paramount priority of enhancing rearing habitat in the Creek depends in part on the water quality within the Creek.

May 21, 2013

Our limited examination of water quality within the Creek did not address all water quality parameters influencing whether it will be used by targeted species. For example, metals (copper, zinc, etc.) were not assessed. The impact of elevated specific conductance observed in the Creek was also not evaluated. The impacts of temperature and several other water quality parameters potentially influencing use of the Creek are summarized below.

Temperature: Aeneas Creek

Water temperature observed in the Creek is cooler than the River by several degrees during summer. However, the Creek's water temperatures did exceed the suggested maximum for salmonid rearing (17° C) (Bell, 1991) during the 2012 monitoring period.

Creek temperatures exceeded the maximum for salmonid rearing (17° C) on 11 days during the monitoring period at Staff Gauge AC-1. Continuous monitoring did not begin until the middle of August. Therefore, the total number of days that the Creek temperatures exceeded the maximum has not been fully characterized and is likely more than was observed during the 2012 monitoring period.

Observed Creek temperatures increased with distance downstream with as much as 4° C difference in the ½ mile between Staff Gauge AC-1 and the mouth of the Creek. This increase is likely caused by slow moving pools from numerous old beaver dams and associated lack of riparian vegetation.

The 2012 temperature excursions above 17° C likely under represent the number of actual days excursions occurred because: 1) the relatively short monitoring period did not cover the warmest part of summer, and 2) continuous temperature measured at a point located 0.5 miles upstream from the Creek mouth where water temperatures were observed to be considerably cooler.

Dissolved Oxygen and pH: Aeneas Creek

Established water quality parameters (Bell, 1991) for salmonid rearing that were evaluated include dissolved oxygen and pH. Dissolved oxygen was within limits, while pH appears to be slightly higher (8.7) than the maximum for salmonid rearing (8.3).

B. The Thermal Impact of Aeneas Creek on the Okanogan River is Small

Aeneas Creek appears to have little thermal impact on the River that is dominated by changes in air temperature.

Aeneas Creek does depress River temperatures by about 2-3° C but this influence dissipate rapidly with distance from the Creek mouth. The influence of the Creek on the River is limited to the immediate vicinity of the Creek mouth, extending up to about 50 feet into the River during mid-summer. Evidence supporting the Creek's limited thermal impact on the River include:

- Shallow and deep temperatures and specific conductance mapping taken from numerous locations measured on August 14 (Figures 5, 6, and 7) showing the Creek's influence is limited to the immediate vicinity of its mouth.
- Shallow and deep water temperatures taken mid-day on August 14 show an increase up to 1° C from upstream of the Creek to downstream (Figures 5 and 6). This increase is attributed to solar heating in this slow-moving reach that appears to have a larger influence on river temperatures than the water flowing in from the Creek.

May 21, 2013

- No appreciable difference in temperature was measured among continuous recording data-loggers located upstream, adjacent to, and downstream of the mouth of the Creek during the continuous monitoring period from August 14 through October 31, 2012.
- The volume of surface water flowing into the River from the Creek on August 14 (1.47 cfs) represented about 0.08 percent of the flow of the River (1,750 cfs). Considering the small contribution in discharge to the River and Creek temperatures near the mouth (20° C) that are only 3-4° C cooler than the River (23 –24° C), the thermal influence of the Creek on the River is small.

Water temperatures appear to be sensitive to changes in air temperature. Evidence supporting the dominant influence that air temperature has on River temperature includes:

- The sharpest River temperature changes occurred on September 11, October 3, and again on about October 16, when air temperatures dropped substantially (10° C or more), as shown in Figure 4.
- Despite input of cool water from the Creek, river temperatures recorded on August 14 actually increased 1° C over a distance of 700 feet from upstream to downstream of the Creek (Figures 5 and 6). This increase is assumed to be caused by solar input and lack of mixing in this relatively slow moving reach.

No evidence was observed indicating the Creek contributes significant groundwater to the River.

C. Calcium precipitation is expected to continue under existing hydrogeochemical conditions in the Creek.

Precipitation of calcium carbonate from the calcite-supersaturated water in the Creek is responsible for cementation of the substrate. Calcium carbonate precipitation is expected to continue under existing hydrogeochemical conditions given the Creek's observed temperature and pH range. Because calcite has a retrograde solubility (more likely to precipitate at higher temperatures), habitat enhancement measures to decrease water temperature will decrease the potential for substrate cementation. Measures currently proposed by CCT AFD, including removal of beaver dams and planting riparian vegetation, are expected to decrease water temperature. Additionally, higher water velocities resulting from beaver dam removal will decrease calcite precipitation. Recent observations of loose gravels in the bed of the lower reach of the Creek where beaver dams were removed in 2012 already show evidence of decreased substrate cementation. If gravels are imported to improve spawning habitat, they should be placed in reaches of the Creek where water velocities are relatively high. Use of limestone gravels should be avoided.

7 References Cited

Bell, M. C., 1991, Fisheries Handbook of Engineering Requirements and Biological Criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Parkhurst, D. L., and Appelo, C. A. J., 2013, User's guide to PHREEQC (Version 3) - A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations, Model Homepage:
http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/

May 21, 2013

Limitations

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

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Attachments

- Table 1 – Hydrologic Survey Results, Aeneas Creek and Okanogan River, August 14, 2012
- Figure 1 – Stream Gauging and Temperature Stations
- Figure 2 – Stream Temperature Reconnaissance Stations
- Figure 3 – Aeneas Creek Hydrograph
- Figure 4 – Temperature and Stream Flow Plots
- Figure 5 – Shallow Temperature Heat Map
- Figure 6 – Deep Stream Temperature
- Figure 7 – Deep Stream Specific Conductance
- Figure 8 – Trilinear Plot for Major ions in Aeneas Creek
- Appendix A – Topographic Survey Exhibits (on CD)
- Appendix B – Raw Data from Dataloggers (on CD)
- Appendix C – Analytical Results for Major Ions from Aeneas Creek collected on August 14, 2012 (on CD)

W:\110163 Aeneas Creek Habitat Enhancement\Deliverables\Hydrologic Monitoring Memo\Aeneas Memo Final - 5-21-13.docx

Table 1 - Hydrologic Survey Results, Aeneas Creek and Okanogan River, August 14, 2012

Time	Station	Location	Depth (feet)	Temperature (degrees C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	Oxidation Reduction Potential (mV)
12:00	1	River	1*	22.97	194	9.07	8.37	6.9
12:02	2	River	10	23.27	192	9.04	8.4	6.8
12:03	2	River	1*	23.17	192	9.24	8.38	7.2
12:19	3	River	1*	23.52	190	9.19	8.38	10.9
12:20	3	River	N/A*	23.5	190	9.19	8.38	10.9
12:41	Ambient Air	NA	-	25.9	-	-	-	-
12:34	23	Creek	0.5	19.56	584	9.78	8.68	26.1
13:07	4	River	12	23.87	190	9.23	8.48	10.3
13:07	4 ¹	River	1*	23.82	-	-	-	-
13:11	5	River	11	23.84	191	8.96	8.46	13.5
13:12	5	River	1*	23.86	193	9.02	8.46	13.7
13:17	6	Creek mouth	6	23.09	281	8.92	8.56	17.8
13:17	6	Creek mouth	1*	23.69	-	-	-	-
13:20	7	Creek mouth	2.5	23.52	244	8.46	8.5	17.3
13:24	8	River	12	23.66	221	8.88	8.52	14.6
13:26	8	River	1*	23.85	202	9.06	8.48	14.7
13:27	9	River	13* ²	23.89	191	9.05	8.5	15.1
13:30	10	River	12	23.84	192	9.25	8.46	17.6
13:30	10 ³	River	1*	23.95	-	-	-	-
13:36	11	River	1.5	24	194	9.08	8.48	18.43
13:36	12	River	12* ²	23.96	194	9.08	8.47	20.3
13:36	12	River	1*	23.97	196	9	8.48	20.4
13:43	13	River	12* ²	23.97	191	9.27	8.47	22.7
13:46	14	River	12	23.9	192	9.26	8.5	22.5
13:51	15	River	5	23.83	193	9.29	8.51	23
13:52	15	River	1	23.85	193	9.36	8.5	23.2
13:56	16	River	12	23.94	193	9.3	8.51	24.2
13:57	16 ⁴	River	1	24.01	-	-	-	-
14:00	17	River	6	24	193	9.19	8.5	26.3
14:01	17	River	1*	24.12	-	-	-	-
14:06	18	River	10	24.12	191	9.19	8.47	34.8
14:09	19	River	6	24.16	191	9.3	8.49	32.2
14:14	19	River	1	24.19	-	-	-	-
14:14	20	Creek mouth	0.5	21	564	8.91	8.68	51.9
14:14	21	Creek mouth	1*	24.12	212	8.95	8.6	33.7
14:14	22	Creek mouth	3.5	22.7	381	9.02	8.67	44
16:20	Ambient Air			29.34				
21:06	23	Creek	0.5	18.62	547	9.49	8.65	92.7

All measurements collected August 14, 2012.

* - Measurement was not taken 0.5' above the bottom of the river.

¹ - Measurement was taken 50' from Station 4.

² - Total depth is deeper than the sampler could reach.

³ - Measurement was taken 20' down stream from Station 10.

⁴ - Measurement was taken 70' from Station 16.

Aspect Consulting

5/21/2013

W:\110163 Aeneas Creek Habitat Enhancement\Deliverables\Hydrologic Monitoring Memo\Tables\Table 1_results.xlsx

Table 1

Hydrologic Monitoring

Page 1 of 1



▲ AC-1

OR-1
(1, 5.5)

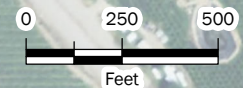
AC-2
(0, 5)

OR-5
(1, 9)

OR-2
(1, 14)

OR-3
(1, 7)

OR-4
(1, 5.5)



▲ Staff Gauge/
Temperature Logger

● Temperature Logger

OR-2
(1, 5.5)

← Depth of lower temperature sensor
(1ft off bottom)

↑ Depth of upper temperature sensor

Stream Gauging and Temperature Stations

Aeneas Creek Fish Habitat Enhancement Project
Colville Confederated Tribes, Washington



MAR-2013

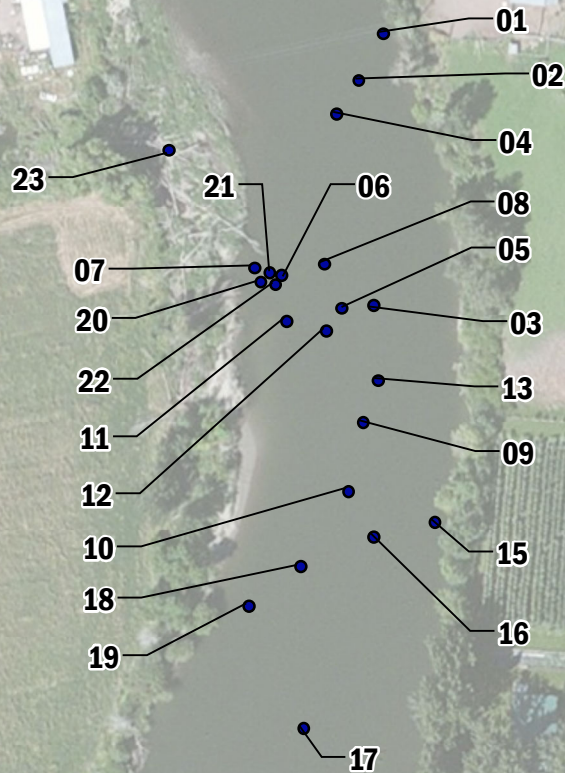
PROJECT NO.
110163-004

BY:
EWM / HRL

REV BY:

FIGURE NO.

1



● Stream Temperature Measured
August 14th, 2012 (multiple depths)

Stream Temperature Reconnaissance Stations

Aeneas Creek Fish Habitat Enhancement Project
Colville Confederated Tribes, Washington



MAR-2013

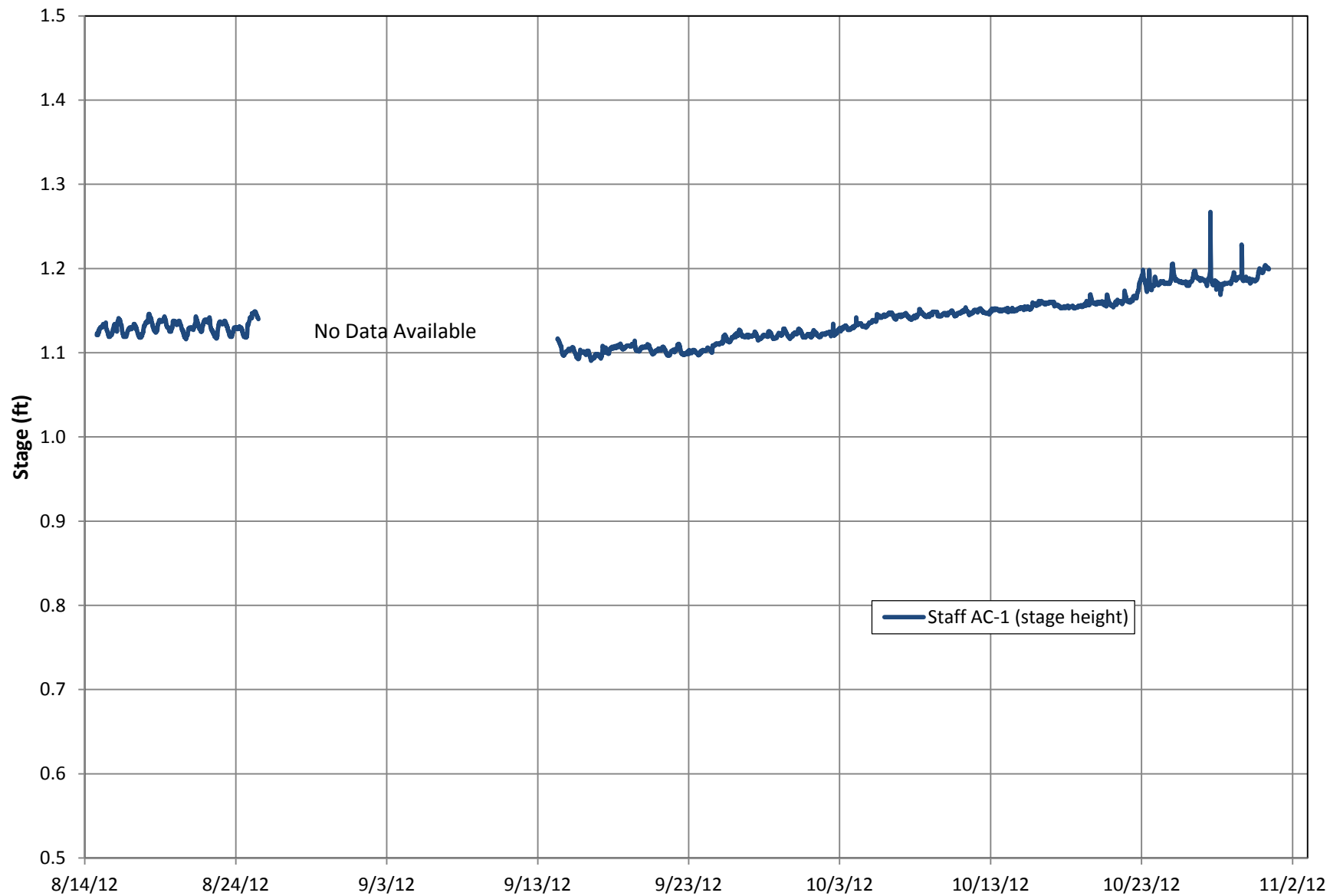
PROJECT NO.
110163-004

BY:
EWM / HRL

REV BY:

FIGURE NO.

2



Aspect Consulting

5/21/2013

K:\Projects\Aeneas Creek\Data\Analyses\Aeneas Creek_Data Plots 121212.xlsm - Staff_C1Plot

Figure 3
Aeneas Creek Hydrograph
Aeneas Creek Habitat Enhancement
Okanogan Basin, WA

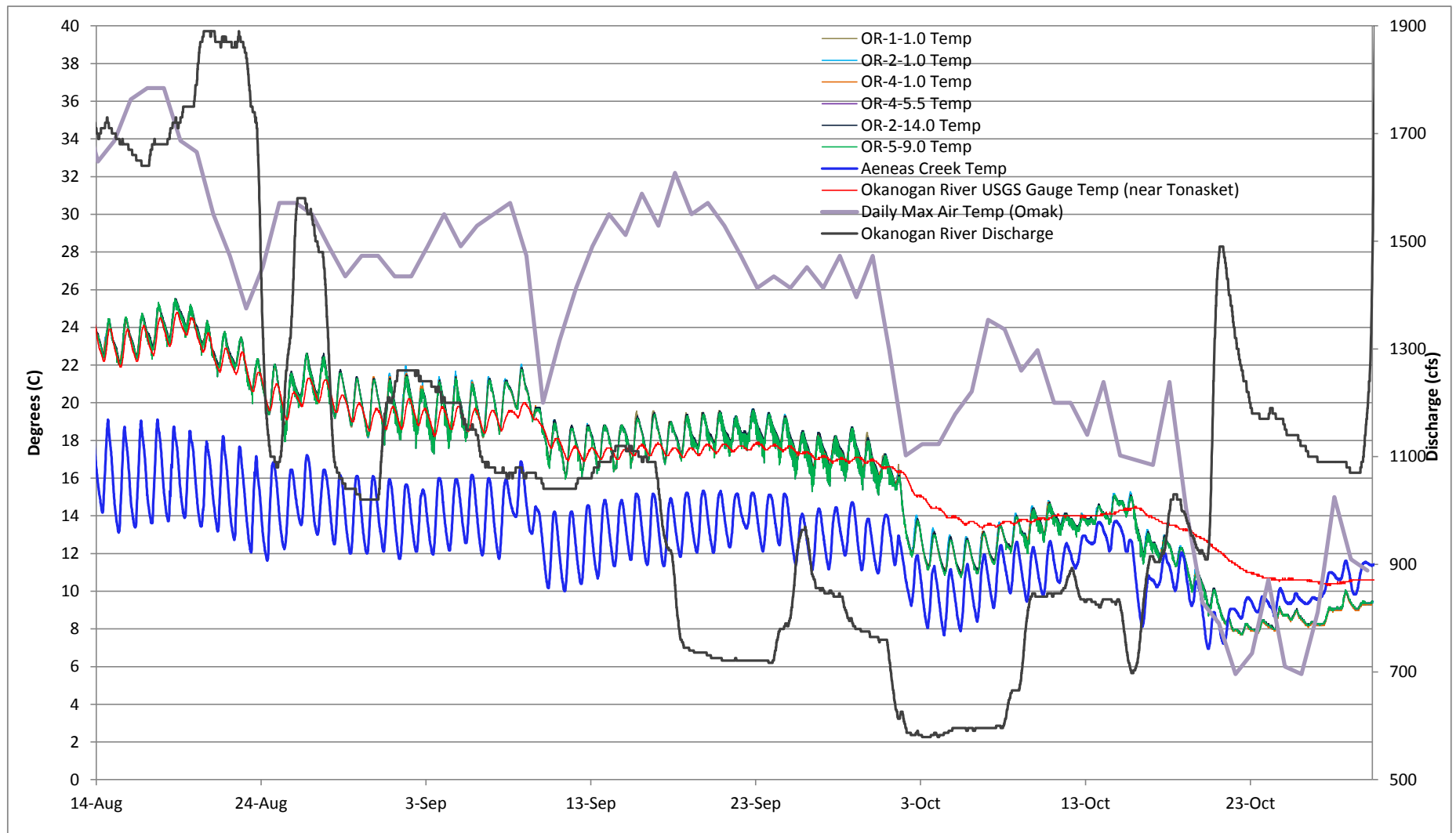
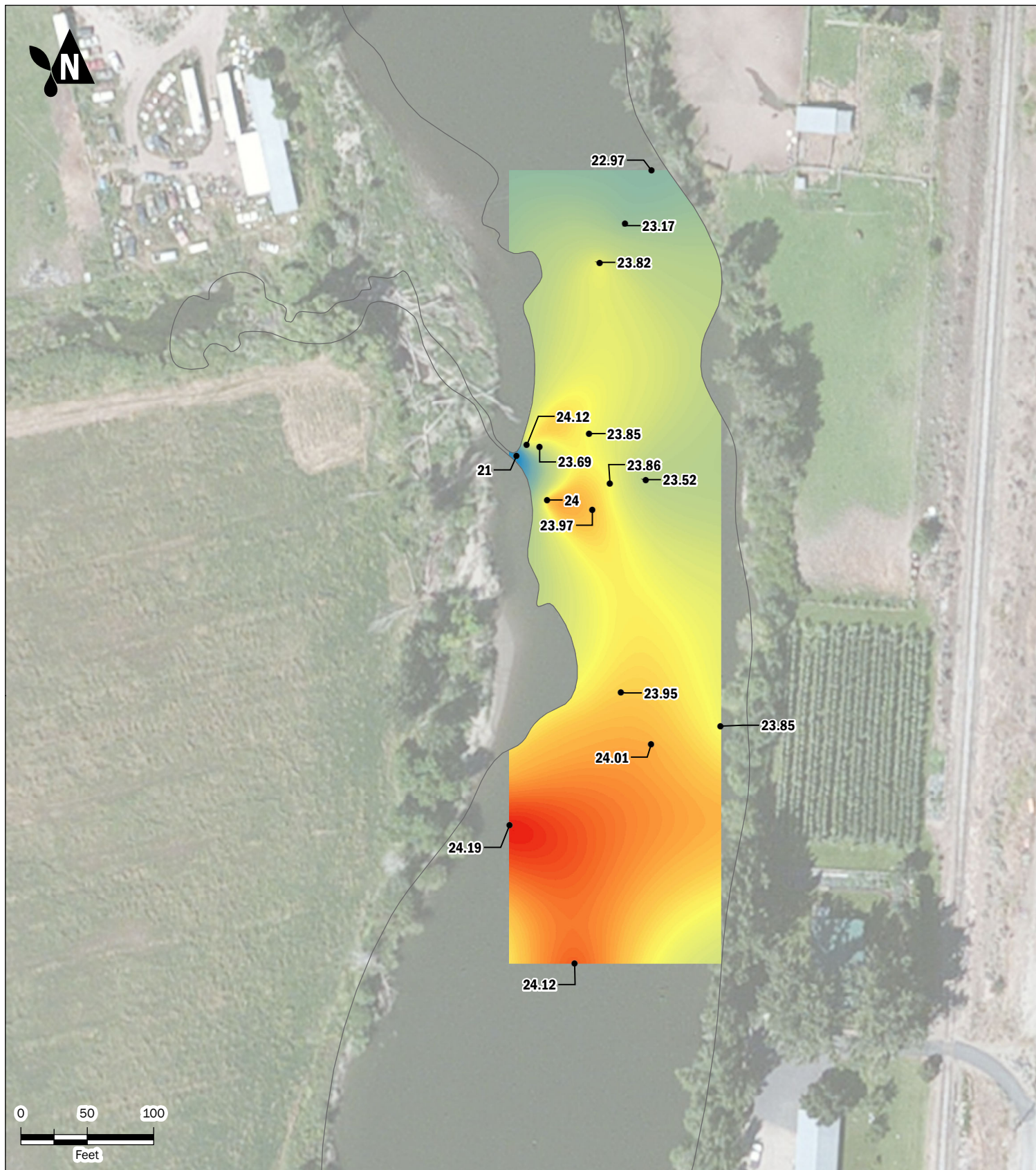


Figure 4

Temperature and Stream Flow Plots

Aeneas Creek Habitat Enhancement

Okanogan Basin, WA



High : 24.19

Low : 21.00

• Sampling Point Temperature

□ Water Boundary

Shallow Temperature Heat Map

Aeneas Creek Fish Habitat Enhancement Project
Colville Confederated Tribes, Washington



MAR-2013

PROJECT NO.
110163-004

BY:
EWM / HRL

REV BY:

FIGURE NO.

5



High : 24.2142

Low : 19.8303

• Sample Site Temperature (°C)

□ Water Boundary

Note: Stations 20, 21 and 23 were measured at shallower depths

Deep Stream Temperature

Aeneas Creek Fish Habitat Enhancement Project
Colville Confederated Tribes, Washington



MAR-2013

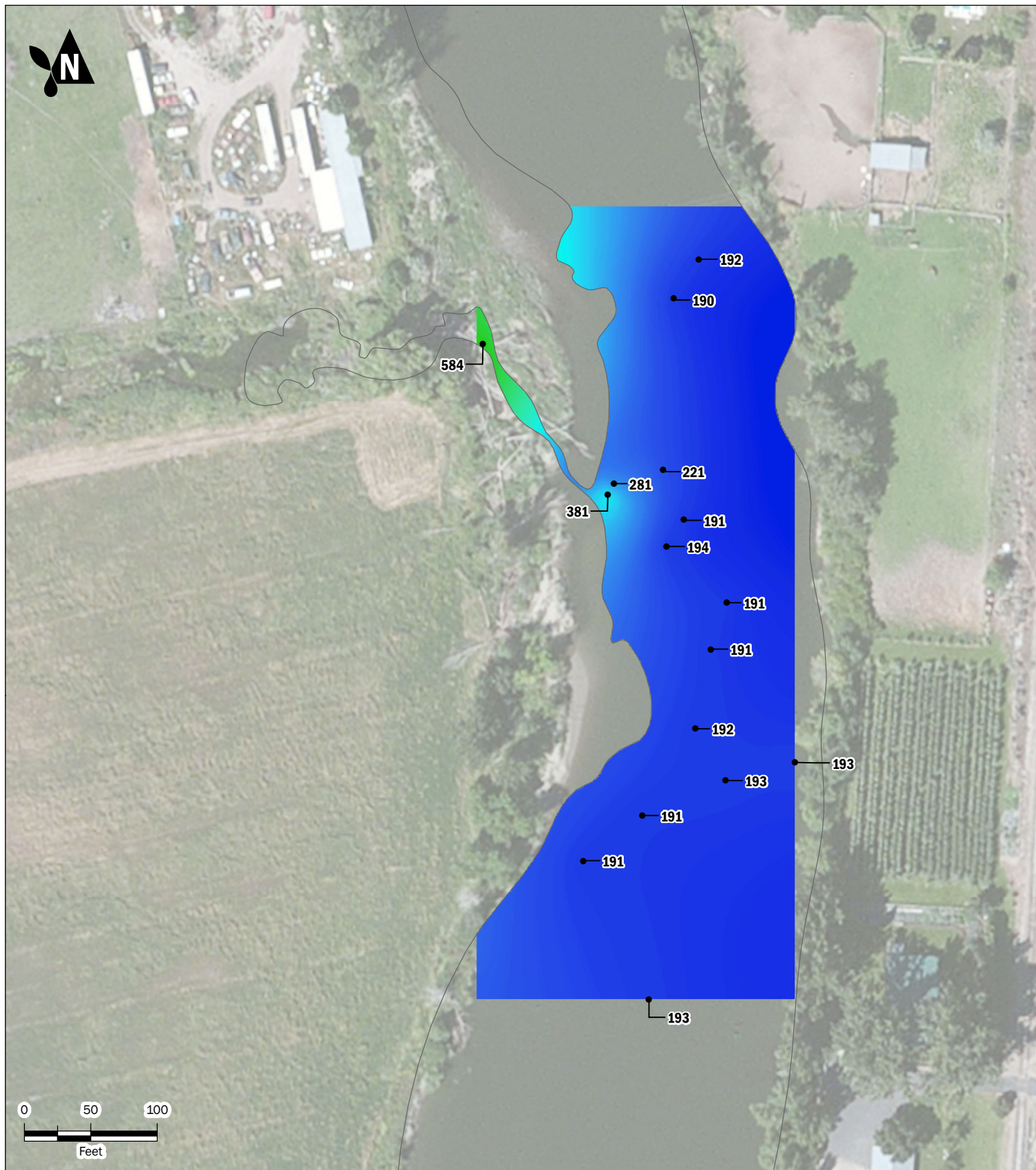
PROJECT NO.
110163-004

BY:
EWM / HRL

REV BY:

FIGURE NO.

6



High : 561.104

Low : 156.839

• Sampling Points
Deep Specific
Conductance ($\mu\text{S}/\text{cm}$)

□ Water Boundary

Note: At Station 23 and 21
conductivity was measured
at a shallower depth

Deep Stream Specific Conductance

Aeneas Creek Fish Habitat Enhancement Project
Colville Confederated Tribes, Washington



MAR-2013

PROJECT NO.
110163-004

BY:
EWM / HRL

REV BY:

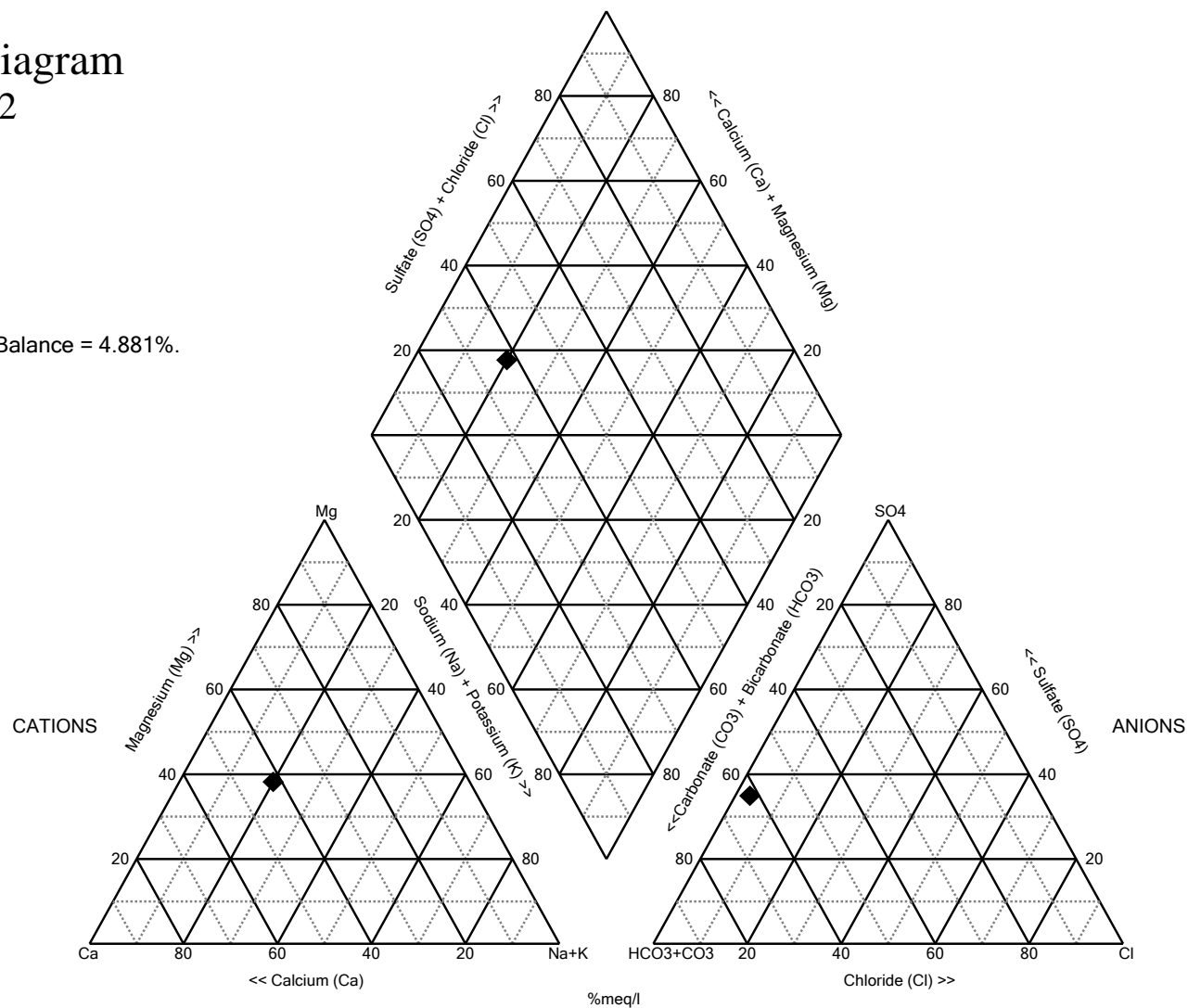
FIGURE NO.

7

Piper Diagram

8/14/2012

Cation-Anion Balance = 4.881%.



Analysis Run 2/26/2013 3:46 PM

Facility: Aeneas Creek Data File: Aeneas Creek Data

Figure 8

Trilinear Plot for Major ions in
Aeneas Creek

Aeneas Creek habitat Enhancement
Okanogan Basin, WA

APPENDICES A-C

Appendix A – Topographic Survey Exhibits (on CD)

Appendix B – Raw Data from Dataloggers (on CD)

**Appendix C – Analytical Results for Major Ions from
Aeneas Creek collected on August 14, 2012 (on CD)**

