Progress Report 2010-2011: Hangman Creek Fisheries Restoration

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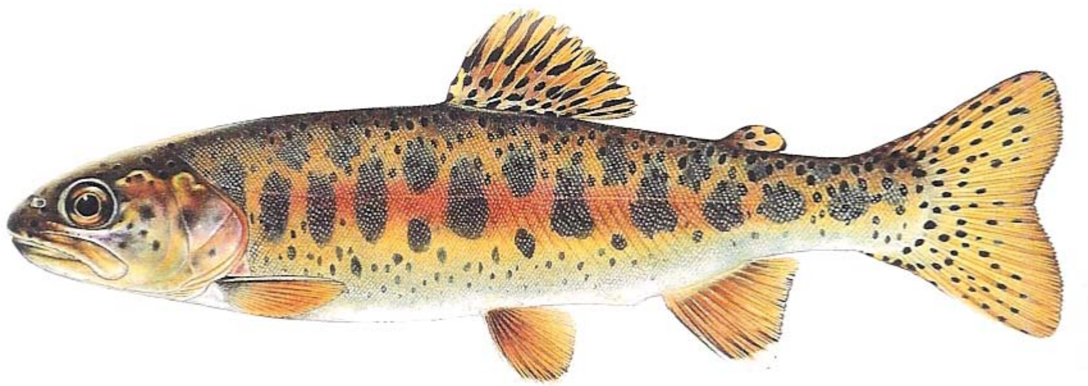

Redband trout (Oncorhynchus mykiss gairdneri)

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1. EXECUTIVE SUMMARY

The BPA project entitled "Hangman Creek Fisheries Restoration Project", which began in 2002, mitigates for lost fishery resources that are of cultural significance to the Coeur d'Alene Tribe. This project funds management actions, and research, monitoring, and evaluation (RME) activities associated with these actions, which are carried out by the Coeur d'Alene Tribe's Fisheries Program to recover populations of redband trout *(Oncorhynchus mykiss gairdneri)* trout in the Spokane basin. This report summarizes RME data collected during 2010-11 that describes the status and trend of redband trout in target sub-watersheds, water quality, hydrology, fish habitat assessments, as well as a summary of restoration projects and the physical and biological responses associated with them. RME was implemented on approximately 157,586 acres in the southern Hangman watershed upstream of the state line.

1.1 Fish Population Status Monitoring (RM&E)

Redband trout continue to be most prevalent in the upper forested reaches of the Hangman watershed during the timeframe when sampling occurs in the summer. These areas are confined to Indian Creek, upper Hangman Creek above the confluence of the SF Hangman, and the upper reaches of Sheep and Mission Creeks. The migrant trap data however suggests a number of fish, much larger than fish sampled during electrofishing surveys, are likely utilizing the mainstem of Hangman Creek as rearing habitat. Given this, we have determined the redband trout within the upper Hangman Watershed are exhibiting two dominate life-history traits. A resident form which is likely to inhabit a natal tributary for the entire portion of their life, and a fluvial form which rears in mainstem habitat and returns to natal tributaries to spawn during the spring. Trend analysis suggests a relatively stable abundance and distribution for the subpopulations residing in Indian Creek and the tributaries upstream of its confluence. The redband trout subpopulations residing in the more confined reaches of Nehchen, Sheep and Mission creeks, however show a high degree of inter-annual variability in abundance.

1.2 Tributary Habitat RM&E

Analysis of physical and chemical attributes have identified land management practices as the most likely contributor for a number of limiting factors for redband trout proliferation in Hangman Creek. Intensive dryland agriculture and upland timber harvest lead to a lack of canopy cover and an increase of erosion. Natural hydrologic processes are severely compromised by channel straightening and lack of protective vegetation resulting in high summer temperatures, high levels of fine sediments, lack of large wood recruitment, low dissolved oxygen levels, and a flashy hydrograph during peak flows coupled with extremely low baseline flows. Examples of these conditions was found in the fish habitat surveys during the reporting period where dramatic differences in all the limiting factors were found between forested reaches on Indian Creek and two tributaries, Tensed and Smith, which are dominated by agriculture practices in the riparian zone. Water quality and temperature monitoring yielded similar results as previous studies since 2002 where fine suspended sediments, turbidity, temperature, dissolved oxygen, and discharge are below acceptable standards for salmonids in reaches where the riparian zone is dominated by dryland farming or grazing.

Our RM& E efforts are designed to monitor these parameters and guide us to effective restoration methods. As beaver becomes an integral part of our restoration strategy, we seek to monitor their activity, limiting factors of their effective alteration of the existing natural processes, and the associated improvement of fish habitat. The improved fish habitat formed behind beaver dams in terms of, temperature reductions and pool formation illustrate the need to design restoration treatments that are supporting beaver. The beaver dam surveys indicate that building materials are lacking larger key pieces and made of mostly mud and grass. The initiation of a treatment to leave aspen cuttings where beaver are active is a direct result of this adaptive management.

1.3 Restoration Action Effectiveness Monitoring

Effectiveness monitoring was conducted in Indian Creek to assess changes in physical habitat metrics as well as a biological response associated with large woody debris (LWD) additions. Pre-treatment, the reach in Indian Creek was identified as an optimal rearing area for redband juveniles and resident adults, although pool habitat was highly limited, resulting in an abnormally low density of sampled trout. Post-treatment habitat surveys showed a dramatic increase in pool habitat as well as an increase in residual depth. As expected, fish densities responded accordingly in the treated reach, resulting in much higher annual densities as compared to the adjacent non-treated control reaches.

2. PROJECT BACKGROUND & STUDY AREA

2.1 Project Background

The Coeur d'Alene Tribe depended on runs of anadromous salmon and steelhead during aboriginal times, and centered their fishing activities along the upper reaches of the Spokane River and in Hangman Creek (Scholz et. al. 1985). It is generally acknowledged that the Coeur d'Alene People shared Spokane Falls with the Spokane People, but Hangman Creek at the confluence with the Spokane River and the fishing site near what is now Tekoa, Washington are recorded as being primarily used by the Coeur d'Alene People (Scholz et. al. 1985). Several estimates have been made of the amount of the anadromous fish resource that was consumed by the Coeur d'Alene People. These estimated annual per capita consumption rates for the Coeur d'Alene's ranged from 100 pounds per year to 700 pounds per year, with the average per capita for Plateau Tribes in general ranging from 300-365 pounds per year (Scholz et. al. 1985).

Construction and operation of the Federal and non-Federal hydropower system during the 20th century directly led to the complete extirpation of all anadromous and some resident fish populations as well as the permanent destruction of thousands of acres of critical fish and wildlife habitat throughout portions of the Upper Columbia River and its tributaries. Such is the case with Chief Joseph, Grand Coulee, and Albeni Falls dams as well as additional hydro facilities constructed along the Spokane River. Simultaneously, rapid changes in land management practices further altered the fish species composition in Hangman Creek and the availability of native terrestrial wildlife habitat (Edelen and Allen 1998). From the World War II era to the present, streams were straightened and channelized to provide more arable lands, with the greatest modifications occurring during the 1950s and 1960s. By 1996, the predominant (65.1%) use of the land within the Hangman Watershed on the Coeur d'Alene Reservation was agriculture, followed by forest (37.9%), grassland (0.2%), developed (0.3%) and wetland (0.006%) (Redmond and Prather 1996). Because of the land modifications to Hangman Creek, the watershed was listed in the Environmental Protection Agency's 303d list in 1998 for habitat alteration, sediment, nutrients, and bacteria. Moreover, tributaries to Hangman Creek within Idaho were also listed in 2002 for elevated levels of temperature.

To address the losses attributed to the establishment of the Federal Columbia River Power System (FCRPS), the Pacific Northwest Electric Power Planning and Conservation Act (Act) of 1980 explicitly gives the Bonneville Power Administration (BPA) the authority and responsibility "to protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries in a manner consistent with the program adopted by the Northwest Power Planning Council (NWPPC) and the purposes of this Act." The reduced capacity of the Hangman Creek Watershed to support native fish and wildlife and its historical importance to the Coeur d'Alene Tribe prompted the Coeur d'Alene Tribe to submit a resident fish substitution project proposal to the Northwest Power Planning Council to begin a coordinated effort to protect and restore fish and wildlife habitats along with the natural function of wetlands, riparian areas, and streams within the Project Area. The projects proposed were intended to restore the native resident fish to Hangman Creek to provide alternate subsistence resources for extirpated salmon. The *Hangman Restoration Project* (BPA Project #2001-033-00) was submitted in conjunction with this Project, *Implement Fisheries Enhancement on the Coeur d'Alene Indian Reservation: Hangman Creek* (BPA Project #2001-032-00). These proposals were submitted during the fall of 2000 for inclusion in the FY2001 – FY2003 budget cycle for the Spokane River Subbasin of the Intermountain Province. These projects were funded as part of the Bonneville Power Administration's commitment "to rebuilding healthy, naturally producing fish and wildlife populations by protecting and restoring habitats and biological systems within them" (Northwest Power Planning Council 2000a).

The primary goal proposed in the original project submittal included:

> Protect and/or restore stream habitats throughout the Hangman Watershed on the Coeur d'Alene Indian Reservation in order to support the restoration or reintroduction of native fish populations that are reduced from their original abundance.

This goal was to be attained through a stepwise process to:

- Conduct baseline investigations to determine native and resident fish stock composition, distribution, and relative abundance in the Subbasin by year 2010 (Priority 1) (Intermountain Province Subbasin Plan 2004).
- Describe biological, physical, and chemical attributes of habitat of Hangman Creek and its tributaries that either support or limit the distribution and abundance of native redband trout.
- Protect and enhance native redband trout populations by implementing habitat restoration measures
- Create a holistic approach to restoration through a public outreach program.
- Create a fishery to support traditional and recreational harvest.

The project began in 2002 with an initial coarse assessment of the spatial distribution of fish assemblages across the upper Hangman watershed, with a particular emphasis on delineating reaches where native and non-native salmonids were present and absent (Peters et al. 2003). Assessment of the watershed continued thru 2009 (Kinkead and Firehammer 2011 and 2012); with yearly water quality analysis that included discharge, TSS, turbidity, pH, conductivity, dissolved oxygen, nutrients, bacteria, and alkalinity; genetic analysis of salmonids; macro-invertebrates; an Instream Flow Incremental Methodology project; and Rosgen channel typing. In 2009 an assessment of fish passage was completed at three locations.

2.2 Study Area

Hangman Creek drains 430,000 acres of northern Idaho and eastern Washington. The study area consists of the portion of Hangman Creek watershed that lies within the Coeur d'Alene Reservation and east into the headwaters outside of the reservation (Figure 1). The Washington-Idaho State border, which corresponds to the border of the Coeur d'Alene Indian Reservation, marks the western boundary of the project area. The total acreage is 157,586 (Kinkead 2011), with 147,993 of that within the reservation. Elevations range from 754 meters in the northwest corner of the Project Area where Hangman Creek flows west into Washington to 1,505 meters at the top of Moses Mountain on the southeastern end of the Hangman/Coeur d'Alene Basin watershed divide. The named tributaries within the basin include Mission, Tensed, Sheep, Smith, Mineral, Nehchen, Indian, the SF Hangman and its' tributaries Conrad, Martin, and the upper part of Hangman Creek east of the Reservation along with its' named tributaries Hill and Bunnel. All of these tributaries were thought to be home to trout in the 1940's (Aripa 2003).

The climate in the Project Area is sub-humid temperate with cool, wet winters and warm, dry summers. Annual precipitation at DeSmet, Idaho for the years 1963-1983 was estimated to range from 70 to 90 cm (WRCC 2008). A distinct precipitation season typically began in October or November and continued through March. Approximately two-thirds of annual precipitation occurred during this period and rain-on-snow events generated by moisture laden Pacific air masses were common in late winter months (Bauer and Wilson 1983). Temperatures in the watershed are mild overall. The average daily maximum for August of the 1963-1983 reporting period was 82.2º F. The average daily minimum for January, which was the coldest month of the year, was 20.9º F. Snows in the lower elevations of the Study Area do not persist throughout the winter and in the higher elevations the snows are usually completely melted by April or May. Weather and land management practices such as tilling, tiling, grazing, riparian vegetation removal, stream channelization, logging, and road building have all contributed to stream sediment pollution and a flashy hydrologic cycle (Spokane County Conservation District 1994, Isaacson 1998). Rain-on-snow events in particular swell streams, contribute to the erosion of lands and cause a pulse of stream sediment pollutants (Bauer and Wilson 1983). The lack of an adequate wetland water storage capacity within the watershed results in little to no base flow during the dry season of August and September.

The original vegetation patterns within the Project Area included the eastern edge of the Palouse Steppe, mesic mountain forests, open woodland transition forests, (Bailey 1995, Lichthardt and Mosely 1997, Black et al. 1998) and wetland/riparian habitats (Jankovsky-Jones 1999). Currently the major vegetation coverage is agriculturally derived (Redmond and Prother 1996) and native habitats have been greatly altered to channel water off the landscape to facilitate agricultural production (Black et al. 1998, Jankovsky-Jones 1999). Forest habitat series' within the Project Area include western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), and ponderosa pine (*Pinus ponderosa*) (Cooper et al. 1991). White pine *(Pinus monticola)* cover type has been eliminated by a combination of harvest and white pine blister rust (Hagle et al. 1989, Maloy 1997). Since settlement of this region, the ponderosa pine and Douglas fir cover types have been greatly reduced, while grand fir, cedar and hemlock cover types have greatly increased (Gruell 1983).

Riparian/wetland plant communities within the Project Area can be divided into five general categories: coniferous forest, deciduous forest, deciduous shrub, graminoid wetlands (Jankovsky-Jones 1999) and camas marsh (Daubenmire 1988). The coniferous forest communities include mountainous riparian communities that are dominated by western red cedar, or mountain hemlock, with alder (*Alnus incana*) populating areas of disturbance from timber harvest. In the lower elevations, a mosaic of riparian communities exists directly from land management practices where the dominant native vegetation includes ponderosa, alder (*Alnus incana*), and hawthorne (*Cretaegus douglasii)*, along with invasive weeds, such as hawkweed (*Hieracium sp.*), reed canary grass (*Phalaris arundinacea*), and common tansy (*Tanacetum vulgare*). Other plants present in less than historical density include; aspen (*Populus tremuloides*) black cottonwood (*Populus trichocarpa*), red-osier dogwood (*Cornus sericea*), and willow (*Salix sp.*). The graminoid wetlands are dominated by grasses (*Agropyron*), sedges (*Carex sp*.) and various rushes (*Eleocharis, Glyceria, Juncus, Scirpus, and Sparganium*), and Camas (Camassia spp).

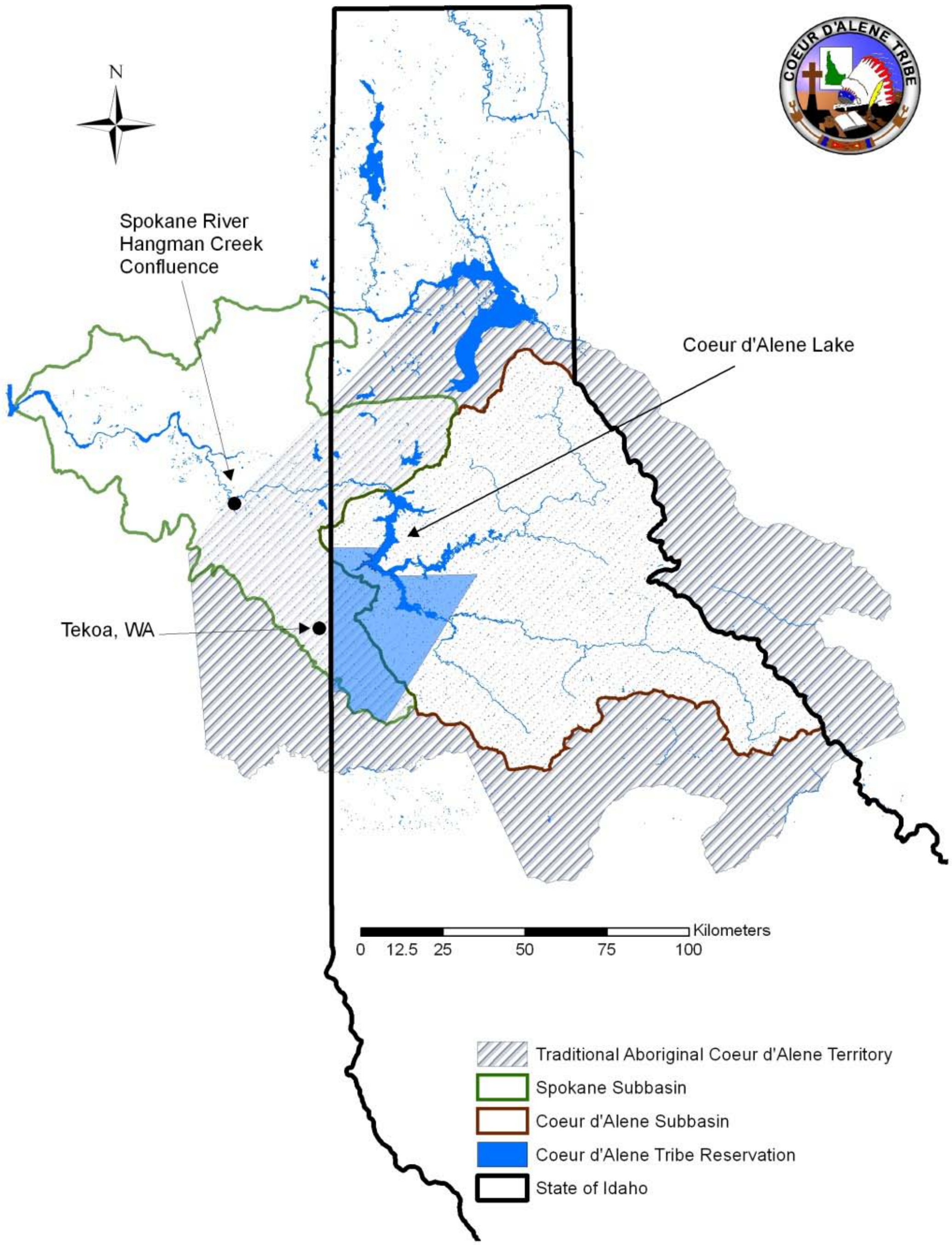


Figure 1. The aboriginal territory of the Coeur d'Alene People encompassed the Coeur d'Alene Subbasin and roughly half the Spokane Subbasin. The major fisheries sites for salmon and steelhead within the aboriginal territory included Spokane River and Hangman Creek. Major fishing sites in Hangman Creek were at the confluence with the Spokane River and near, what is now, the town of Tekoa, Washington.

3. INTRODUCTION to RM&E

3.1 Fish Population Status Monitoring (RM&E)

3.1.1 Status and trends of juvenile fish productivity in tributaries relative to habitat quality improvement targets

Fisheries assessments from 2002 - 20011 in Hangman Creek indicate distinct linkages between land management practices and the presence of salmonids. In land managed for timber production and small home sites, habitat includes medium to dense forest canopy, gravel and cobble dominated substrate, and temperatures conducive to salmonid spawning and rearing (Peters et al. 2003; Kinkead and Firehammer 2011, 2012). In valleys dominated by various agriculture practices, discharge, temperature, dissolved oxygen, excess fine sediments, and lack of canopy and instream complexity coincide with an absence of salmonids during summer rearing. These stream reaches however have been shown to have some value as migration corridors and possible fall and winter rearing. During summer rearing periods, salmonids are found in upper headwater streams where temperatures remain below 20 degrees C. Salmonids are rarely sampled in stream reaches where temperatures exceed this threshold for a significant amount of time. It is an important goal to improve habitat quality to facilitate movement between disconnected rearing habitats and increase both survival and growth across all stages of the life history for remnant populations of redband trout.

3.1.2 Status and trend of spatial distribution of fish populations

Assessment of the fisheries populations included a broad spatial sampling in order to determine distribution over the entire Hangman watershed within Idaho boundaries, and later was prioritized in 20005 to exclude the northern part of the watershed that was almost entirely devoted to dry-land farming. Though redband trout were present in annual sampling events in the upper Hangman Creek watershed during 2008-9 (Kinkead and Firehammer 2012), they were limited in their distribution to a few distinct tributary reaches. Redband trout were found in upstream forested reaches of Mission, Sheep, Indian, Hangman, and South Fork Hangman creeks, whereas downstream reaches in most of these tributaries, including the main-stem of Hangman creek, that were directly affected by agriculture were practically devoid of trout. Moreover, redband trout were found to be most widely distributed, albeit at low numbers in many of the sampled reaches in Indian Creek, a primarily forested sub-watershed. Fish distribution is further limited by the presence of barriers in Indian and Bunnel Creeks. One significant change in distribution of salmonids in the Hangman watershed during 2008-9 (Kinkead and Firehammer 2012) was the absence of any sampled cutthroat trout in upper Nehchen Creek where they had a constant presence in a small reach in the upper forested portion of the watershed. The negative trends since 1955 have been dramatic; resulting in a loss of 75% of the range of fish distribution in the watershed, which closely followed the removal of riparian canopy (Kinkead and Aripa 2005, unpublished data)

The lack of older age classes in the summer electroshock sampling further highlights the need for migration trapping in the watershed despite the low numbers of fish caught. A large portion of the fish captured in our migration traps were over 200mm in length, as in previous years (Kinkead and Firehammer 2011). The lack of large fish in the summer surveys but their presence in migrant traps could be attributed to seasonal differences in habitat use in the upper Hangman watershed. Large adults may be overwintering in deep main-stem habitat and then intercepted in traps during spring spawning migrations as they ascend tributaries. Further, post-spawn fish may then move back down into main-stem habitat as conditions in tributaries become sub-optimal during summer rearing periods. We intend to continue our trapping efforts to provide additional information regarding seasonal habitat use. Additionally, it is hoped that the use of VIE tagging initiated in 2009 will provide more information regarding exchange among sub-watersheds.

3.1.3 Status and trend of juvenile abundance and productivity of fish populations

Juvenile fish abundance in the upper Hangman watershed has shown the highest densities in the forested reaches within each subwatershed over the course of the project. This trend has remained relatively constant since summer electrofishing sampling was initiated in 2003. We have however observed a basin-wide increase in the abundance of redband trout within each forested subwatershed, with the exception of upper Nehchen Creek where no fish have been sampled since 2009 (Kinkead and Firehammer 2011, 2012). The highest and most stable abundances of redband trout have been present in Indian Creek and the subwatershed upstream, including upper Hangman and the SF Hangman Creek. These streams have a notable lack of dryland agricultural practices, and although forest harvest is extensive in these areas, riparian habitat has remained relatively intact. The recorded densities in these forested reaches of Hangman Creek compare very favorably to densities recorded in other regions that support redband trout (Zoellick et al. 2005, Dambacher and Jones 2007). The upper forested reaches of Sheep and Mission Creeks have continued to support redband trout, albeit in much lower densities than the aforementioned subwatersheds. The recorded density of trout in these two subwatersheds has also been much less stable from one year to the next. This level of fluctuation is consistent with isolated subpopulations of fish and wildlife throughout the natural world (Rockwood 2006, House 1995).

3.2 Tributary Habitat RM&E

3.2.1 Tributary habitat conditions that may be limiting achievement of biological performance objectives

Previous monitoring efforts in the Hangman Creek watershed (Peters et al. 2003, Kinkead and Firehammer 2011, 2012) have shown that much of the disparity in the distribution and density of redband trout among tributaries and among reaches within tributaries could be explained by the dramatic differences in the physical and chemical attributes that constituted habitat suitability in the upper Hangman watershed. Forested reaches in Indian Creek and in upper Sheep and

Mission creeks, where redband trout were commonly found, as well as upper Nehchen Creek where transplanted cutthroat trout have occurred, typically had a lower percentage of fines in surveyed riffle substrates, greater canopy cover, and more LWD than in other reaches, such as downriver reaches of Sheep and Mission creeks and main-stem reaches in Hangman creek, where agriculture predominated. In addition, summer temperature profiles, most likely related to the presence of canopy cover, were cooler and more suitable for incubation and rearing in upper forested reaches of monitored sub-watersheds than in downriver agricultural reaches. Migration barriers, whether seasonal or year-round, are limiting the connectivity of sub-populations and decreasing useable habitat for redband trout in Hangman Creek. Many of the forested watersheds have culverts that may be limiting access to spawning grounds for salmonids.

Channel forming processes were found to be highly impaired in the stream reaches managed for agriculture using Rosgen channel typing surveys during previous research. Deeply incised channels reduce the frequency of overbank flows and, as a result, impair normal functions of a stream-riparian ecosystem. The perched water table, which lays above clay soil layers, has become detached from the channel. Salmonid rearing habitat is limited in both the summer and winter due to a lack of deep pools along with a flashy hydrograph where frequent high flows contain TSS concentrations with sub-lethal effects. Habitat is further degraded by low summer discharge and concomitant low dissolved oxygen and high temperatures. The ability of beaver to reverse these detrimental effects to fish habitat and restore natural hydrological processes has resulted in new RME efforts tracking dam location, size, and materials, and associated fish habitat behind dams.

4. RM&E METHODS: PROTOCOLS, STUDY DESIGNS, & STUDY AREA

4.1 Fish Population Status Monitoring (RM&E)

4.1.1 Trout Abundance and Distribution during Summer Rearing Periods

Stream reaches were stratified into relatively homogeneous types according to broad geomorphologic characteristics of stream morphology, such as channel slope, channel sinuosity, valley width, and other physical habitat parameters. Stream reaches were further stratified by basin area to ensure that both mainstem and tributary habitats were represented in the stratification scheme. Sample locations within each stratum were randomly selected in proportion to the total reach length. The length of each sample unit was defined 200 feet. In addition, sample sites were chosen to monitor and evaluate ongoing and future restoration possibilities within the upper Hangman watershed.

Thirty three sites were electro-fished in the summer to quantify the abundance and distribution of fishes during the early stages of base flow conditions (Figure 2). Fish were sampled between June and July in order to survey stream reaches that are intermittent, as well as avoiding stress on fish in temperature limited reaches. These sites and the electrofishing methods were established in 2009 and were replicated in 2010. Trout populations were estimated using the removal-depletion method (Seber and LeCren 1967, Zippen 1958). Block nets were placed at the upstream and downstream boundaries to prevent immigration and emigration during sampling. Each sample site was electro-fished using the standard guidelines and procedures described by Reynolds (1983). Fish were stunned using a Smith-Root Type VII pulsed-DC backpack electro-fisher and then collected. Two electro-fishing passes were made for each sample site as the standard procedure. A third pass was conducted if the number of salmonids captured in the second pass was more than 50% of that captured in the first pass. In 2011, we transitioned into single pass electrofishing at the same established sites to monitor trends in trout populations. Block nets were still placed at the upstream and downstream boundaries of each transect. Captured salmonids, including redband and cutthroat trout, were identified, enumerated, measured (TL to nearest mm), and weighed (g). All fish 1+ and older were visually inspected for Visible Implant Elastomer (VIE) tags from previous sampling events. Trout without a VIE were tagged using four separate colors and marking either the left or right side of the fish for a total of 8 possibilities to track migration from any of the tributaries previously identified as fish-bearing, as well as three sections of the main stem of Hangman (Picture 1 &Picture 2). Other species such as longnose dace, redside shiner, longnose sucker, and sculpin (spp.) were considered incidental catch and were only counted.

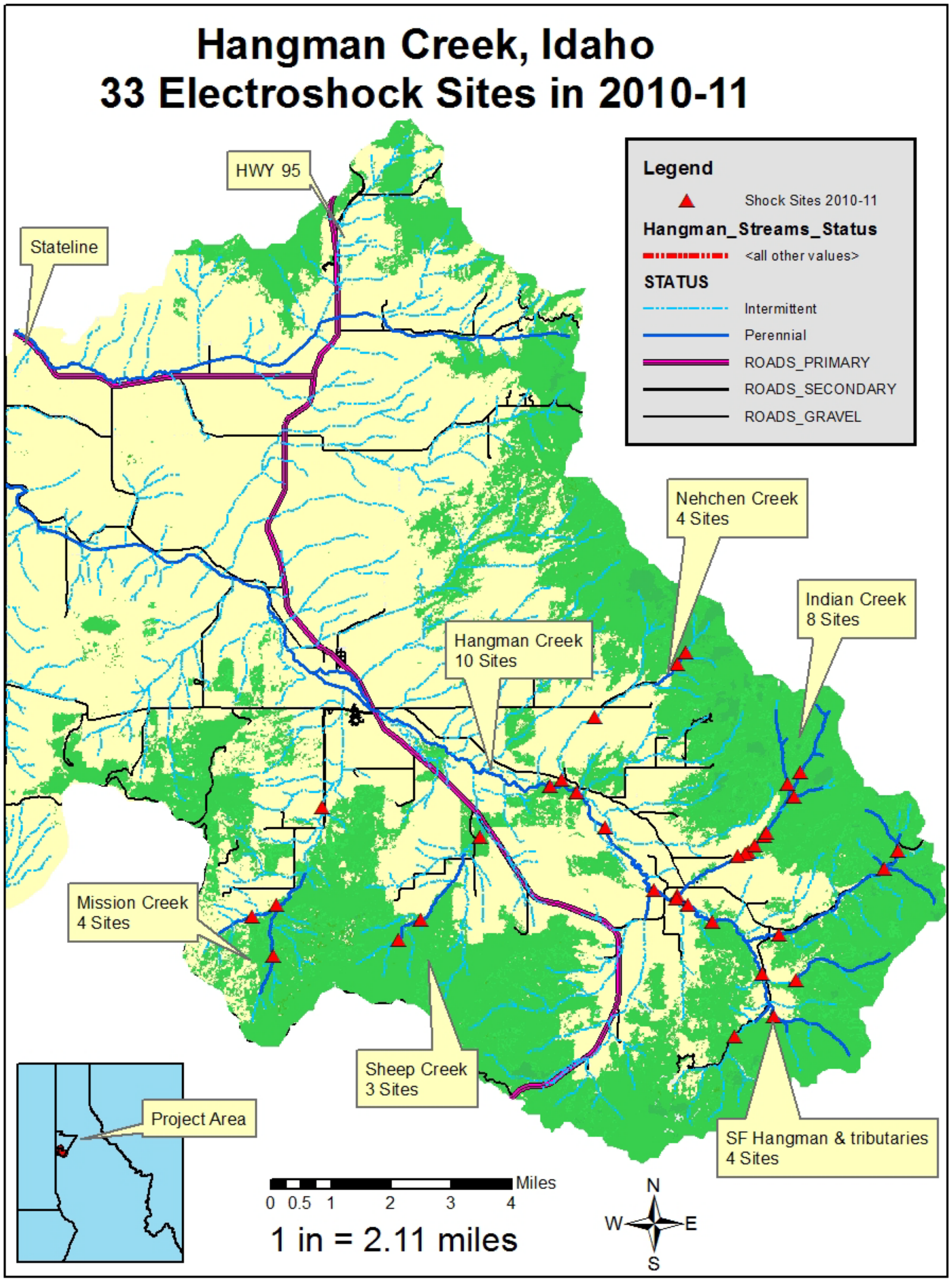
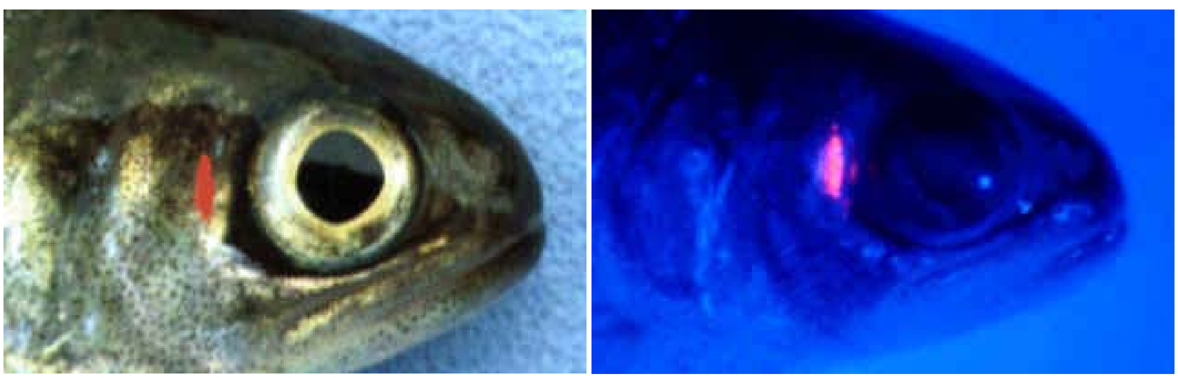


Figure 2. Electrofishing sample sites throughout the Hangman watershed 2010-11.

Picture 1. Processing of fish in 2008-9 consisted injection of Visible Implant (VIE) which were color and location coded to track an individual's movement in the watershed.



Picture 2. VIE tagged coho salmon (O. kisutch) smolt under ambient light and with UV light.

Index site abundances were estimated for fish considered at least one year of age (hereafter referred to as age 1+) separately for each salmonid species using the removal-depletion method (Zippen 1958; Seber and LeCren 1967). Site estimates were calculated using the following equation for two pass removals (Armour et al. 1983):

$$N = \frac{U_1}{1-(U_2/U_1)}$$

where:

N = estimated abundance;

U_1= number of fish collected in the first pass; and

U_2= number of fish collected in the second pass.

The standard error of the estimate was calculated as:

$$se(N) = \sqrt{\frac{M(1-M/N)}{A-\left[(2p)^2(U_2/U_1)\right]}}$$

where:

se(N) = standard error of the estimate;

M= $U_1 + U_{2;}$

A= $(M/N)^2$; and

p= $1-\frac{U_2}{U_1}$.

Abundance estimates when more than two passes were necessary were calculated using the following equation (Armour et al. 1983):

$$N = \frac{M}{1-(1-p)^t}$$

where:

N = estimated population size

M = sum of all removals ($U_1 + U_2 + \ldots.U_t$)

t = the number of removal occasions

U_i = the number of fish in the i^{th} removal pass

C = $(1)U_1 + (2)U_2 + (3)U_3 + \ldots..(t)U_t$

R = (C-M)/M

p = $(a_0)1 + (a_1)R + (a_2)R^2 + (a_3)R^3 + (a_4)R^4$

a_i = Polynomial coefficient from Table 8 (Armour et al. 1983).

The standard error was calculated as:

$$se(N) = \sqrt{\frac{N(N-M)M}{M^2 - \frac{N(N-M)(tp)^2}{(1-p)}}}$$

The approximate 95% confidence interval for the site abundance estimate was calculated as follows (Armour et al. 1983):

$$95\%CI = N \pm 2 * \sqrt{\text{var}(N)}$$

An analysis was conducted to determine the level of annual variability among mean densities within each subwatershed during summer electrofishing surveys. This variability was calculated by generating a coefficient of variation (CV). Due to the lack of sampling effort in 2007 and 2008, as well as the establishment of new electrofishing sites in 2009, two CV calculations were generated for each subwatershed; from 2003 to 2006, and for 2009 to 2011. The CV calculation was used as a comparison from one subwatershed to another, giving us a relative level of trout density variability over the time period(s) specified above. The CV was calculated using the following formula:

$$CV = \frac{\sigma}{\mu}$$

where:

$CV =$ the coeffiecient of variation
$\sigma =$ standard deviation of the mean density within each sampling period
$\mu =$ mean density over the entire sampling period

4.1.2 Indian Creek Stream-wide Abundance

Abundance within the entire Indian Creek watershed was calculated using electrofishing data from 2010 and 2011. Multiple pass electrofishing data was used to calculate the abundance for 2010. We used the output from a linear regression model, which compared the relationship between multiple and single pass electrofishing, to estimate the abundance for single pass electrofishing in 2011 using the following equation:

$$y' = mx + b$$

Where:

y' = Estimated abundance
m = x variable, or the slope of the line generated from the linear regression model
x = Number of fish caught in a single pass electrofishing survey
b = y-intercept generated from the linear regression model

Three watershed reaches were identified in Indian Creek. The reaches were stratified by land use, gradient, and dominate habitat type including riparian composition (

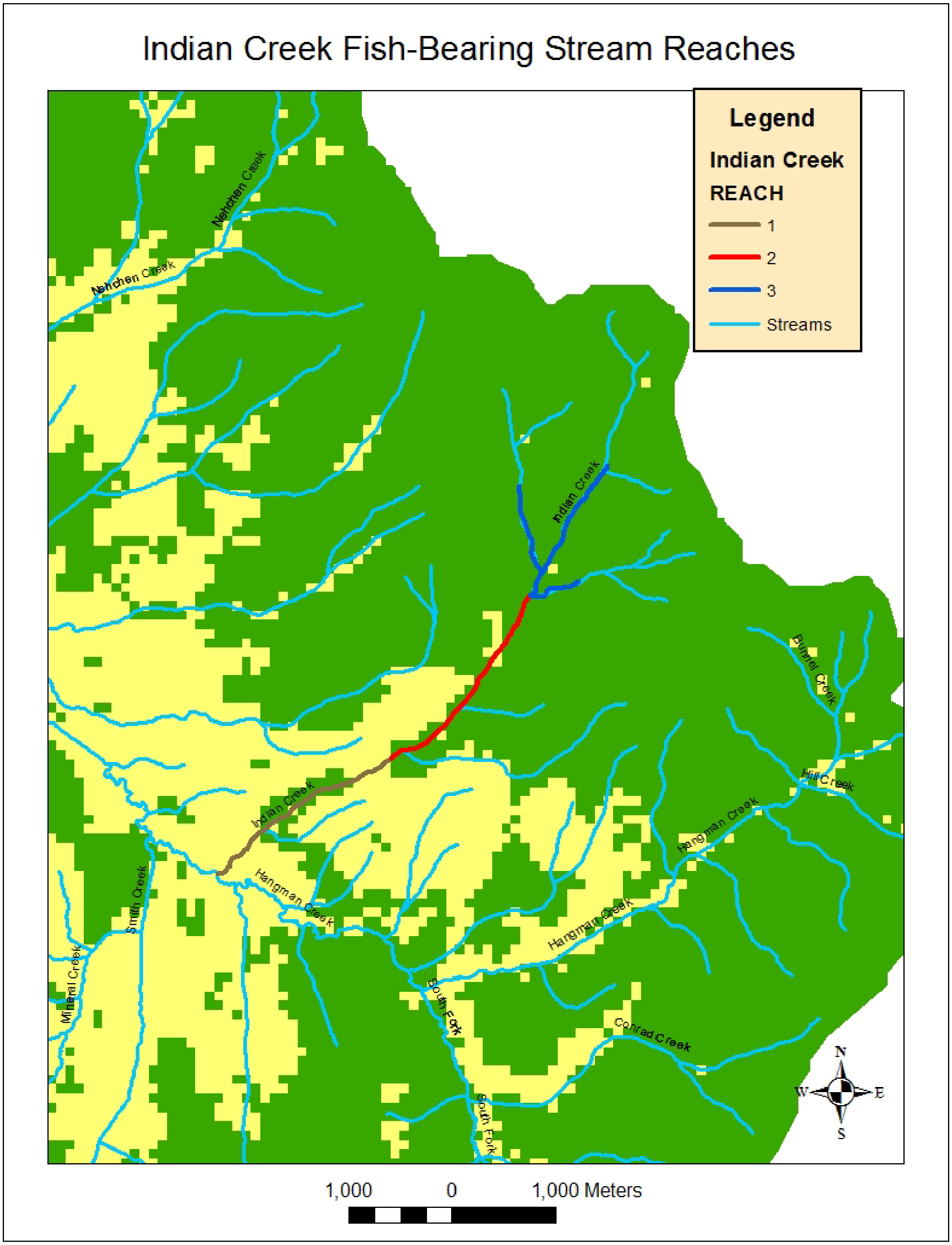


Figure 3). Abundance estimates for each reach were calculated using the following formula:

$$N_x = L(\frac{\sum n}{\sum l})$$

where:

N_x = Abundance in Reach (x)
L = Length of Reach (x)
n = Abundance estimate per site sampled in Reach (x)
l = Length of site sampled within Reach (x)

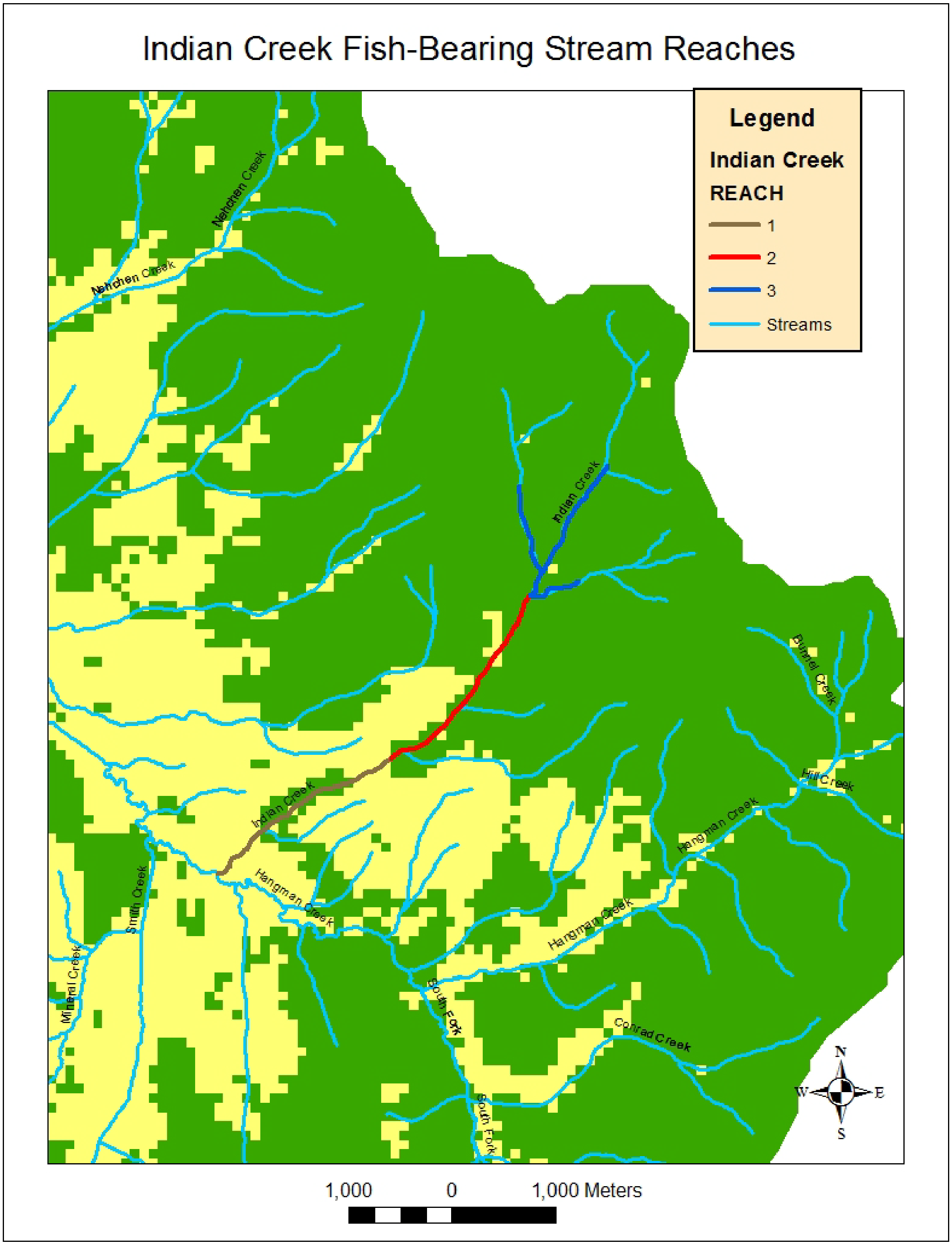


Figure 3. Stream Reaches identified in Indian Creek based on habitat type.

The standard error was calculated as the square root of the total variance:

$$se(N_x) = \sqrt{\left\{\left(\frac{L}{\sum l}\right)\left(\sum var(r)\right) + \left[\frac{\left(\left(\frac{L}{\sum l}\right)(t)\right)\left(\left(\left(\frac{L}{\sum l}\right)(t)\right)-t\right)\left(\sum varC(y)\right)}{(t)(t-1)}\right]\right\}}$$

where:

$\left(\frac{L}{\sum l}\right)\left(\sum var(r)\right)$ = Measurement Variance

and:

$\left[\frac{\left(\left(\frac{L}{\sum l}\right)(t)\right)\left(\left(\left(\frac{L}{\sum l}\right)(t)\right)-t\right)\left(\sum varC(y)\right)}{(t)(t-1)}\right]$ = Sampling Variance

where:

$\sum var(r)$ = Total variance among sites in Reach (x)
t = # of sites sampled within Reach (x)
$\sum varC(y)$ = Calculation used to generate sampling variance among fish densities at sampled sites within Reach (x)

where:

$$varC(y) = l^2(y_i - \hat{y})^2$$

and:

y_i = Density estimate at site i
$\hat{y}$ = Mean density within Reach (x)

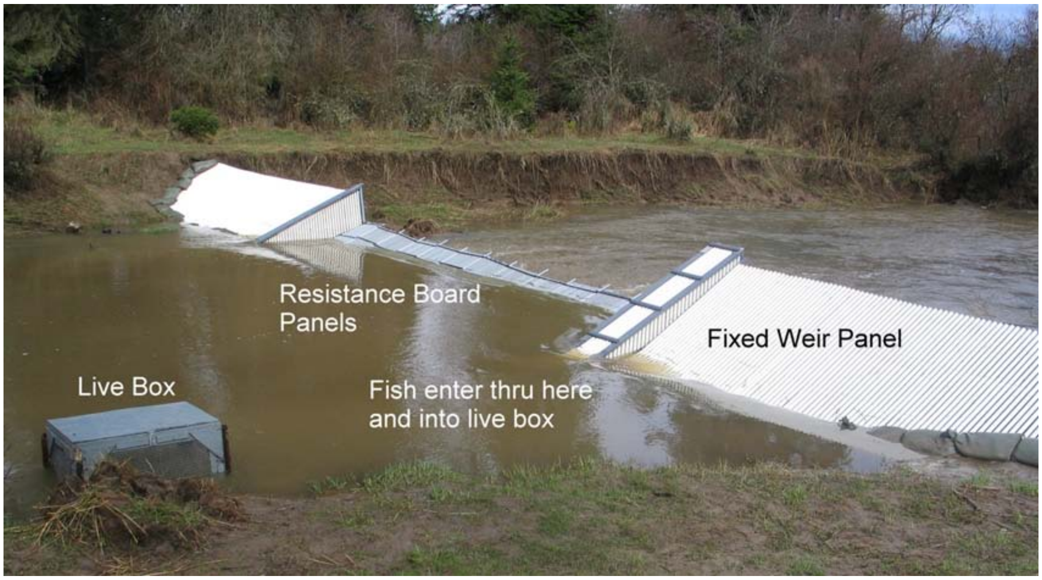
The total abundance for Indian Creek was then estimated by summing the abundance across all three reaches in Indian Creek.

4.1.3 Trout Migration

Migration traps were installed near the mouth of Nehchen and Indian Creek to assess migratory life history patterns, length and age frequency distribution, and relative abundance of migrating trout. In the past, both the feasibility of installing and maintaining traps and the ultimate efficiency of trapping efforts have largely been determined by the runoff patterns of the respective watersheds. In 2008 and 2009, the periodic, low duration peaks in the hydrograph related to rain-on-snow events and/or heavy rains generally resulted in very low trapping efficiency. In 2010 and 2011, trapping efforts were continually modified to improve trapping efficiency during these periods of high runoff. Traps were manually cleaned and repaired if necessary at least once a day to ensure proper function. Traps were installed March 1st and were monitored and maintained until June 22.

The design was a modification of the juvenile downstream trap used by Conlin and Tuty (1979). Traps consisted of a weir, runway and a holding box (Picture 3). Traps boxes were made by welding rebar, chicken wire, and aluminum sheet metal for the cover. The barrier fences were made from a combination of rebar/chicken wire with rebar hammered into stream banks for support. Paired upriver and downriver traps were placed approximately 10 meters apart and installed at each location to capture fish moving upstream from the main-stem of Hangman and fish moving downstream from the upper watershed, respectively. A resistance board weir, modified after the design used by Stewart (2002), was used to trap upstream migrants in the main-stem of Hangman Creek, and was located below the confluence of Nehchen Creek (Picture 4). The weir was built with spacing between the PVC pickets to accommodate the size of redband trout age 2 and older in Hangman Creek. Traps were checked and cleaned at least once daily during peak spawning periods from April through the mid-May. Fish captured in the traps were identified, counted, measured, and weighed. Fish were tagged in the same manner as in summer electroshocking. Based on internal scale analysis, all fish over 150mm in total length were recorded as adults, as this size was most likely to translate to at least a 3 year old trout (Firehammer and Kinkead, 2011). This is also consistent with what we have observed in the field and what others studies on interior redband trout have concluded (Cramer et al 1999, Muhlfeld 2002).

Picture 3. Standard upstream trap used at Nehchen and Indian Creeks.



Picture 4. Resistance Board Weir used in Hangman Creek from early March until mid June.

4.2 Tributary Habitat RM&E

4.2.1 Status Monitoring

4.2.1.1 Water Quality

Sample stations were spatially distributed to provide a representative coverage across the watershed using geomorphology, steam order, riparian and upland vegetation, and fish presence/absence as classification variables. Twenty-seven stations in the southern section of the Hangman Creek watershed were monitored for water quality during 2010-11, which included 11 primary and 16 secondary sample sites (Figure 4). Sampling was conducted during June and August to characterize the critical time frames of spawning and incubation, and baseline flows.. A complete list of sample site locations and water quality variables can be found in Appendices E and C, respectively. Temperature, dissolved oxygen, pH, and conductivity were monitored at each station using the YSI Model 556. Data was downloaded into the built in data logger, and transferred into excel format. Quality control was maintained through strict adherence to the standard operating procedures outlined in the YSI® manual (YSI Corporation 2004). Instrument calibration took place at the beginning of each day of monitoring. A calibration log was used to record the date and time of calibration, the analyst performing calibration, the calibration parameters, and other comments. At the end of the monitoring run, the instrument was checked for drift. All readings were recorded in the calibration log. All standards used for calibration were traceable to NIST Aqueous Electrolytic Conductivity Standard, or other comparable standards. Reagents used for calibration were accompanied by the following documentation:

manufacturer, lot numbers, expiration dates, and date opened. A logbook was kept which contains all information related to preparation of reagents and standards.

Water samples were also collected at each station for the analysis of various water quality variables that included total suspended solids (TSS) and turbidity. Samples were collected using a certified water collection device, and transferred to the appropriate containers for transportation to the contract laboratory. Transportation containers were specially cleaned and prepared by the contract laboratory.

4.2.1.2 Continuous Temperature Monitoring

HOBO temperature loggers (Onset Computer Corp.) were installed at 30 locations in 2010-11, and distributed across the upper Hangman Creek watershed to develop stream temperature profiles (Figure 5). In 2011, two additional loggers were deployed in the beaver pond and adjacent riffle around Sheep Creek Beaver Dam #73 to analyze the influence of beaver ponds on localized stream temperature. Loggers were typically deployed over the period from March/April to October and programmed to record water temperatures hourly (accurate to ± 0.6^{o}C). Loggers were downloaded on average two times a year. Daily minimum and maximum water temperatures were computed for each logger, and seven-day moving averages were calculated for each daily temperature metric.

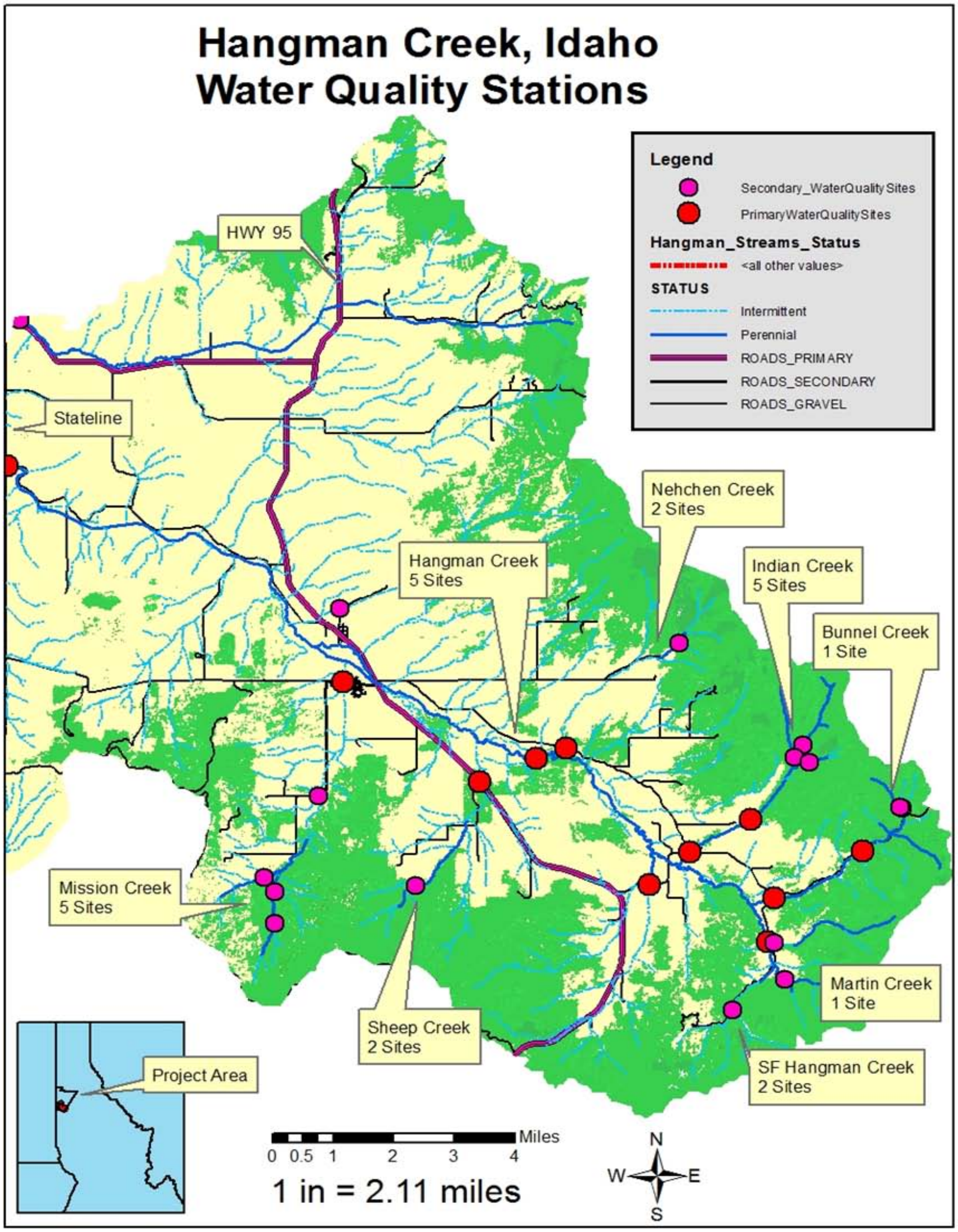


Figure 4. Water Quality Sites in the Hangman Creek watershed during 2010-11.

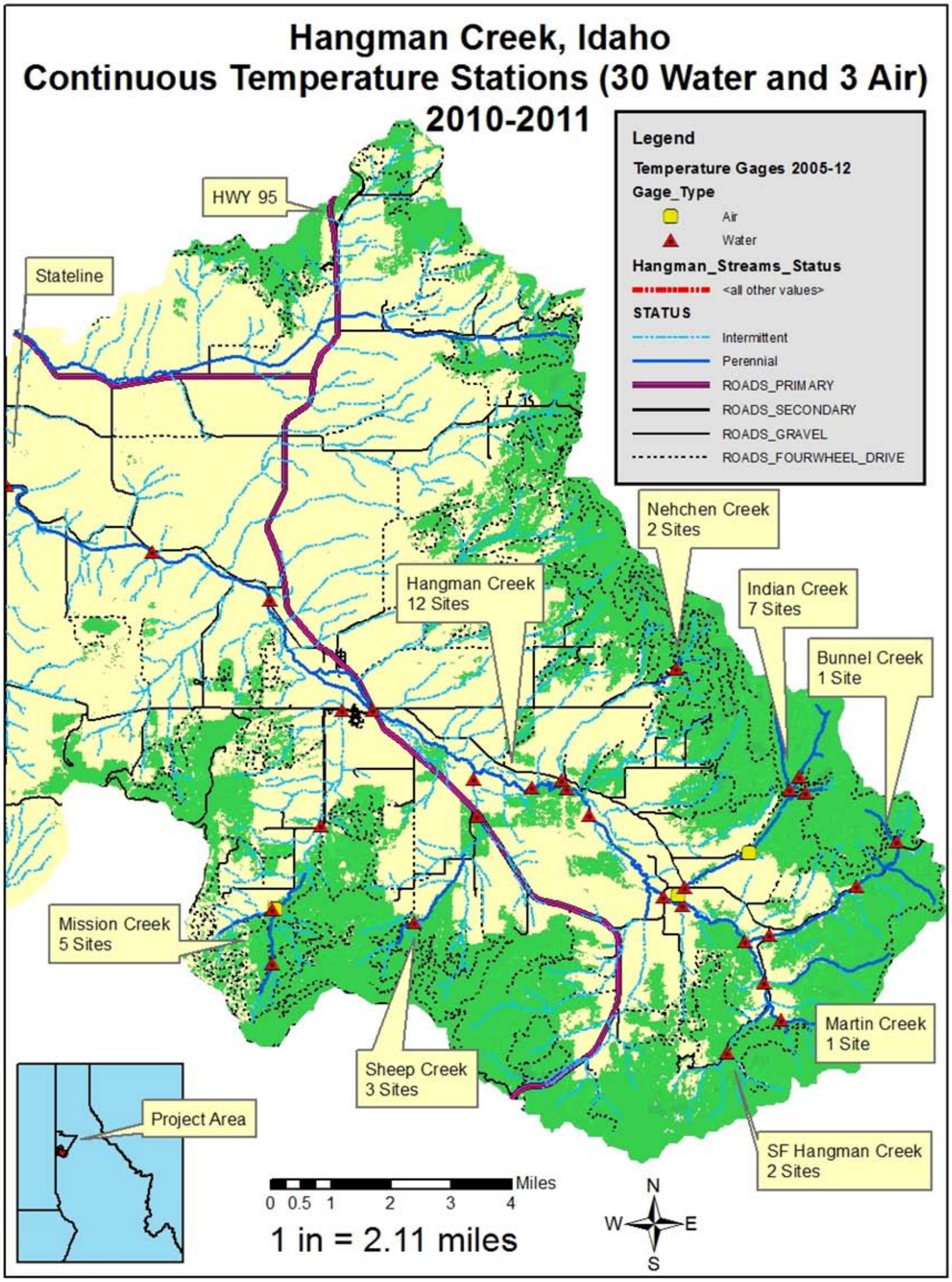


Figure 5. Continuous temperature monitoring sites in the Hangman Creek watershed during 2010-11.

4.2.1.3 Physical Habitat Assessment

In 2010 and 2011, intensive physical habitat metrics were obtained using methods based on the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO) developed by Kershner et.al (2004). Eleven sites throughout the upper Hangman watershed were surveyed for physical habitat attributes such as canopy cover, substrate composition, large woody debris volume, sinuosity, and pool habitat (Figure 6). Four of these sites were surveyed to evaluate the effectiveness of habitat restoration actions and are referred to below in section 4.2.2.1. The remaining seven sites within the study area were surveyed to gain an initial assessment of habitat parameters before potential restoration actions are to be implemented.

Upon arrival to the habitat assessment site, a 500 foot tape was attached near the water surface and spooled out along the thalweg until reaching the uppermost end of the transect. A random number between 0 and 50 was then selected for the first of ten cross-section locations for physical habitat measurements. The remaining nine cross-section locations were established at equal distances apart along the 500 foot stream survey reach, each location 50 feet from the previous. At each cross section location, wetted and bankfull stream widths were measured, along with stream habitat type, percent areal fish cover, percent bank erosion, and canopy cover.

Canopy Cover

Vegetative canopy cover (or shade) was determined using a conical spherical densiometer, as described by Platts et al. (1983). The densiometer determines relative canopy "closure" or canopy density, depending on how the readings are taken. This monitoring was only for canopy density, which is the amount of the sky that is blocked within the closure by vegetation, and this is measured in percent. Canopy cover over the stream was determined at each of the six cross sections established following the habitat typing survey. At each cross section, densiometer readings were taken one foot above the water surface at the following locations: once facing the left bank, once facing upstream at the middle of the channel, once facing downstream at the middle of the channel and once facing the right bank. Percent density was calculated collectively over these four readings, and then averaged over the ten locations at a site.

Channel Substrate

Substrate composition was measured at six randomly located sites within the 500 foot survey reach; two within pool tailouts, and 4 within riffles. 50 pebble counts were conducted at each site, equally distributed across the bankfull width of the stream. Particle size was determined as the length of the "intermediate axis" of the particle; that is the middle dimension of its length, width and height. At each point through the cross section, a measuring stick or finger was placed on the substrate and the one particle the tip touched was picked up and the size measured. Along with the measurement of the particle size, location within the cross section was also recorded as either wetted or dry.

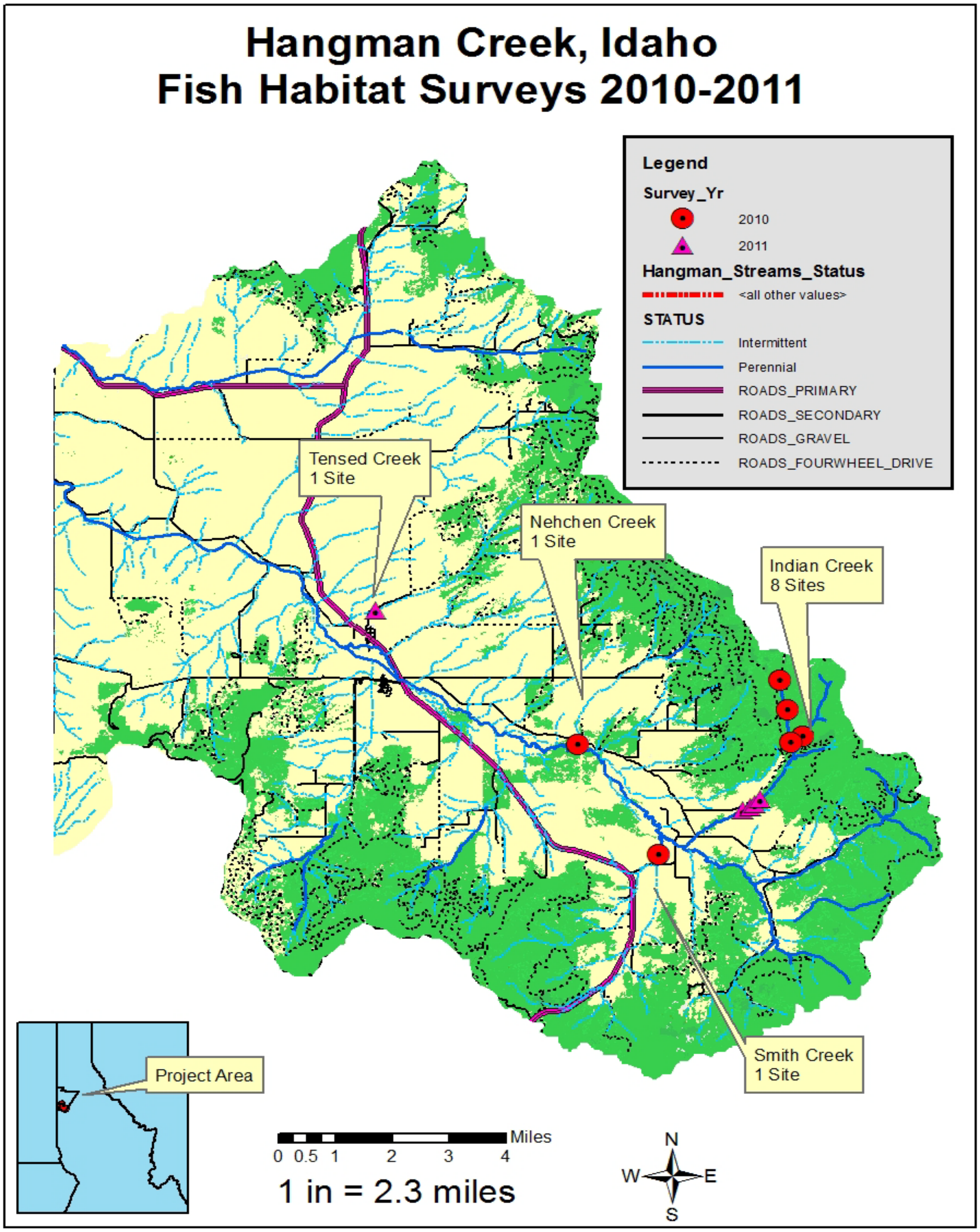


Figure 6. Physical habitat survey sites sampled during 2010-11 in the Hangman Creek watershed.

Large Woody Debris

This survey of monitored stream reaches was an inventory of the number and size of individual pieces of large woody material observed along a longitudinal transect through the reach. All woody debris greater than 4 inches in diameter and 4 feet in length that lay within the bankfull width was recorded. Tree root wads were tallied separately as these typically provide additional habitat benefits because of their size and complexity. For this protocol the definition of a root wad was that it was dead, that it was detached from its original position, that it has a diameter where the tree trunk meets the roots of at least eight inches and that it was less than six feet long from the base of the root ball to the farthest extent of the trunk (Schuett-Hames 1999).

Each transect was walked along the thalweg, starting at the downstream end of the reach. The first five pieces encountered along each transect were measured. Afterwards, diameter and length were estimated and measurements were taken at every fifth piece. Position and function were recorded for all LWD encountered along each transect. This included material that was suspended above the water surface and extended outside of the wetted stream width. The survey is not intended to include living trees or shrubs that hung over the water. Measurements taken of all LWD were the diameter at the center point (average diameter) and the total length of the piece over 4 inches in diameter. The number and total volume of LWD throughout the reach was calculated for each site (River4m, Ltd. 1999).

Pool Volume

Pools were identified by first measuring the depth at the downstream control point. The maximum depth of the pool was calculated from measuring the depth at the deepest point in the pool. If the maximum depth minus the minimum depth was greater than one foot residual depth, the habitat unit was classified as a pool. For each pool, three stream widths were measured: 1) half-way between maximum depth and the downstream end of the pool, 2) the point of maximum depth, and 3) halfway between the maximum depth and the upstream end of the pool. Three depth measurements were taken where each channel width was measured. Channel widths only included the portion of the channel where the water depth was greater than the minimum depth plus one foot. Pool lengths and stationing of each width location were collected so that a pool volume could be determined. In addition, information regarding the type of pool and the mechanism forming the pool was also collected. Pool forming mechanisms include boulder, wood, and other. Types of pools include dammed pools, scour pools, and other. The aim with this methodology is to examine the quantity and quality of pool habitats that can be used periods of low flow.

4.2.1.4 Beaver Dam Location and Attributes

Beaver dams were surveyed during the fall of 2010 and 2011 along a 4 mile reach of Hangman Creek (Nehchen Creek confluence to 0.5 m above Indian Creek confluence), a 0.5 mile reach of Mission Creek on Allotment 632, and a 0.5 mile reach of Sheep Creek on allotments A336/340.

These reaches were shown in the past to have beaver activity. Dams were downloaded onto GPS and dam morphology was recorded for each dam. Various attributes that described dam morphology and in-stream habitat influenced by the dam were measured and recorded at each dam surveyed. Dam morphology attributes included dam type, which indexed the apparent stability, complexity, and derelict state of the dam; the materials used to build the dam; and the dam width and height (Table 1). A subset of all dams located were selected based on dam size and location in the watershed to get a broad idea of the effects of dam building might have on the mainstem and two tributaries sampled. The in-stream habitat influenced by the dam was considered to be the channel length that was backwatered by the dam (i.e., the length of channel upstream over which water surface elevation did not change). Attributes evaluated along the backwatered channel length included the inundated surface area, pool surface area, pool volume, and mean residual pool depth. Inundated surface area was calculated by multiplying the backwatered channel length by the average of five wetted channel widths measured at equidistant intervals along the channel length. Pools were identified and measured along the backwatered length using the criteria and protocol described above (see *Pool Volume*). Pool lengths and their respective measured widths and depths were used to calculate the collective pool surface area and volume, and the mean residual depth for pools associated with each dam. In-stream habitat was only measured during the fall survey of 2010.

Table 1. Categories used to describe available dam types and dam-building materials. Active dams are considered those in which a presences of fresh material has been detected (e.g., green stems, recently placed mud).

Attribute	Categories
Dam type	Active single dam with large wood
	Active dam complex composed of multiple dams utilizing large wood and/or mid-channel islands
	Active single dam without large wood
	Inactive single dam with large wood
	Inactive dam complex composed of multiple dams utilizing large wood and/or mid-channel island
	Inactive single dam without large wood
Dam materials	Key pieces (> 4 inches in diameter; length >= bankfull width)
	Other large wood (> 4 inches in diameter)
	Large wood with root wad
	Small wood (< 4 inches in diameter)Herbaceous plant material
	Mud
	Other

4.2.2 Action Effectiveness

4.2.2.1 Physical Habitat Assessment in a LWD Treated Reach of Indian Creek

In 2010, two sites in Indian Creek were surveyed to evaluate the response of physical habitat metrics to implemented actions. These sites were compared to the habitat measurements obtained in 2004 at the same location to evaluate if measured responses were the result of the implemented restoration actions. In addition, two sites were also surveyed in control reaches to permit comparisons between treated and untreated reaches. These sites correspond with the electrofishing sites referenced in Figure 7.

4.2.2.2 Trout Abundance in a LWD Treated Reach of Indian Creek

In 2009 fish sampling using electroshock methods was set up with control/treatment pairs in order to evaluate effectiveness of large woody debris additions within reach 2 of Indian Creek. Indian 2.5 and Indian 2.7 electrofishing sites were established within this treated reach of Indian Creek, while Indian 2.3 and Indian 2.9 were established on either end of the treated reach and used as control sites (Figure 7). A repeated measures analysis was used to compare densities of redband trout between the treated and control sites in Indian Creek from 2009 – 2011. Densities from only the first pass of the multiple pass electrofishing surveys in 2009 and 2010 were used in this comparison.

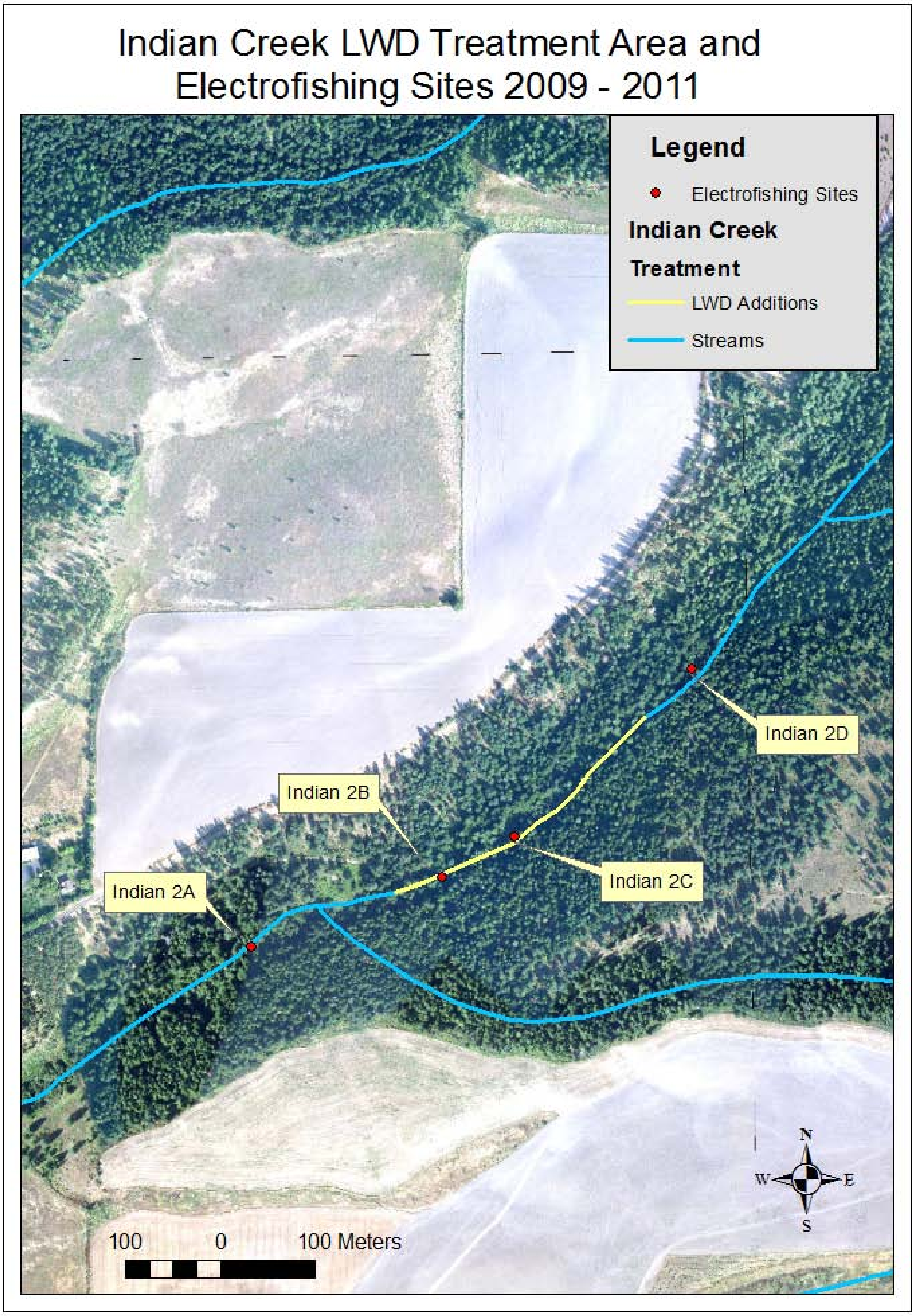


Figure 7. Habitat survey and electrofishing sites within and adjacent to the treated area of Indian Creek.

5. RESULTS

5.1 Fish Population Status Monitoring (RM&E)

5.1.1 Single and Multiple Pass Electrofishing Relationship

We used a simple linear regression analysis to compare the relationship of abundance estimates derived from multiple pass electrofishing and the number of fish caught in the first pass of these sampling events. This analysis was conducted in sampling events where 2 or more total fish were captured (Figure 8). The relationship was very strong, with R^2 values greater than 0.96. The linear regression model generated from this output is shown in appendix A.

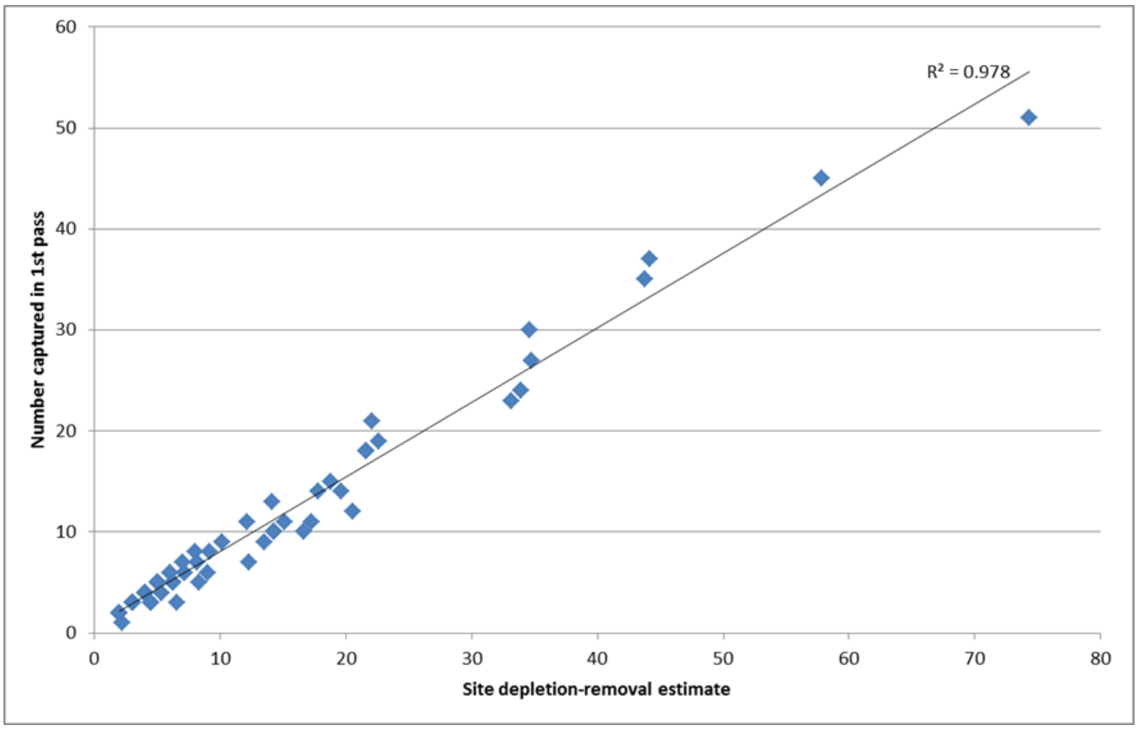


Figure 8. Relationship between redband trout captured during single and multi-pass electrofishing. This figure includes all sites where at least 2 total fish were captured.

5.1.2 Trout Abundance and Distribution during Summer Rearing Periods

Redband trout were primarily found throughout the upper forested reaches of the Hangman watershed. A total of 284 and 246 redband trout were captured in the first pass of electrofishing in 2010 and 2011, respectively, across 33 sites (Table 2 and Table 3). The highest mean densities of redband trout were found in upper Hangman Creek (73.8 fish/100m), Indian Creek (42.6 fish/100m), and upper Sheep Creek (34.4 fish/100m). Considerable densities of fish were also captured in the SF Hangman, Martin, and the WF Mission Creek. Densities of redband continued to be very low, or non-existent in lower reaches of Sheep and Mission Creek, mainstem reaches of Hangman Creek, and upper Nehchen Creek. Other species sampled included sculpin spp and temperature tolerant cyprinids such as redside shiners (*Richardsonius balteatus*) and speckled dace (*Rhinichthys oculus*). Speckled dace and redside shiners continued to dominate the seven most downstream reaches of Hangman, and the lowest sample site(s) in all of the tributaries.

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Table 2. Density estimates for redband trout throughout the Hangman Creek watershed based on multi-pass electrofishing in 2010.

Index Site	Passes	Total RBT Captured	RBT Estimate	RBT 95% CI	RBT density (fish/100 m)
		Hangman mainstem			
Hangman 1	3	1	1	1 - 1	1.6
Hangman 2	2	0	0	.	0.0
Hangman 3	2	1	1	1 - 1	1.6
Hangman 4	2	4	5	4 - 8	7.4
Hangman 5	2	1	1	1 - 1	1.6
		Indian Creek			
Indian 1	2	6	6	6 - 8	10.2
Indian 2	2	6	6	6 - 6	9.8
Indian 3	2	21	22	21 - 25	35.4
Indian 4	2	22	22	22 - 23	36.1
Indian 5	2	34	35	34 - 37	56.7
Indian 6	2	17	21	17 - 31	33.7
Indian 7	2	12	14	12 - 19	22.1
Indian 8	3	32	33	32 - 36	54.3
N.F. Indian 1	2	8	9	8 - 13	14.8
E.F. Indian 1	2	4	4	4 - 4	6.6
		Mission Creek			
Mission 1	2	0	0	0	0.0
Mission 2	3	6	7	6 - 10	10.7
Mission 3	2	0	0	0	0.0
W.F. Mission 1	2	4	4	4 - 4	6.6
		Nehchen Creek			
Nehchen 1	2	2	2	2 - 2	3.3
Nehchen 3	2	0	0	0	0
Nehchen 4	2	0	0	0	0
		Sheep Creek			
Sheep 1	2	1	1	1 - 1	1.6
Sheep 2	2	33	35	33 - 39	56.9
Sheep 3	2	10	10	10 - 10	16.6
		Upper Hangman Creek			
Hangman 6	2	12	12	12 - 13	19.8
Hangman 7	2	1	1	1 - 1	1.6
Hangman 8	2	67	74	67 - 84	121.8
Conrad 1	2	0	0	0	0.0
Martin 1	2	21	22	21 - 25	35.4
S.F. Hangman 1	2	17	18	17 - 21	29.2
S.F. Hangman 2	2	0	0	0	0.0

Table 3. Summary of redband trout captured during electrofishing surveys throughout the Hangman Creek watershed in 2010-11. 2010 data only includes fish captured in the first pass.

	2010		2011	
Index Site	**RBT Captured (1st pass only)**	**RBT density (fish/100 m)**	**RBT Captured**	**RBT density (fish/100 m)**
		Hangman mainstem		
Hangman 1	1	1.6	0	0.0
Hangman 2	0	0.0	1	1.6
Hangman 3	1	1.6	0	0.0
Hangman 4	3	4.9	4	6.6
Hangman 5	1	1.6	0	0.0
		Indian Creek		
Indian 1	5	8.2	6	9.8
Indian 2	6	9.8	3	4.9
Indian 3	18	29.5	16	26.2
Indian 4	21	34.4	14	23.0
Indian 5	30	49.2	22	36.1
Indian 6	12	19.7	10	16.4
Indian 7	9	14.8	12	19.7
Indian 8	23	37.7	22	36.1
Indian 9	3	4.9	8	13.1
N.F. Indian 1	6	9.8	8	13.1
E.F. Indian 1	4	6.6	3	4.9
		Mission Creek		
Mission 1	0	0.0	0	0.0
Mission 2	3	4.9	4	6.6
Mission 3	0	0.0	0	0.0
W.F. Mission 1	4	6.6	12	19.7
		Nehchen Creek		
Nehchen 1	2	3.3	5	8.2
Nehchen 3	0	0.0	0	0.0
Nehchen 4	0	0.0	0	0.0
		Sheep Creek		
Sheep 1	1	1.6	0	0.0
Sheep 2	27	44.3	15	24.6
Sheep 3	9	14.8	12	19.7
		Upper Hangman Creek		
Hangman 6	11	18.0	5	8.2
Hangman 7	1	1.6	3	4.9
Hangman 8	51	83.6	39	63.9
Conrad 1	0	0.0	0	0.0
Martin 1	18	29.5	18	29.5
S.F. Hangman 1	14	23.0	3	4.9
S.F. Hangman 2	0	0.0	1	1.6

The annual variation in mean density of trout within each subwatershed is described by the coefficient of variation (CV). From 2009-2011, the CV was highest in Mission, Sheep, and Nehchen Creek, and lowest in Indian and Upper Hangman. A similar pattern is also apparent from 2003-2006, with the exception of Mission Creek (Table 4). It should be noted however that trends in mean densities within Nehchen Creek may be skewed due to a limited sample size.

Table 4. Coefficient of variation for each subwatershed sampled during summer electrofishing in the Hangman Watershed. No sampling occured in 2007 and 2008.

	Coefficient of Variation	
Subwatershed	**2003-2006**	**2009-2011**
Mission	0.18	0.40
Sheep	0.79	0.31
Nehchen	1.20	0.98
Indian	0.32	0.08
Upper Hangman		0.17

5.1.3 Indian Creek Stream-wide Abundance

Indian Creek was estimated to have approximately 7.2 km of fish-bearing stream length. This portion of Indian Creek was separated by three distinct reaches at 2.0 km, 2.3 km, and 2.9 km in length. Mean density of age 1+ fish across both years was the highest in reach 2 at 36.1 fish/100m and the lowest in reach 1 at 9.2 fish/100m. Although reach 2 makes up just 32% of the total fish bearing stream length in Indian Creek, we estimate it supports on average over 61% of the age 1+ rearing redband trout.

Total variance, which included measurement and sampling variance, was consistently low in each year, resulting in tight confidence intervals around our total abundance estimate. Measurement variance, the variance calculated from density estimates derived from either multiple pass electrofishing or obtained from the linear regression model, accounted for only 0.2%, 1.3% and 2.1% of the total variance in 2009, 2010, and 2011, respectively. The total abundance estimates for each year were not significantly different from one another (Table 5).

Table 5. Abundance estimates of redband trout for the entire Indian Creek watershed in 2009, 2010, and 2011.

Reach	# Sites	2009 RBT Abundance	Total Variance	2010 RBT Abundance	Total Variance	2011 RBT Abundance	Total Variance
Lower	2	237.9	39885.5	193.2	23.8	169.4	3797.9
Middle	6	736.3	38101.5	901.0	12866.4	764.7	8793.9
Upper	3	155.0	5711.1	311.3	13842.4	373.3	10640.3
			95% CI		**95% CI**		**95% CI**
Total	11	1129.2	640 - 1618	1405.5	1129 - 1682	1307.4	1050 - 1565

5.1.4 Trout Migration

A total of 235 redband trout were captured in our migrant traps in 2010. 65 of the redband trout caught were classified as mature adults, of which 50% were deemed to be fluvial adults (200mm or larger). A total of 171 redband trout were captured in our migrant traps in 2011. 108 of the redband trout were classified as mature adults, of which 45% were deemed to be fluvial adults (Table 6).

Table 6. Summary of redband trout captured in migration traps in 2010-11.

		2010			2011		
Stream	**Trap Type**	**Total Fish**	**150mm+ (% Total)**	**200mm+ (% Total)**	**Total Fish**	**150mm+ (% Total)**	**200mm+ (% Total)**
Nehchen	UP	26	6(23)	4(15)	15	14(93)	4(26)
	DOWN	35	18(51)	7(20)	45	33(73)	25(55)
Indian	UP	18	12(66)	8(44)	26	19(73)	10(38)
	DOWN	151	25(16)	9(7)	82	39(47)	8(9)
Hangman	UP	5	4	4	3	3	1

Hangman Creek

In 2010, we captured a total of five redband trout, 4 of which were recorded as adults all larger than 244mm in length. These four fish were captured from April 18 – April 28. The trap was actively fishing approximately 90% of the time from February 12 – June 14. In 2011, we captured a total of three redband trout, all recorded as adults. However, two of these fish barely met the minimum size requirement of 150mm. The last fish was recorded at 357mm in total length, the largest redband trout we have actively captured in the Hangman watershed. This fish was captured on April 20th. Due to the prolonged period of high spring runoff and over-bank flows in 2011, the trap was actively fishing for approximately 70% of the time from February 15 – June 16.

Nehchen Creek

In 2010, we captured a total of 26 redband trout in the upstream migration trap and 35 in the downstream migration trap. Catch in the upstream trap included 6 adults, 4 of which were 203mm – 215mm in length. All of the redband trout classified as adults were caught from May 11 – June 21. There were no recapture events in the upstream trap in 2010. The upstream migration trap was actively fishing for approximately 90% of the time from February 23 – June 24. Catch in the downstream trap included 18 adults, 7 of which were 205mm – 231mm in length. The majority (97%) of the juveniles and sub-adult redband trout were captured from May 13 – June 21 (Figure 10). Twelve of the redband trout were recaptured fish tagged in lower Nehchen Creek, either from previous trapping episodes or from summer electrofishing. The downstream migration trap was actively fishing for approximately 90% of the time from March 26 – June 24.

In 2011, we captured a total of 15 redband trout in the upstream migration trap and 45 in the downstream migration trap. Catch in the upstream trap included 14 adults, 4 of which were 215mm – 236mm in length. All of the redband trout classified as adults were caught from March 29 – June 8. There were no recapture events in the upstream trap in 2011. The upstream migration trap was actively fishing for approximately 80% of the time from March 8 – June 22. Catch in the downstream trap included 33 adults, 25 of which were 200mm – 273mm in length. All of the juveniles and sub-adult redband trout were captured from June 3 – June 24 (Figure 10). Four of the redband trout caught in the downstream trap were recaptured fish, two of which were tagged in Nehchen Creek and the other two tagged at the Hangman Creek migration trap. The downstream migration trap was actively fishing for approximately 90% of the time from May 27 – June 24.

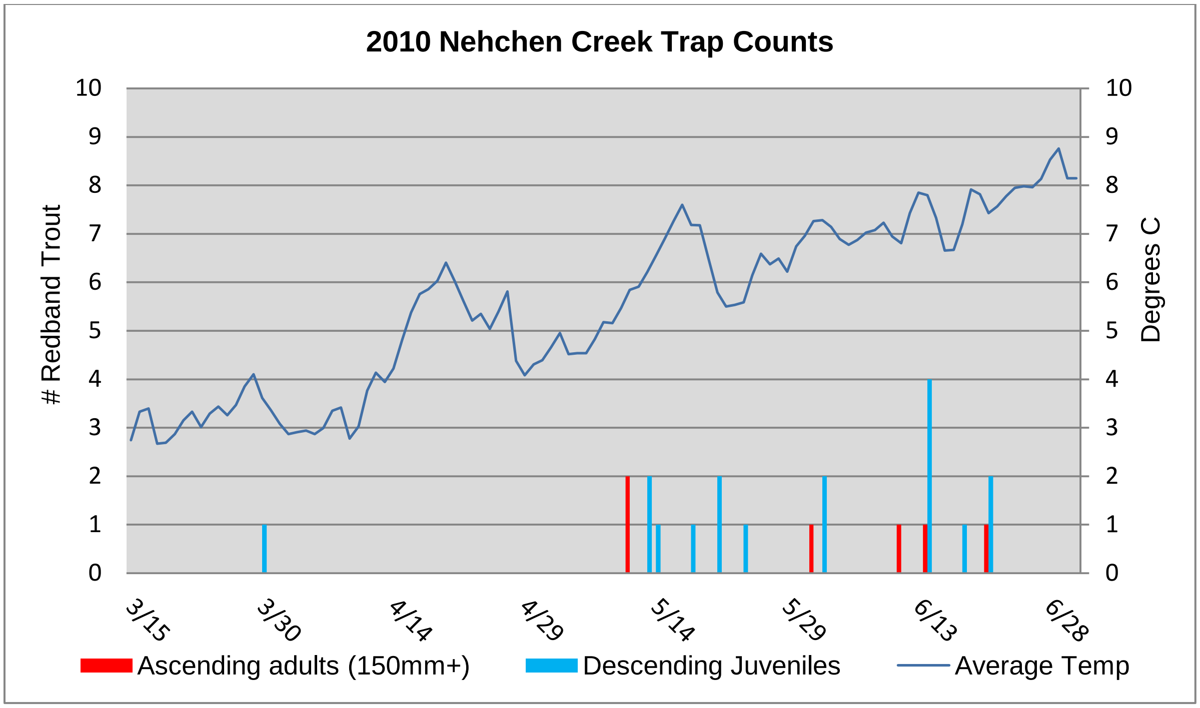

Figure 9. Nehchen Creek trap trap counts of redband trout with average daily temperature showing timing of ascending adults and descending juveniles in 2010.

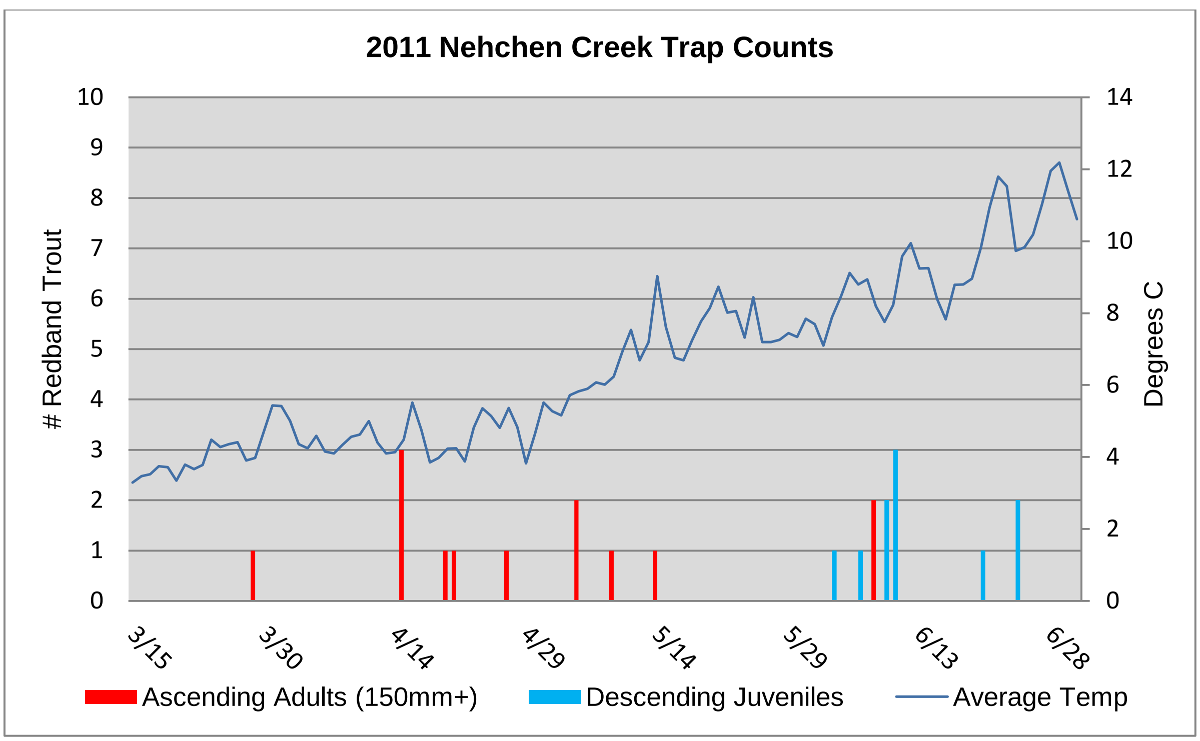

Figure 10. Nehchen Creek trap counts of redband trout with average daily temperature showing timing of ascending adults and descending juveniles in 2011.

Indian Creek

In 2010, we captured a total of 18 redband trout in the upstream migration trap and 151 in the downstream migration trap. Catch in the upstream trap included 12 adults, 8 of which were 201mm – 273mm in length. All of the redband trout classified as adults were caught from April 19 – June 1. There were no recapture events in the upstream trap in 2010. The upstream migration trap was actively fishing for approximately 90% of the time from February 24 – June 24. Catch in the downstream trap included 25 adults, 9 of which were 200mm – 318mm in length. All of the juveniles and sub-adult redband trout were captured from April 19 – June 21 (Figure 11). 16 of the redband trout were recaptured fish tagged Indian Creek, either from previous trapping episodes or from summer electrofishing. The downstream migration trap was actively fishing for approximately 90% of the time from April 16 – June 24.

In 2011, we captured a total of 26 redband trout in the upstream migration trap and 82 in the downstream migration trap. Catch in the upstream trap included 19 adults, 10 of which were 201mm – 283mm in length. All of the redband trout classified as adults were caught from April 24 – June 20. There were 6 recapture events in the upstream trap in 2011, all of which were tagged in Indian Creek from prior trapping events or summer electrofishing. The upstream migration trap was actively fishing for approximately 80% of the time from April 23 – June 22. Catch in the downstream trap included 39 adults, 8 of which were 204mm – 267mm in length. All of the juveniles and sub-adult redband trout were captured from May 16 – June 22 (

Figure 12). Fourteen of the redband trout caught in the downstream trap were recaptured fish, 13 of which were tagged in Indian Creek and the other tagged in Nehchen Creek. The downstream migration trap was actively fishing for approximately 90% of the time from May 13 – June 24.

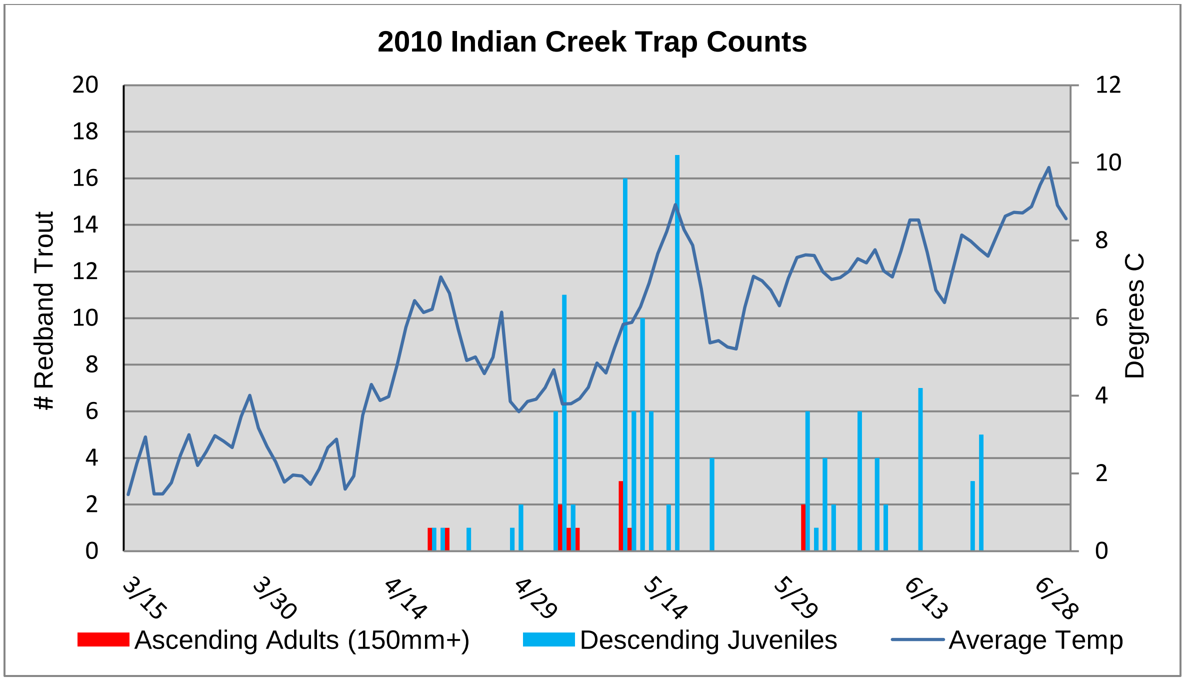

Figure 11. Indian creek trap counts of redband trout with average daily temperature showing timing of ascending adults and descending juveniles in 2010.

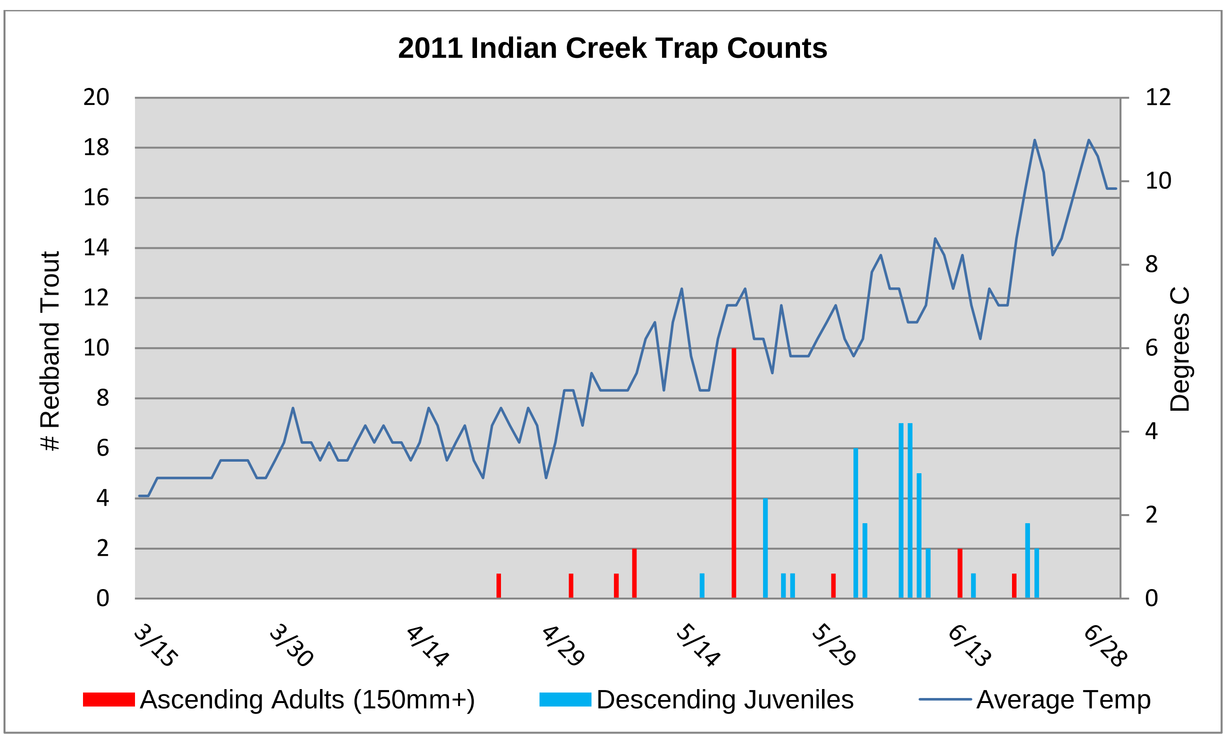

Figure 12. Indian Creek trap counts of redband trout with average daily temperature showing timing of ascending adults and descending juveniles in 2011.

5.2 Tributary Habitat RM&E

5.2.1 Status Monitoring

5.2.1.1 Water Quality

Measured levels of discharge during baseline flow conditions were dramatically different among tributaries sampled in the upper Hangman Creek watershed over the reporting period (Table 6). In the lowermost reaches in Indian Creek, measured discharge exceeded 0.27 cfs (range 0.27 – 0.40cfs) in each of the two monitoring years; values were relatively lower in two of the three assessed reaches in the three upper forks of Indian Creek, but never were there only standing pools or a lack of water. The North Fork of Indian had the highest discharge of the three at 0.25 and 0.14 over the monitored timeframe. The uppermost forested site in Hangman Creek (i.e., Hangman-Forest) also exhibited higher base-flow discharge values with 0.14 and 0.40 cfs for 2010 and 2011. Mission Creek had a comparatively lower discharge showing at or lower than 0.01 cfs at all of the five sample sites in 2010 and at or lower than 0.06 cfs for all sites during 2011. Sheep Creek was almost dry (0.01cfs) in 2010, but had a higher base flow in 2011 of 0.11cfs. Nehchen Creek was completely dry by late July in both years. Field notes indicate additional timber harvests in the Nehchen Creek watershed in 2010. All of the remaining sample sites upstream of the Coeur d'Alene Reservation show some discharge, with upper South Fork Hangman dry by August.

Tributary differences in dissolved oxygen measured during baseline conditions in 2010-11 in the upper Hangman watershed displayed similar patterns as that described for discharge (Table 7). In all monitored reaches in Indian Creek and in the uppermost forested site in Hangman Creek, dissolved oxygen never was found to fall below 6.9 mg/L. Dissolved oxygen measured in the only wetted reach in Nehchen Creek also exceeded this value in 2009. Conversely, dissolved oxygen was found to drop below 6.0 mg/L in at least one of the monitored reaches in Mission, Sheep, and South Fork Hangman sub-watersheds, and in the lowest main-stem site in Hangman Creek. As expected, low dissolved oxygen was often associated with low levels of measured discharge in these reaches.

Other water quality data, such as pH, conductivity, and turbidity were collected during 2010-11, during June and August. From 2010 to 2011, pH values typically ranged from 6 to 7.5, which suggest that pH is not a limiting factor in the upper Hangman Creek watershed (Appendix C).

Table 7. Summary of dissolved oxygen and discharge in Hangman Creek during 2010-11

	2010		2011	
Site	DS (cfs)	D.O. (mg/L)	DS (cfs)	D.O. (mg/L)
Hangman				
Hangman-Stateline	<0.3	3.14	0.45	4.16
Hangman-Buckless	0.23	6.26	0.35	5.60
Hangman-SF Road	0.07	6.74	0.40	7.20
Hangman-Forest	0.14	8.10	0.40	8.56
Mission				
Mission-Desmet	0.00	0.00	0.06	0.95
Mission-KVR	0.01	3.90	0.04	4.17
MF Mission	0.01	7.55	0.03	7.62
EF Mission	0.00	0.00	0.00	5.84
WF Mission	0.01	4.17	0.01	6.20
Sheep				
Sheep-HWY 95	0.01	4.34	0.11	3.42
Upper Sheep	0.07	8.16	0.04	8.55
Nehchen				
Lower Nehchen	DRY	0.00	DRY	0.0
Upper Nehchen	0.05	7.82	0.04	8.38
Smith				
Smith	DRY		DRY	0.00
Indian				
Indian-Sanders	0.32	7.87	0.40	8.04
Indian-Pow Wow	0.27	8.93	0.36	9.08
MF Indian	0.06	7.48	0.14	7.72
NF Indian	0.25	9.61	0.16	10.23
EF Indian	0.03	7.85	0.05	8.19
SF Hangman				
Lower SF Hangman	0.08	5.30	0.12	5.41
Upper SF Hangman	DRY	0.00	0	0
Martin	0.10	6.07	0.10	6.33
Upper Hangman Tributaries				
Bunnel	0.08	8.25	0.03	9.08
Parrot	0.01	6.34	0.02	7.08

5.2.1.2 Continuous Temperature Monitoring

Temperature profiles in the Hangman watershed exhibited a distinct difference between sampling locations in agriculturally dominant reaches and in forested upper reaches of fish-bearing tributaries (Table 8 - Table 9).There was no appreciable difference between the years. Generally temperatures exceeded both spawning/incubation and rearing thresholds a much greater percentage of the time as recorded in hours within lower non-forested sites than in upriver forested sites within the mainstem of Hangman at RM 12.2 and below and in Mission and Sheep Creeks. Moreover, in monitored years of 2010-2011, upper forested sites in each of these five sub-watersheds only had one minimal example of exceedance over the established threshold values. When considering all sites in aggregate within a monitored subwatershed, Indian and Nehchen creeks displayed cooler temperature profiles than Mission and Sheep creeks in the upper Hangman Creek watershed. Temperature thresholds are more commonly exceeded during rearing timeframes, occurring 12 of 14 samples in the lower reaches of Hangman Creek leading up to RM 12.2. In contrast, upper sections of Hangman Creek and all the tributaries with increased canopy show the threshold temperature levels are more commonly exceeded during the spawning timeframe.

Temperatures monitored in the mainstem of Hangman show that the reach at RM 14.8 as key to where temperatures begin to rise significantly. Temperatures exceeded threshold values collectively over spawning/incubation and rearing timeframes at less than 2% of the hours recorded at RM 14.8 in both years recorded. However, for reaches downstream of RM 14.8, values ranged from 19% - 38% of the hours recorded in 2010 (Table 8), and from 13% - 33.74% in 2011 (Table 9). From RM 14.8 to the headwaters the temperature thresholds were exceeded < 2% overall in 2010, and < 3% in 2011.

Differences between subwatersheds indicate Indian Creek and Nehchen are the least thermally impaired of the four fish bearing tributaries within tribal boundaries, with Sheep and especially Mission being the more thermally impaired. Overall temperatures in 2010 exceeded thresholds at Mission Creek RM 0.4 (20.09%), Sheep RM 0.0 (17.83.52%), and Indian Creek RM 0.3 (0.07%). Temperatures were lower in 2011 with overall temperature exceedance at Mission RM 0.4 (18.98%), Sheep RM 0.1 (5.49%), and Indian RM 0.3 (0.31%). Nehchen Creek maintained temperatures never exceeding thresholds up until discharge reaches zero in mid July in both 2010 and 2011.

Temperatures rising and falling along the longitudinal profile of Hangman Creek reflect the influence of canopy, and or, ground water inputs in the mainstem and tributaries. In the mainstem of Hangman temperature exceedance levels showed moderate increases up to RM 14.8, with one area of decreasing temperatures at RM 15.9 which is next to a forested hill. Below RM 14.8 temperatures dramatically increase as shown in the ever increasing exceedance percentages (Table 8 and Table 9). Temperature monitoring devices were continually vandalized at RM 16.9 where temperature is normally slightly higher than RM 18.5 and therefore a gap in the longitudinal profile. Similar results in Mission Creek during 2010-11 show an abrupt increase in temperatures as the threshold exceedance percentages for spawning and rearing went from 0.0% at RM 4.8 to 28.07% at RM 0.4 (Table 8), and a similar increase in 2011 of 0% - 18.98%. We also graphed the 7-day moving average maximum temperature as we have in previous years and these figures are available in Appendix D.

Beaver dams in the Sheep Creek drainage during the winter of 2009/10 remained intact and temperature gages placed in the deep part of the pool behind one of these dams indicates the temperature in such deep pools is colder and not susceptible to high diel fluctuations like the riffle entering the pool. Temperatures remained stable the entire summer (Figure 13).

Table 8. Summary of continuous temperature monitoring in the Hangman Creek watershed during 2010. Percent of hours exceeding temperature limits of 14 degrees C. for spawning and 20 degrees C. for rearing.

Location	Forested	**Spawning Limit** % hrs > 14 Deg C May 1 - June 30	**Rearing Limit** % hrs > 20 Deg C July 1 - Aug 31	**Overall** May 1 - Aug 31
Hangman-Stateline RM 0.0	N	34.15	42.47	38.30
Hangman-Liberty RM 3.1	N	29.03	32.33	30.70
Hangman-Farm RM 5.8	N	25.96	13.84	19.90
Hangman-HWY 95 RM 8.1	N	19.79	47.45	33.60
Hangman-Buckless RM 10.5	N	12.02	32.39	22.29
Hangman-Nehchen RM 11.6	N	15.57	26.95	21.31
Hangman-Morefield RM 12.2	N	14.82	38.78	26.90
Hangman- Larson RM 14.8	N	1.09	1.41	1.25
Hangman-Crawford RM 15.2	N	2.39	0.00	1.19
Hangman-Cordell RM 15.9	N	0.89	0.00	0.44
Hangman-Bennett RM 16.5	N	1.71	0.00	0.85
Hangman-Forest RM 18.5	Y	0.00	0.00	0.00
Mission-DeSmet RM 0.4	N	28.07	12.23	20.09
Mission-KVR RM 2.3	N	13.24	0.00	6.57
Mission-Allotment 632 RM 3.9	Y	0.00	0.00	0.00
Mission-M.F. RM 4.8	Y	0.00	0.00	0.00
Mission-W.F. RM 0.2	Y	0.00	0.00	0.00
Sheep-Confluence RM 0.0	N	17.83	0.60	9.15
Sheep-HWY 95 RM 0.6	N	15.57	1.48	8.50
Sheep-Upper RM 2.6	Y	0.00	0.00	0.00
Nehchen-Lower RM 0.1	N	0.00	*	*
Nehchen-Upper RM 2.9	Y	0.00	0.00	0.00
Indian-Sanders RM 0.3	N	0.00	0.13	0.07
Indian-Pow-wow RM 1.4	Y	0.00	0.00	0.00
Indian-Upper RM2.9	Y	0.00	0.00	0.00
Indian-E.F. RM0.3	Y	0.00	0.00	0.00
Indian-N.F. RM 0.1	Y	0.00	0.00	0.00
S.F. Hangman-Lower RM 0.7	N	1.09	0.00	0.54
S.F. Hangman-Upper RM 1.7	Y	0.00	0.00	0.00
Martin RM 0.2	Y	0.00	0.00	0.00
Bunnel RM 0.2	Y	0.00	0.00	0.00

** Dry channel after July 20th*

Table 9. Summary of continuous temperature monitoring in the Hangman Creek watershed during 2011. Percent of hours exceeding temperature limits of 14 degrees C. for spawning and 20 degrees C. for rearing.

Location	Forested	**Spawning Limit** % hrs > 14 Deg C May 1 - June 30	**Rearing Limit** % hrs > 20 Deg C July 1 - Aug 31	**Overall** May 1 - Aug 31
Hangman-Stateline RM 0.0	N	22.49	29.44	25.99
Hangman-Liberty RM 3.1	N	22.28	26.55	24.43
Hangman-Farm RM 5.8	N	21.19	31.05	26.16
Hangman-HWY 95 RM 8.1	N	29.29	36.42	33.74
Hangman-Buckless RM 10.5	N	13.82	30.85	22.41
Hangman-Nehchen RM 11.6	N	14.22	11.90	13.05
Hangman-Morefield RM 12.2	N	15.18	21.71	18.47
Hangman- Larson RM 14.8	N	3.55	0.00	1.76
Hangman-Crawford RM 15.2	N	4.44	0.00	2.20
Hangman-Cordell RM 15.9	Y	0.00	0.00	0.00
Hangman-Bennett RM 16.5	Y	0.00	0.00	0.00
Hangman-Forest RM 18.5	Y	0.00	0.00	0.00
Mission-DeSmet RM 0.4	N	22.08	15.93	18.98
Mission-KVR RM 2.3	N	9.50	0.00	4.71
Mission-Allotment 632 RM 3.9	Y	0.00	0.00	0.00
Mission-M.F. RM 4.8	Y	0.00	0.00	0.00
Mission-W.F. RM 0.2	Y	0.00	0.00	0.00
Sheep-Confluence RM 0.0	N	11.07	0.00	5.49
Sheep-HWY 95 RM 0.6	N	11.83	0.00	5.86
Sheep-Upper RM 2.6	Y	0.00	0.00	0.00
Nehchen-Lower RM 0.1	N	0.48	*	*
Nehchen-Upper RM 2.9	Y	0.00	0.00	0.00
Indian-Sanders RM 0.3	N	0.62	0.00	0.31
Indian-Pow-wow RM 1.4	Y	0.00	0.00	0.00
Indian-Upper RM2.9	Y	0.00	0.00	0.00
Indian-E.F. RM0.3	Y	0.00	0.00	0.00
Indian-N.F. RM 0.1	Y	0.00	0.00	0.00
S.F. Hangman-Lower RM 0.7	N	0.55	0.00	0.27
S.F. Hangman-Upper RM 1.7	Y	0.00	0.00	0.00
Martin RM 0.2	Y	0.00	0.00	0.00
Bunnel RM 0.2	Y	0.00	0.00	0.00

** Channel dry after July 16*

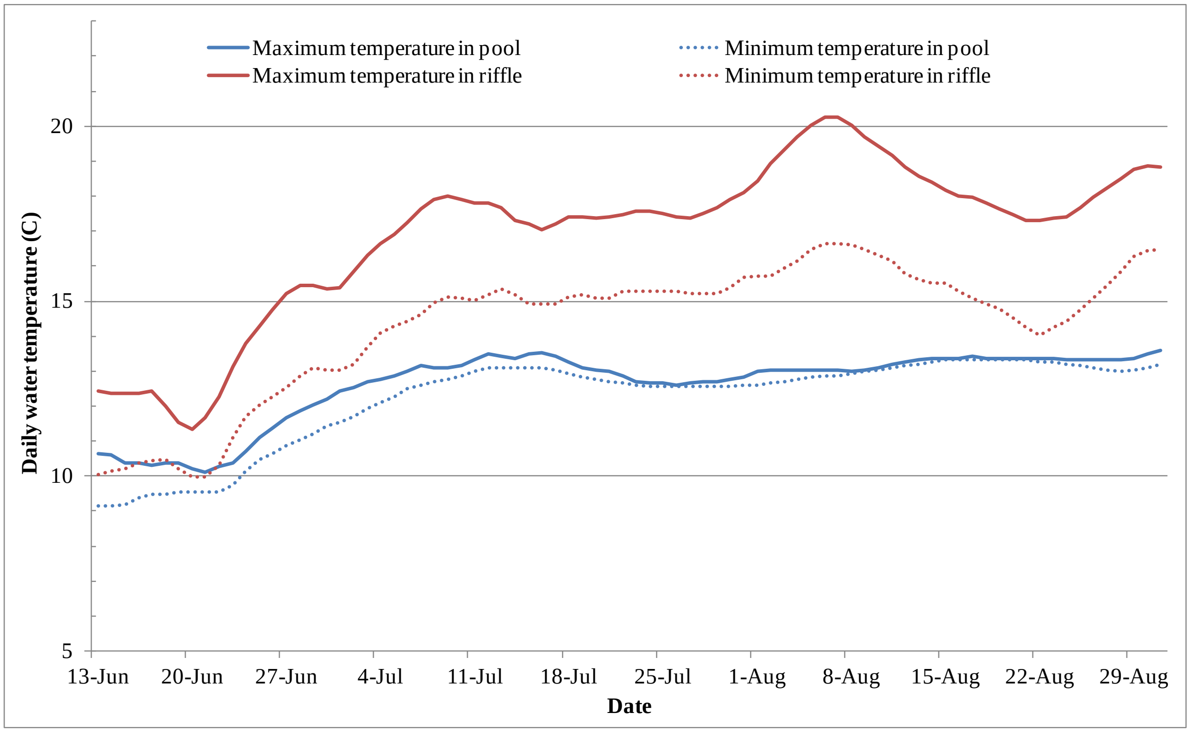

Figure 13. Comparison of daily minimum and maximum temperatures within a 5.5 ft deep pool formed by a beaver dam with the glide entering the pool during summer 2011 at Sheep Creek RM 1.1.

5.2.1.3 Physical Habitat Assessment

Initial habitat assessments conducted in 2010 and 2011 on seven sample sites ranged from lowland agriculturally influenced habitat to upland forested habitat. The two sites located in agriculturally influenced habitat (Tensed and Smith Creeks) were defined by little to no canopy cover contributed by woody plants, high amounts of fine sediment, a complete lack of large woody debris, and no measurable pool habitat. Field notes indicate the majority of the canopy cover at these two sites was contributed by invasive reed canary grass. These sites were located in the lower portions of Tensed and Smith Creeks, which were historically straightened and channelized to promote dry-land agriculture. In the early fall at the time of sampling, Tensed Creek was completely dewatered. The remaining initial assessment surveys, with the exception of Lower Nehchen Creek, were conducted in upland forested habitat located in the headwaters of Indian Creek. These sites were generally defined by high levels of woody species canopy cover, fine sediment loads of 25% or less in the wetted channel, moderate volumes of LWD, and moderate to low percentages of pool habitat. Pools in these survey sites were generally small and shallow, with residual depths averaging 0.2 meters (Table 10).

Table 10. Stream Habitat Metrics generated from surveys conducted in the Hangman Creek watershed 2010-11.

		Mean percent canopy cover		Mean percent fines		Large woody debris metrics		Pool habitat metrics	
Stream	**Site**	**Total**	**Pecent non-woody plants**	**Bankfull**	**Wetted**	**Count (#/100 m)**	**Volume (m^3/100 m)**	**Percent pool**	**Mean residual pool depth (m)**
				2010					
Indian	2A [b]	93.8	0.8	52.9	8.3	27	18.5	40.0	0.22
Indian	2B [a]	89.1	1.5	46.0	10.9	21	9.5	38.8	0.28
Indian	2C [a]	95.7	1.8	64.0	16.6	33	8.7	46.1	0.24
Indian	2D [b]	85.9	0.3	55.7	16.6	28	9.7	32.1	0.20
Tensed	2.5	80.3	100.0	78.0	DRY	0	0.0	DRY	DRY
				2011					
NF Indian	0.3	91.9	0.0	52.6	25.1	15	6.9	22.0	0.19
NF Indian	2.3	99.0	0.0	41.4	6.6	20	7.3	16.4	0.21
NF Indian	1.3/0.1	90.4	0.0	49.4	19.4	19	8.2	4.1	0.15
Indian	5.1	93.7	5.2	29.1	2.3	20	4.7	16.4	0.24
Nehchen	0.1	56.5	9.6	43.1	10.9	1	0.0	45.8	0.31
Smith	0.7	39.2	87.5	43.0	16.0	0	0.0	NA	NA

[a] Indicates survey sites within the reach treated with LWD and pool forming structures in Indian Creek

[b] Indicates survey sites used as measurable controls adjacent to the treated reach in Indian Creek

5.2.1.4 Beaver Dam Locations and Attributes

We surveyed a total of 180 beaver dams from 2009-2011 in the Hangman Creek watershed, of which 29% were considered active. Stream reaches with the highest densities of beaver dams included Upper Mission Creek, Sheep Creek from RM 0.6 to 1.4, and Hangman Creek from RM 11.0 to 12.0 and RM 14.0 to 16.0. The areas of higher beaver activity corresponded to lower gradient stream reaches with ample food and building materials (Figure 14 andFigure 15). Beaver dams were composed of predominantly small building material such as small diameter wood, grasses, mud, and rock. Beaver dams ranged in height from 0.3 feet to 6.2 feet. In addition, Sheep Creek had the highest proportion of active dams and a higher mean dam height than any other stream with the exception of Tensed Creek, which only had a single active dam at the time of survey. Very few dams surveyed were utilizing large wood that would serve as a key piece for maintaining integrity through times of high stream run-off (Table 11).

Back watered areas behind 11 beaver dams were measured within the larger surveyed area. These dams ranged in height from 0.3 feet to 4.6 feet with widths of 12 feet to 44 feet. Inundated length, as well as residual pool volume, was greatest behind dams that persisted in streams sections with a gradient of less than 1% (Table 12).

We surveyed a total of 180 beaver dams from 2009-2011 in the Hangman Creek watershed, of which 29% were considered active. Stream reaches with the highest densities of beaver dams included Upper Mission Creek, Sheep Creek from RM 0.6 to 1.4, and Hangman Creek from RM 11.0 to 12.0 and RM 14.0 to 16.0. The areas of higher beaver activity corresponded to lower gradient stream reaches with ample food and building materials (Figure 14 and Figure 15). Beaver dams were composed of predominantly small building material such as small diameter wood, grasses, mud, and rock. Beaver dams ranged in height from 0.3 feet to 6.2 feet. In addition, Sheep Creek had the highest proportion of active dams and a higher mean dam height than any other stream with the exception of Tensed Creek, which only had a single active dam at the time of survey. Very few dams surveyed were utilizing large wood that would serve as a key piece for maintaining integrity through times of high stream run-off (Table 11).

Back watered areas behind 11 beaver dams were measured throughout the surveyed area. These dams ranged in height from 0.3 feet to 4.6 feet and widths of 12 feet to 44 feet. Inundated length, as well as residual pool volume, was greatest behind dams that persisted in streams sections with a gradient of less than 1% (Table 12).

Table 11. Summary of beaver dam attributes surveyed in 2009-2011.

Stream	**Total #**	**Active**	**% using exclusively small materials**	**Mean Height (ft)**
		2009 and 2010		
Hangman	102	18	100	1.5
Mission	3	0	100	1.4
Indian	10	0	70	2.4
Sheep	5	5	100	2.7
Tensed	1	1	100	3.3
		2011		
Hangman	33	15	100	1.2
Mission	11	3	100	2.1
Sheep	15	10	90	1.9

Table 12. Summary of back-watered area behind selected beaver dams surveyed in 2010-11.

	Dam Metrics		Inundated Water		Pool Measurements	
Stream	**Dam Height (ft)**	**Width (ft)**	**Length (m)**	**Area (m^2)**	**Total Length (m)**	**Residual Volume (m^3)**
Hangman	0.6	14.0	176.8	1623.2	148.7	121.1
Hangman	1.1	18.0	96.9	502.2	76.2	38.5
Hangman	0.3	12.0	12.2	29.1	0.0	0.0
Hangman	1.1	24.0	103.6	849.3	95.4	168.0
Hangman	1.6	30.0	152.4	1184.5	130.6	183.6
Sheep	3.9	44.0	215.8	1701.9	214.9	906.6
Hangman	4.6	29.0	133.5	874.9	133.2	205.2
Hangman	0.5	13.3	7.9	28.9	0.0	0.0
Hangman	0.4	14.0	20.1	65.5	10.1	0.7
Indian	2.9	.	17.4	105.6	4.3	0.1
Hangman	1.5	19.5	85.3	385.0	63.4	39.9

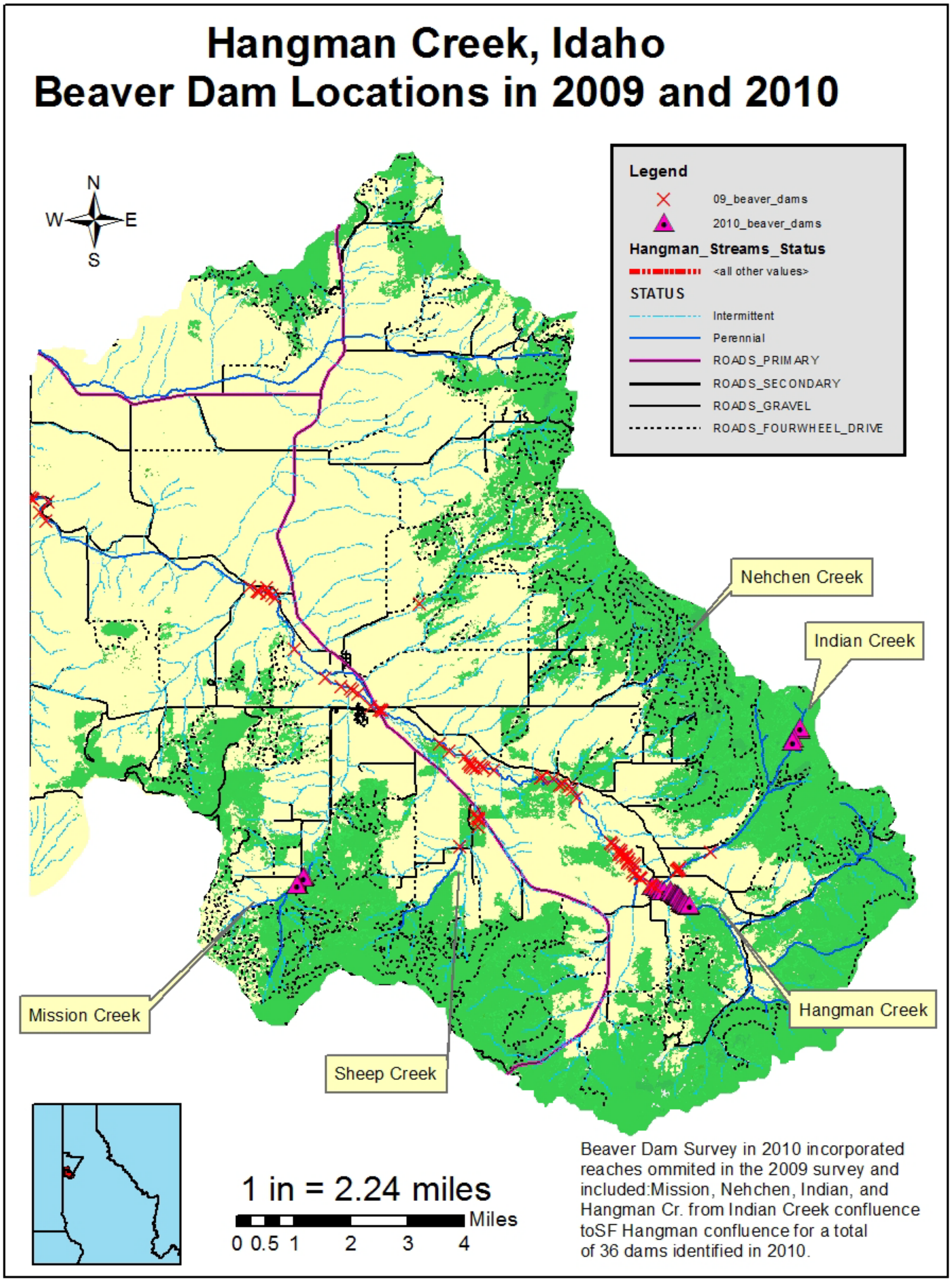

Figure 14. Beaver dam locations throughout the surveyed areas of the Hangman Creek watershed in 2009-10.

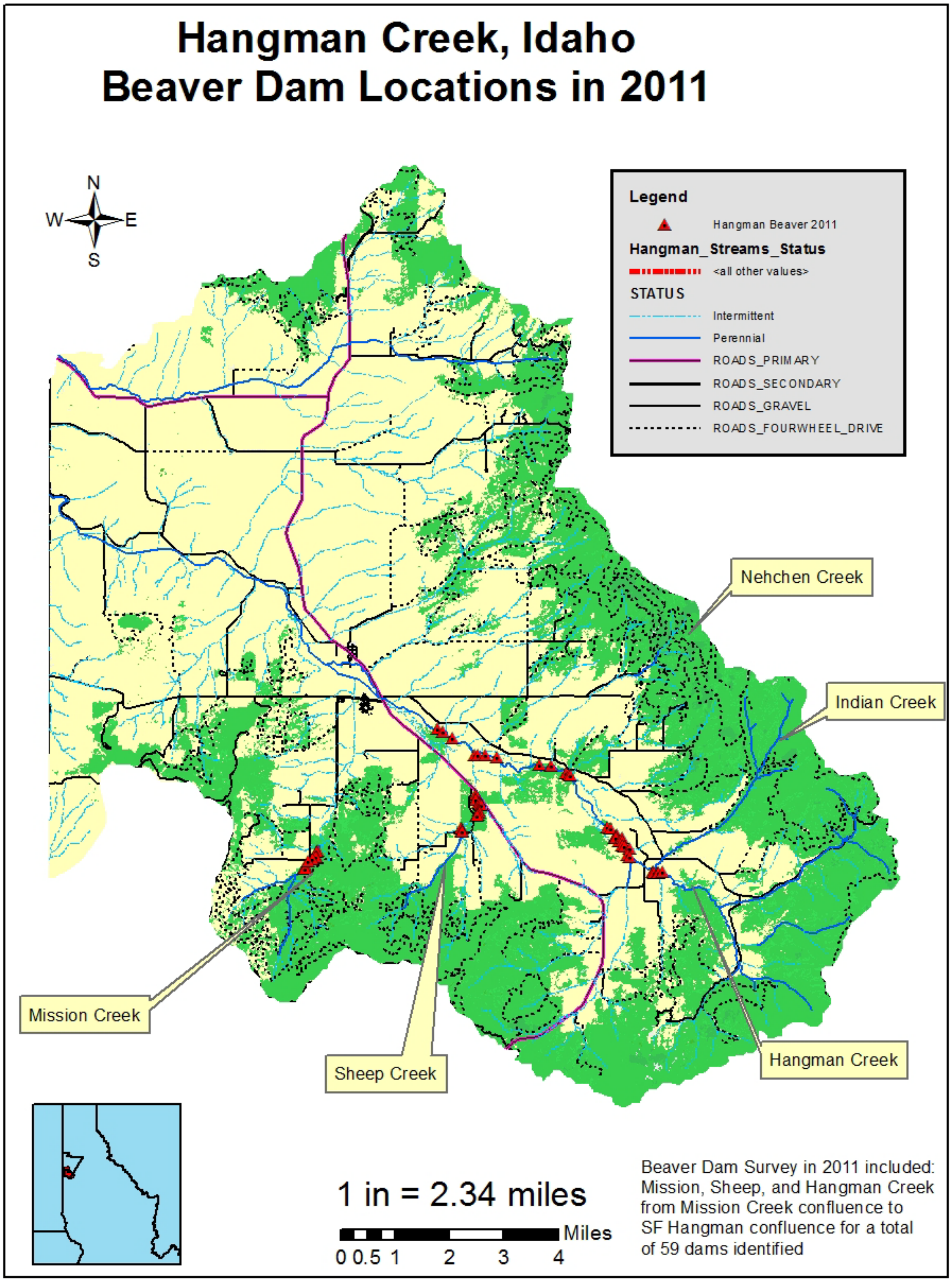

Figure 15. Beaver dam locations throughout the surveyed areas of the Hangman Creek watershed in 2011.

5.2.2 Action Effectiveness

5.2.2.1 Physical Habitat Assessment in a LWD Treated Reach in Indian Creek.

Effectiveness monitoring was conducted in Indian Creek after the addition of LWD to approximately 1500 feet of stream length. Metrics collected pre-treatment (2004) showed low numbers of pools with relatively shallow residual depths. It is noteworthy that restoration on reaches 2B and 2C reflected the greatest need, and habitat on reaches 2A and 2D was more suitable for salmonids, hence no action was needed (Kinkead 2013). After the addition of large wood and pool forming structures such as J-hooks and cross veins, the total number of pools doubled, mean residual pool depth increased by over 60%, and overall pool habitat increased by over 44% in site 2B (Table 13). In addition, site 2C in the treated reach also showed a high percentage of pool habitat. Metrics obtained from the habitat surveys adjacent to the treated reach of Indian Creek showed measurably smaller residual pool depths while maintaining similar percent pool habitat and larger volumes of LWD (Table 10).

Table 13. Habitat metrics before and after the addition of large woody debris and pool-forming structures in Indian Creek site 2B.

Indian Creek Reach 2B								
	Large Woody Debris			**Pool Habitat Metrics**				
	Counts/100 m		**Volume**					
	Total #	**# >18" diameter**	**m^3/ 100m**	**Mean Residual Depth (m)**	**St Dev. Residual Depth**	**Total # Pools**	**# Pools >1 ft deep**	**Percent pool**
Pre-treatment	36	5	8.52	0.17	0.06	9	0	26.9
Post-treatment	21	10	9.51	0.28	0.13	18	7	38.8

5.2.2.2 Trout Abundance in a LWD Treated Reach in Indian Creek

Results from the repeated measures analysis indicated a significant difference (p-value = 0.06) between the number of fish caught in treated and control reaches of Indian Creek from 2009 – 2011. The repeated measures analysis however did not indicate a significant difference in numbers of fish caught within treated or control reaches (Appendix B). The sampling sites within the treated portion of Indian Creek had consistently higher densities of redband trout than the two control sites located on the adjacent ends of the treated area (Table 14). Trend analysis throughout reach 2 in Indian Creek also showed a much larger increase in the density of redband trout within the treated reach when compared to the adjacent control reach (Figure 16).

Table 14. Redband trout captured in treatment and control sites in Indian Creek 2009-11.

	2009		2010		2011	
Site	**# captured in 1st Pass**	**RBT density (fish/100 m)**	**# captured in 1st Pass**	**RBT density (fish/100 m)**	**# captured in 1st Pass**	**RBT density (fish/100 m)**
2.3 (control)	15	24.6	18	29.5	16	26.2
2.5 (treatment)	37	60.7	21	34.4	14	23.0
2.7 (treatment)	19	31.1	30	49.2	22	36.1
2.9 (control)	11	18.0	12	19.7	10	16.4

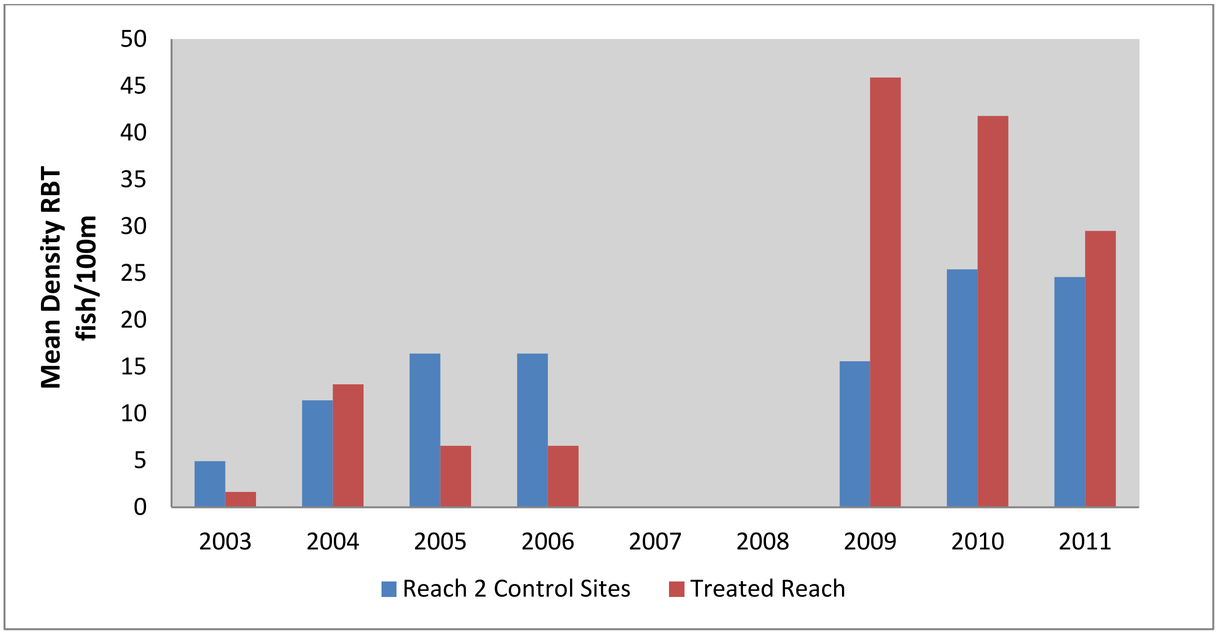

Figure 16. Trend in mean density of redband trout in control and treated sites of reach 2 in Indian Creek. No fish sampling occurred in 2007 or 2008. Restoration actions were completed in 2008.

6. SYNTHESIS of FINDINGS: DISCUSSION/CONCLUSIONS

6.1 Fish Population Status Monitoring (RM&E)

6.1.1 Trout Abundance and Distribution During Summer Rearing Periods

Redband trout distribution has been largely limited to forested reaches of the Hangman watershed. Reaches of Hangman Creek upstream of, and including, Indian Creek, form a continuous expanse of homogenous habitat that allows dispersal of fish among tributary habitats, which may explain the relatively stable densities of trout sampled annually in these tributaries. However, the subpopulations of redband trout found in Sheep, Nehchen, and Mission Creeks are largely isolated from each other and from the aforementioned subpopulations, leaving them especially susceptible to changes in environmental conditions due to natural or anthropogenic influences, and inbreeding depression. This isolation was apparent from the small genetic distance between Mission/Sheep collections and those of upper Hangman and Indian Creek (Small and Von Bargen 2005; Figure 2a). Nehchen, Sheep, and Mission Creeks for example have shown high variability in trout densities during summer rearing periods since consistent electrofishing surveys were initiated in 2003 (Kinkead and Firehammer 2012).

Given that the overall objective of this project is to expand the entire population and increase the overall distribution, it is apparent that not only should we continue to preserve the remnant population(s) of redband trout in the upper Hangman watershed, we should also work to increase the likelihood of dispersal between subpopulations and into historical habitats. Focusing restoration actions for the benefit of the resident and fluvial forms of redband trout present in the Hangman watershed will help us achieve our objectives. Resident redband, along with the rearing progeny of fluvial adults, will benefit from rehabilitation actions such as the addition of large woody debris, localized canopy reestablishment, barrier removal, and sediment abatement in the tributaries throughout upper Hangman Creek. Fluvial adult redband however require restoration actions on a much larger scale. Extensive stream degradation due to channelization, wetland removal, beaver suppression, and riparian vegetation removal has led to large sections of the mainstem of Hangman Creek and the lower portions of many tributaries to become void of any suitable trout habitat. In addition, the aforementioned habitat alterations have resulted in rapid runoff and large scale flooding throughout lower Hangman Creek. Future restoration plans in the upper Hangman watershed should continue to promote favorable conditions in the upper tributaries, while increasing habitat connectivity throughout the mainstem and lower portions of the tributaries.

6.1.2 Trout Migration

In the future, it is apparent that we will have to build on our current monitoring designs to evaluate dispersal and the relative abundance as we implement new large scale habitat restoration. The data collected at trout migration traps have recently shown the first evidence of movement between tributaries. The mouth of Nehchen Creek is approximately 5.8 km downstream of Indian Creek and the migration corridor passes through marginal trout habitat at best. Movement between subpopulations, especially those that are more isolated from one another, can lead to increasing the connectivity of tributary subpopulations to promote a more robust and resilient population structure that would in turn minimize the adverse consequences (e.g., demographic stochasticity, inbreeding depression) that arise from isolated, small populations (Gilpin and Soule 1986). The trap data has also shown evidence of larger, fluvial forms of redband trout that are moving from the mainstem of Hangman Creek into tributaries to spawn. Tracking movements such as these are essential for determining the influence fluvial and resident redband trout have on promoting genetic variability and increasing the range of redband trout throughout the upper Hangman Basin.

6.2 Tributary Habitat RM&E

6.2.1 Status Monitoring

6.2.1.1 Changes to RM&E Protocols

The habitat RM&E was altered in 2010-11 in order to collect priority data in a more cost effective manner and guide us to the most effective restoration methods. Given the extensive baseline data collected from 2002 – 2009 (Peters et al. 2003; Kinkead and Firehammer 2011, 2012), it was determined to replace the time consuming Rosgen channel typing completed previously with a survey targeting fish habitat attributes. This allowed us to complete additional sample sites and compare large woody debris (LWD) loading in treated versus control reaches within Indian Creek. Winter water quality sampling was discontinued in the reporting period in order to reassess methods. Plans are in place to work with the Coeur d'Alene Tribe's Water Resources Program to use advanced equipment to more effectively measure discharge during high flows. Temperature continues to be a very cost effective way to gather data and we added an assessment of temperatures in pools created by beaver dams, as well as a survey of beaver dams over an extensive area of Hangman Creek.

6.2.1.2 Fish Habitat

Habitat surveys conducted in 2010 and 2011 were completed to gather a full assessment of Indian Creek reaches 2 and 3 and to gather initial assessments of the agriculturally impacted portions of Tensed and Smith Creeks. Surveys completed in Indian Creek confirmed earlier Rosgen surveys showing high levels of fine sediment throughout the upper Indian Creek watershed when compared to Nehchen Creek and the other forested subwatersheds in upper Hangman Creek (Kinkead and Firehammer 2011, 2012). This factor is currently thought to be the most limiting variable influencing redband trout abundance in this subpopulation. Large wood loading in Indian Creek however meets the Coeur d'Alene Tribe's standard of $6m^3$/100m of stream length in seven out of the eight sites surveyed. It should be noted however that this criteria would not have been satisfied in sites 2B and 2C prior to our restoration efforts. Future restoration efforts in Indian Creek should be focused on the transport and sorting of sediment to improve spawning conditions for redband trout to a level described by Muhlfeld (2002).

6.2.1.3 Water Quality

Tensed and Smith Creeks, much like other smaller low-lying tributaries in the Hangman watershed, were highly affected by agricultural practices. Limiting factors such as discharge rates, dissolved oxygen, temperature, substrate size, canopy cover, and levels of LWD all have an impact on these streams ability to support trout. Although it could be argued that canopy cover in these two streams is relatively high, the composition of the canopy is composed of mainly herbaceous plants such as reed canary grass. Clearly, large scale restoration efforts such as stream realignment, re-connection to the floodplain, and the reintroduction of woody plants are needed to reach conditions that can support a larger, stable number of redband trout.

Water quality in all mainstem and lower tributary habitats exhibited suboptimal discharge and related low dissolved oxygen, with the exception of Indian Creek during 2010-11. Data collected during the reporting period is consistent with previous studies and shows a strong correlation to agricultural practices having a delirious impact upon discharge and water quality.

6.2.1.4 Continuous Temperature Monitoring

Various studies have indicated that redband trout distribution is dependent upon optimal water temperatures. Meyer et al. (2010) found the probability of occurrence of redband trout in southwest Idaho streams to increase as the amount of stream shading increased. The authors also noted that redband trout were always present in the desert streams that were examined in their study when mean summer temperatures were between 10 and 16^{o}C, but were less likely to occur as temperatures increased from 16 to 22^{o}C. Densities of redband trout in southwest Idaho desert streams have also been found to be positively correlated with the percent of canopy cover and stream shading (Zoellick and Cade 2006), and to be negatively correlated with maximum summer stream temperatures (Zoelllick 2004).

As supported by the findings of the aforementioned studies, data collected in 2010-11 support conclusions by Kinkead and Firehammer (2011, 2012) , which identified a lack of canopy cover and concomitant high summer temperatures to be a significant factor limiting the distribution and abundance of redband trout in many of the stream reaches in the upper Hangman Creek watershed. The link between stream shading and temperature was especially evident for mainstem reaches in Hangman creek where summer temperatures were documented to sharply increase over relatively short distances downstream as the riparian canopy markedly decreased. Throughout the reporting period, stream temperature metrics in downriver reaches of Mission and Sheep creeks and in the mainstem of Hangman Creek, where canopy cover was lacking, exceeded established temperature thresholds a high percentage of the time. The metric that was chosen to evaluate thermal suitability was the percent time water temperatures exceeded 14^{o}C during a spawning/incubation timeframe (i.e., May 1 – June 30) and 20^{o}C during summer rearing periods (i.e., July 1 – August 31), and it has shown to be a good indicator of salmonid presence.

New data gathered to describe thermal heterogeneity within pools behind beaver dams shows the potential that stable beaver dams could have on reaching temperature goals for rearing habitat.

Temperatures remained stable in these backwatered habitats over the entire summer with little diel fluctuations.

6.2.1.5 Beaver Dam Location and Attributes

Historically, beaver have had a large presence throughout the Hangman Creek watershed (Aripa 2003). As our restoration practices evolve to restore natural processes, it is clear beaver will need to be an integral part of our planning and implementation. Given this, a monitoring program was initiated in 2009 in conjunction with BPA project # 2001-033-00. The results of our monitoring efforts show that beaver are still persisting throughout the Hangman watershed, albeit it in much lower numbers than in the past. As we implement restoration actions designed to promote beaver proliferation, such as planting native woody plants in riparian areas, reinforcing existing beaver dams, and supplying wood for beaver to feed on and build with, the monitoring of beaver distribution and relative numbers is essential to determine if our restoration actions are effective.

6.2.2 Action Effectiveness

6.2.2.1 Physical Habitat Assessment in a LWD Treated Reach of Indian Creek

The addition of large wood and pool forming structures to small streams, as was done in a reach of Indian Creek, can elicit measurable changes to physical habitat characteristics in relatively short time periods. Stream measurements two years after restoration was implemented showed not only an increase in overall pool habitat, but larger amounts of heterogeneity between pools and along the stream reach. This level of heterogeneity is important for providing habitat for all life stages of redband trout throughout the year. Our goal is to continue this type of restoration approach, using intensive habitat assessments to understand what physical habitat attributes are limiting and implement actions to remedy the problems caused by these limiting factors.

6.2.2.2 Trout Abundance in a LWD Treated Reach of Indian Creek

As habitat restoration is implemented, it is vital to understand the effectiveness of our restoration actions as it relates to not only physical habitat parameters within and adjacent to treated reaches, but to redband trout survival, dispersal, and proliferation. The restoration actions implemented in Indian Creek have shown how the addition of wood can impact pool formation and have a significant influence on trout densities. Albeit the formation of deeper and more plentiful pools may only be creating a localized response by attracting trout from adjacent reaches, it is apparent that the trout prefer this type of habitat, specifically during the summer rearing periods. Monitoring methods such as this will continue to be implemented throughout the Upper Hangman basin to evaluate the effectiveness of our restoration actions.

7. TRIBUTARY HABITAT RESTORATION AND PROTECTION

7.1 Introduction to Restoration Activities

Implementation of restoration and enhancement activities that occurred in the Hangman Creek watershed during two contract periods, May 1st 2010 – April 30th 2012, is summarized in Table 15. This is followed by a more detailed site characterization and summary of activities for individual treatments. In two locations, multiple treatments have been implemented to meet the objectives for the given resources. These treatments are grouped under the same project ID heading so that the interrelationship of activities is more apparent.

A brief explanation of the project ID that is used in the summary table and in the detailed descriptions is warranted here. The project ID is an alphanumeric code that corresponds to the location of individual treatments in relation to the river-mile of the drainage network for the watersheds of interest. The first digit of the code signifies the watershed that the treatment is located in, using the first letter in the watershed name (e.g., HA=Hangman Creek, SH=Sheep Creek, etc.). The series of numbers that follow correspond to the river-mile location (in miles and 10ths) at the downstream end of treatment sites. River mile is tabulated in an upstream direction from mouth to headwaters and treatments that are located in tributary systems have river mile designations separated by a forward slash (/). For example, the downstream end of project IN_1.5 is located in the Indian Creek watershed 1.5 miles up from the confluence with Hangman Creek. If a tributary of Indian Creek 1.0 mile up the mainstem, it would be designated IN_1.5/1.0. In the case of Hangman Creek the 0.0 RM marker is at the Idaho/Washington boundary and river miles are measured from Stateline. This nomenclature is intended to indicate the spatial relationship of treatments to the mainstem and tributary aquatic habitats having significance to the target species. Furthermore, it readily conveys information about the relationship of multiple treatments by indicating the distance to common points in the drainage network. Site descriptions include drainage area derived from GIS methods and bankfull discharge which was obtained from Rosgen channel typing surveys and analyzed using River Morph software (Kinkead and Firehammer 2011 and (Kinkead and Firehammer 2012).

Table 15. Summary of restoration/enhancement activities associated metrics completed for BPA Project #2001-032-00.

Project Description			Project Chronology		
Project ID	Activity	Treatments (Metrics)	Pre--2010	2010	2011
HA_11.9	Plant Vegetation	Riparian Enhancement (55.7 acres; 5280 ft of streambank	Planted 8,750 conifers, 1,949 potted hardwoods, and 650 willow shoots	Planted 74 hardwood pots and 250 willow shoots	------------
HA_11.9	Increase Instream Habitat Complexity and Stabilization	Offer Aspen Clippings to Beaver (Materials for 1 beaver dam)	NA	------------	915 ft³ aspen
IN_1.5	Plant Vegetation	Riparian Enhancement (1.4 acres; 3,000 ft of streambank)	Planted 600 conifers, 110 hardwoods and 100 forbs/shrubs	------------	------------
IN_1.5	Increase Instream Habitat Complexity and Stabilization	Add Wood Structures to 1,000 feet of stream	Built 14 large wood and 2 rock structures	Built 12 large wood and 3 rock structures	------------
SH_0.8	Plant Vegetation	Riparian Enhancement (59.0 acres; 5,069 ft of streambank)	------------	326 potted hardwood s planted	250 willow shoots planted
SH_0.8	Increase Instream Habitat Complexity and Stabilization	Develop Design	------------	------------	Contracted R2 Resource Associates for a large wood addition and riparian enhancement design
SH_0.8	Increase Instream Habitat Complexity and Stabilization	Offer Aspen Clippings to Beaver (Materials for 6 beaver dams)	------------	------------	3660 ft³ aspen
BU_0.6	Install Culvert	Install Fish Passage Structure	------------	Installed 1 culvert on Bunnel Creek and one drainage culvert on Sanders-Emida Road	------------
MI_3.8	Increase Instream Habitat Complexity and Stabilization	Offer Aspen Clippings to Beaver (Materials for 4 beaver dams)	------------	------------	1,525 ft³ aspen

7.2 Prioritization of Restoration Efforts Using Beaver

The Coeur d'Alene Tribe contracted Herrera Environmental Consultants, Inc. to evaluate the feasibility of using beaver as a restoration tool across the entire upper watershed as a cost-effective means of restoring the connection between incised streams and floodplains, and to replenish ground water (Herrera 2011). Beaver (*Castor Canadensis)* used to thrive in the watershed, but they now inhabit a fraction of their historic range. Beaver are capable of altering their surroundings to create their preferred habitat conditions, which in turn benefit native fish and other aquatic species. Beaver dams and the riparian vegetation required by beaver improve surface water and hyporheic connectivity, can reduce instream temperatures, and provide the complex habitat conditions used by redband trout and other cold water aquatic species. Although beaver are active in the upper Hangman Creek watershed, existing watershed conditions, such as flashy hydrology, channel confinement, and a lack of native riparian vegetation, result in frequent damage to beaver dams and their associated aquatic habitat.

Herrera conducted reach and watershed-scale assessments of upper Hangman Creek and its tributaries to characterize existing habitat and geomorphic conditions, document conditions associated with existing beaver dams, and develop criteria to rank the restoration potential of individual sites. Ranking criteria included reach significance for fisheries, landowner cooperation, degree of floodplain disconnection, unit stream power, and the potential to restore native vegetation used by beaver for food and dam construction. Site attributes compiled in a GIS database developed from field and map data were used to rank potential project sites in terms of their suitability for the restoration of beaver habitat. Five priority reaches were selected, for which conceptual restoration strategies aimed at restoring beaver habitat were developed. A suite of recommended restoration actions are included in this document (Herrera 2011). They include:

- Placement of instream structures to encourage beaver dam construction
- Floodplain and channel excavation to reconnect the floodplain
- Modification of existing infrastructure to improve hyporheic conditions, and
- Restoration of native riparian vegetation.

Site-specific application of the restoration actions is recommended for each of the five priority reaches. The recommendations are intended to guide the Coeur d'Alene Tribe in restoring the reaches with regard to their unique characteristics. Although numerous reaches ranked high for the restoration of beaver habitat, Herrera's findings indicate landscape-scale changes that work toward restoring the pre-settlement hydrologic regime would be necessary if habitat conditions are to be restored to their full potential. If such landscape-scale changes are made, beaver may be able to construct and maintain persistent dams that would rebuild floodplain connectivity and provide the desired habitat conditions for redband trout throughout the upper Hangman Creek watershed.

Based on the findings of this study, we propose to accelerate the trajectory for recovering habitat by utilizing restoration approaches that emulate the ecosystem engineering effects of beaver and enhance the stability of natural dams where they exist in the watershed. General prescriptions have been developed for five stream reaches where the approach is deemed to have the greatest potential for restoring habitats in the near-term and eliciting positive population responses from redband trout. The prescriptions utilize a strategy of supporting beaver activity through the use of beaver attracting structures, stabilization of existing dams, and efforts to improve riparian conditions to supply beaver the necessary supplies for food and dam building materials. Herrera (2011) identified two tributary reaches, Sheep SHMF02 and Mission MIMF04 (Figure 17), as priority for establishing beaver in the watershed. Furthermore, Herrera concluded that Indian Creek is not a priority for use of beaver to attain restoration goals. The narrow width of the floodplain and the minimal potential of saturated soils in Indian Creek indicate the lower relative potential impact of beaver colonization (Green and Kinkead 2008). Addition main-stem reaches below Mission Creek identified as HAMF04 (Herrera 2011) show poor potential until significant changes are made in watershed land use practices. We are using this study as further evidence that hardwood clippings left for beaver in 2011 within Mission Creek Reach 4, Sheep Creek Reach 2, and Hangman Creek, Reach 11 is feasible to contribute toward our restoration goals (Figure 17)

The first project utilizing these principles in the Hangman watershed will be implemented in 2012 in Sheep Creek A336/340 on Reach 2 (Figure 17). The project will be closely monitored to inform the implementation of similar projects that are prescribed in this proposal to be implemented at prioritized locations throughout the upper watershed.

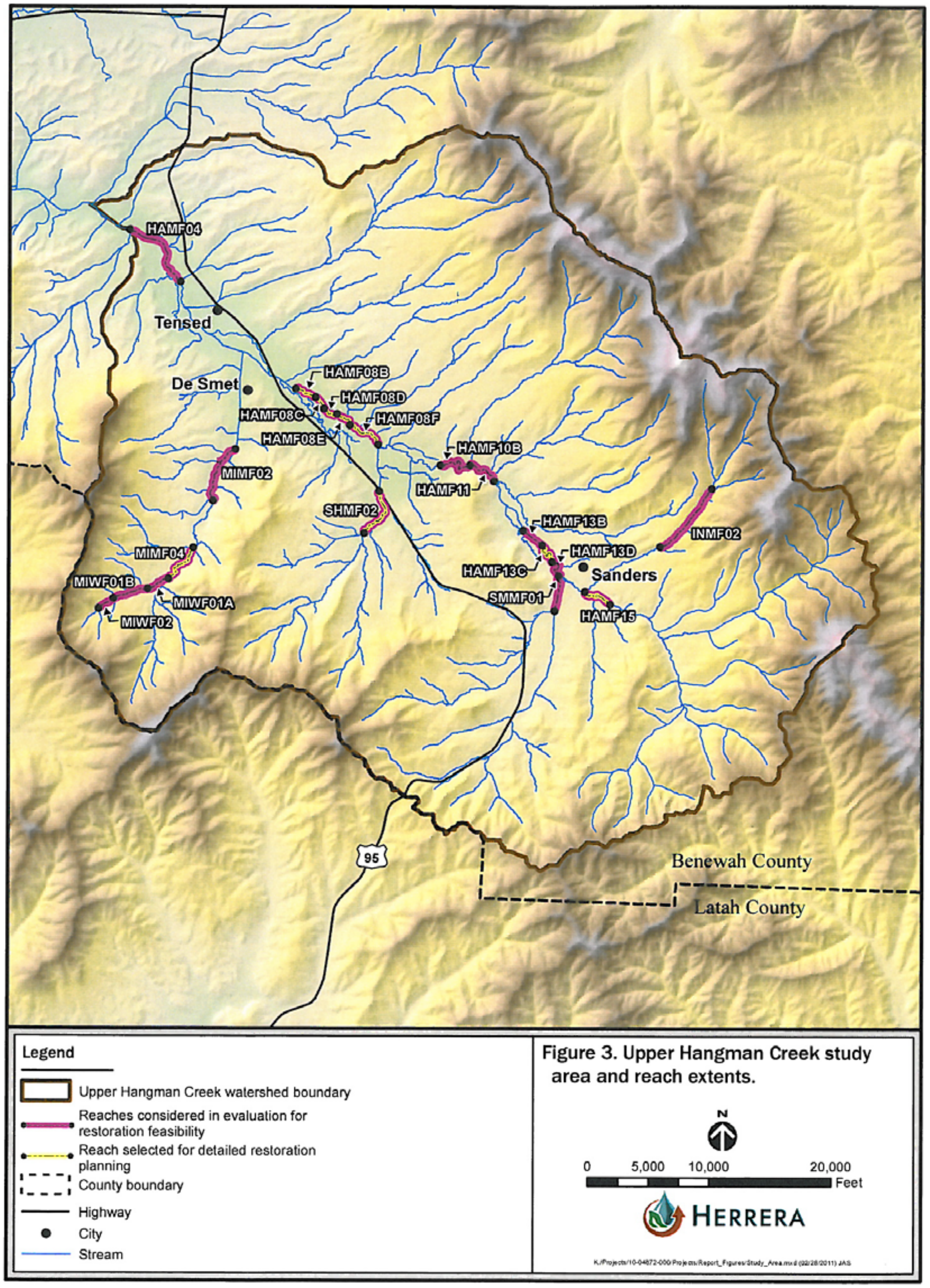

Figure 17. Map of reaches assessed and prioritzed for restoration utilizing beaver (from Herrera 2011).

7.3 Project IN_1.5: Large Wood Additions to Indian Creek

Project Location:

Sub-Watershed: Indian Creek
River Mile: 1.5 RM

Legal: T44N, R4W, Sec 36
Begin: Lat 47.11345°N Long -116.77966°W

Site Characteristics:

Slope/Valley gradient: 1.5%
Valley/Channel type: B4c
Bkf Discharge (cfs): 140

Aspect: SE | Elevation: 2,844 - 2875 ft.
Proximity to Water: In channel and riparian
Drainage Area: ($3.32mi^2$)

Other: *Indian Creek lies 25.6 miles up Hangman Creek from the Washington/Idaho Boundary. Project implements instream treatment and riparian enhancement to mimic historical conditions.*

Problem Description: Following World War 2 Indian Creek was dominated by a Western Red Cedar/ fern complex with a mosaic of open stands of aspen and alder following natural disturbances, with white pine, ponderosa pine, and Douglas fir in the uplands (Aripa 2003). However, most of the cedar in this short 0.4km section of Indian Creek was harvested approximately 25 years ago resulting in the current conditions.

The watershed has mostly third order growth at this time. Currently red alder, fern, and various forbs dominate the riparian habitat, and grand fir dominates the upland. Expiring mature alder are contributing to numerous and unstable side channels, but no pools are formed from the unstable woody debris jams. Pools average 0.7 ft deep and fine sediments are limiting spawning in this reach. The only pools found are formed by remnant downed cedar (Kinkead and Firehammer 2011). Habitat upstream (Reach 2D) and downstream (Reach 2A) of this reach is closer to historical conditions with cedar dominating the riparian area.

Indian Creek is home to the most robust population of Redband trout in the Hangman Creek watershed and is currently the only perennial tributary of Hangman Creek within reservation boundaries, and is considered a priority to protect and enhance for purposes of disbursing native trout into other areas of the watershed.

Description of Treatment: The large woody debris project was initiated in 2008 and completed in spring of 2010. There now are two separate 500 foot treated reaches identified as Indian Reach 2B and 2C (Figure 7, Figure 18, and Figure 19). The primary strategy for this restoration project was to treat the most impacted reach (2B and 2C), by adding stable wood for pool forming processes, along with secondary goals of decreasing erosion and creating a mosaic of stored fine sediments and sorted gravels for spawning. The riparian zone was already well established with alder and forbs, and the goal was to limit disturbance while placing large woody debris structures. Accordingly, all structures were built by hand with logs moved in with a portable log hauler on rubber wheels. The channel was not dredged for placement and banks were seldom excavated with shovels to place the logs at proper angles. Much of the aspen present in an earlier survey was either removed or blown out by high flows.

A variety of wood and rock structures were built including cross veins (Picture 5), large and small check dams (Picture 6), j-hooks (Picture 7), and split log structures for bank protection and creating undercut cover for fish (Picture 8). In one case an entrenched section was intensely treated with numerous structures in order to agrade the channel, decrease erosion, and create self-sustaining scour pools. Agradation was initialized by installing a large check dam downstream of the entrenched area (Picture 6, left panel). A wood cross vein and 2 j-hooks were installed within the same section to create scour pools (Picture 7). Large logs were also placed vertically and horizontally on two sharp corners where extensive erosion had occurred (Picture 5). Logs were also used to plug some of the side channels (Picture 9) in order to direct more flow into the main channel, and to narrow widened channels. Maintenance has been minimal, although was required at the large check dam in order to armor the outside edges and prevent erosion of the banks outside the placed log.

These LWD structures were only intended to function until the recruitment of conifers improves. In 2005 and 2006, 600 cedar plugs were planted in this reach and have shown excellent survival rates (Kinkead and Firehammer 2011). Forbs and hardwood plantings were utilized in areas disturbed by LWD installation (Kinkead and Firehammer 2012). Overall the project was shown to be a success at accomplishing the goals set forth. The reach with the most impairment is now greatly improved. The incised channel filled in within 2 years and the pools created are self-sustaining. Side channels are closed to all but the highest flows and raw banks are not seen on the reach at this time.

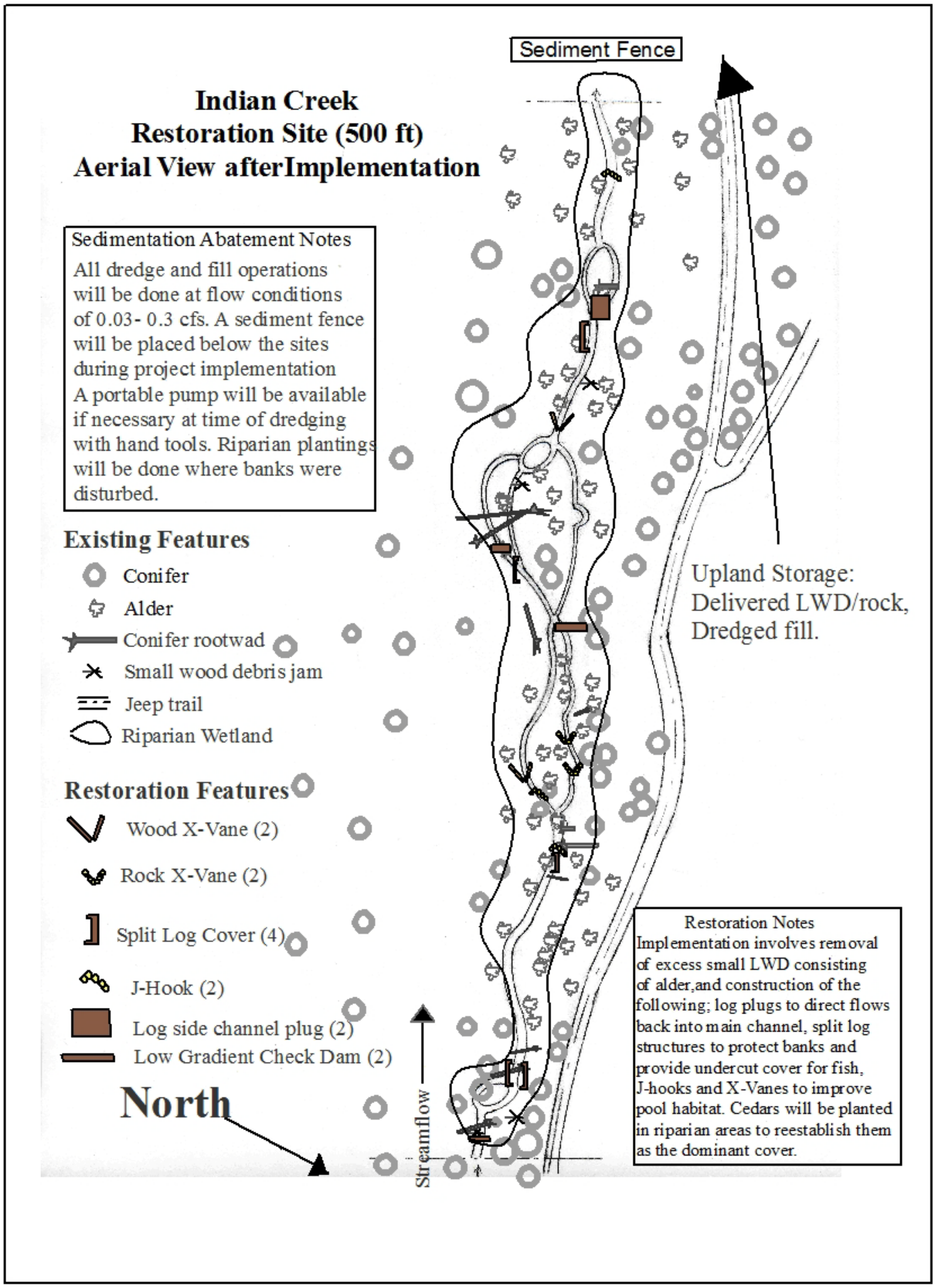

Figure 18. Design map of a large woody debris placement project on Indian Creek, Reach 2B intiated in 2008.

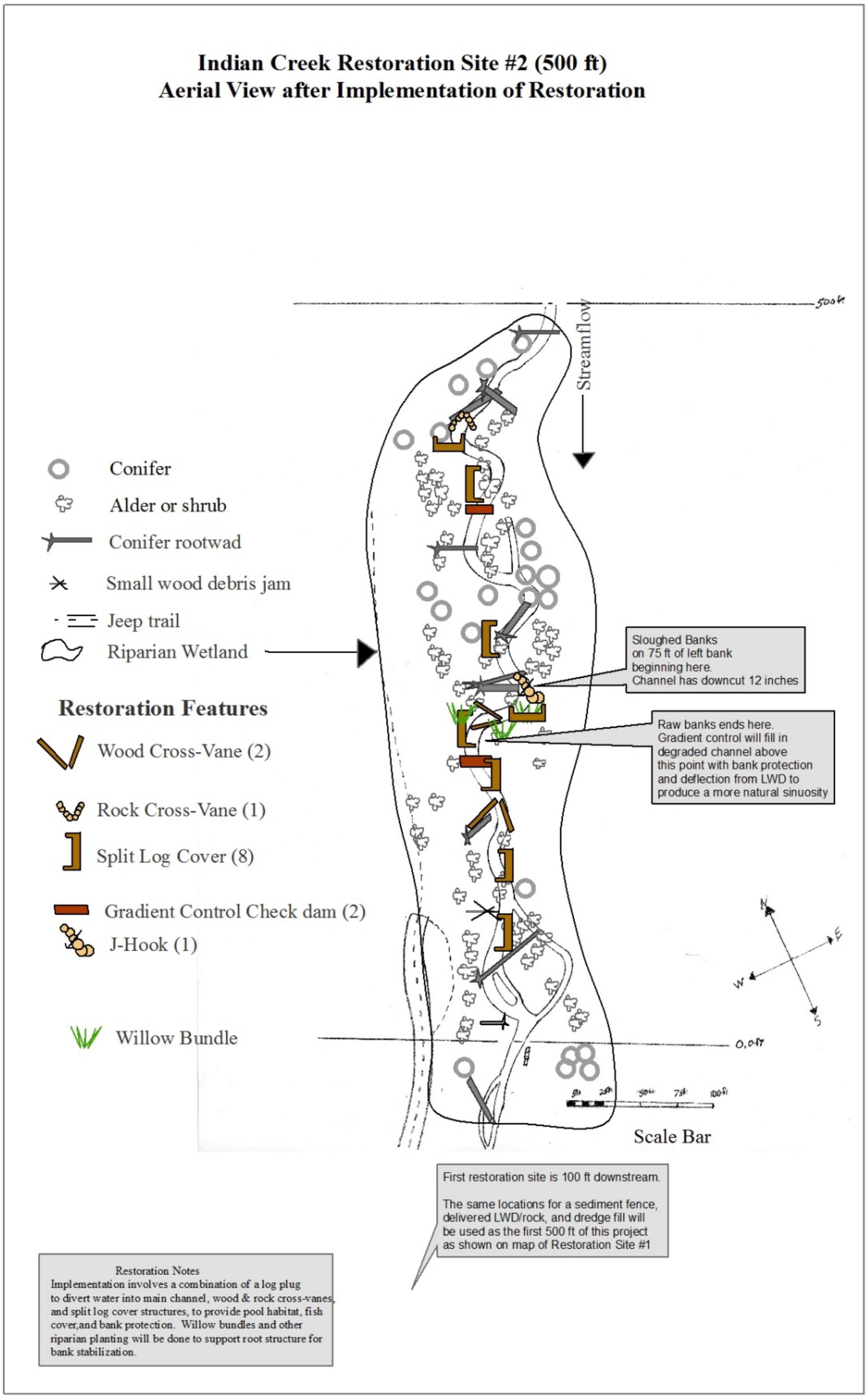

Figure 19. Map of a large woody debris placement project on Indian Creek, Reach 2C intiated in 2009 and completed in spring 2010.

Picture 5. Cross veins were by far the most successful technique to create pools below and behind the structures (left panel), and in combination with vertical logs to protect raw banks (right panel).

Picture 6. Check dams were used to facilitate channel aggradation (left panel), as well as provide plunge and dammed pool habitat (right panel).

Picture 7. The 125 foot-long incised section of channel with 4.0 feet of raw bank was rehabilitated with a large check dam (previous picture) to facilitate channel aggradation with two j-hooks, one cross vein and vertical logs in the background and horizontal log placements in the foreground, resulting in 1.0 ft of aggradation with continuous pool habitat.

Picture 8. Channel alteration techniques using split log structures to armor banks at elk trails (left panel), and log in mid channel to narrow a wide and shallow section (right panel).

Picture 9. The least successful LWD techniques were the low level check dams where scour sometimes occurred under the log (left panel), and side channel plugs which directed some, but not all flow into the main channel (right panel).

7.4 Project HA_11.9: Riparian Enhancement at Sweatlodge Area

Project Location:

Watershed: Hangman Creek
River Mile: 11.9 RM

Legal: T44N, R4W, Sec 28 NW ¼
Lat: 47.130289°N   Long: -116.834803 °W

Site Characteristics:

Slope/Valley gradient: 0.5%
Valley/Channel type: C5
Bkf Discharge (cfs): 423

Aspect: NW
Elevation: 2,605 ft.
Proximity to Water: Riparian
Drainage Area: (39.9mi²)

Other: *Hangman Reach 11 (HA11).Reach lies within CDA Tribal Trust land 1030 and commonly referred to the "Sweatlodge Area". Riparian enhancement was initiated in 2005 and has been ongoing with different treatments and plant protection methods.*

Problem Description:

Anthropogenic impacts have resulted in an incised channel lacking a connection between the stream and associated riparian habitat. Rosgen channel typing surveys (Kinkead and Firehammer 2011) found the bankfull height to be below sloughing banks (Picture 10). The reach is currently managed to exclude grazing and dryland farming , but impacts upstream from dryland farming and active forest management result in a flashy hydrograph. Reed Canary grass (*Phalaris arundinacea*) and other noxious weeds such as tansy ragwort (Senecio Jacobaea) dominate the riparian area, with some alder (*Alnus incana*), Pacific ninebark (*Physocarpus capitatus*), and Mackenzie willow (*Salix mackenzieana)*. Uplands consist of a mixed forest and meadow with Hawthorne (*Crateaegus monogyna*) as the dominate shrub. Beaver inhabit the area but are unable to build stable dams due to the paucity of larger building materials. Beaver surveys summarized in this report indicate a lack of larger building materials needed to build stable dams.

Picture 10. Hangman Creek, Reach 11, riparian and channel conditions in 2005.

Description of Treatment

The objective of the treatment is to stabilize banks with native riparian plants capable of supporting beaver and creating canopy cover. Potted hardwoods and willows were planted in Tribal Trust Land T1030 as a continuation of efforts initiated in 2005 (Kinkead and Firehammer 2011) using the same techniques used in 2009 (Kinkead and Firehammer 2012). Plantings were done to replace specific locations of the property with poor survival rates during 2005-7. Seventy-four 5 gallon pots of aspen (*Populus tremuloides*), coyote willow (*Salix exigua*), and alder (*Alnus incana*), along with 25 Drummond willow (*Salix drummondia*) poles and 225 Mackenzie willow poles were planted in 2010. Protective cones were placed on all hardwood trees and thirty hog panel enclosures were constructed to give protection from high flows and wildlife. First-year survival rates ranged from 60% - 85% and are summarized in Table 16.

Table 16. Summary of riparian enhancement in the Hangman Creek watershed and associated first year survival rates in 2010.

Hangman Cr: Summary of Riparian Enhancement & Survival Rate of Various Plants

2010	# Planted	% Survival 1st Year
Alder (5 gallon)	25	62.0
Aspen (5 gallon)	25	60.0
Willow (5 gallon)	24	85.0
Willow shoots (Dummond)	25	70.0
Willow shoots (MacKenzie)	225	65.0

7.5 Project SH_0.8: Riparian Enhancement of Sheep Creek

Project Location:

Sub-Watershed: Sheep Creek | Legal: T44N, R4W, Sec 36
River Mile: 0.8 RM | Begin: Lat 47.11345°N Long -116.77966°W

Site Characteristics:

Slope/Valley gradient: 0.8% | Aspect: S | Elevation: 2,706 ft.
Valley/Channel type: F5 | Proximity to Water: In channel and riparian
Bkf Discharge (cfs): 80.6 | Drainage Area: (7.2mi²)
Other: *This 2nd reach of Sheep (SH2) begins above the bridge at HWY 95 and continues until the culvert on the Benewah County road. Reach passes thru CDA Tribal Allotment A336/340.*

Problem Description:

Historically, the Sheep Creek valley was likely a mosaic of open stands of conifers, wet meadows and stream corridor riparian forest. Forest composition and structure would have been maintained by frequent fires. A compositionally diverse, deciduous/coniferous forest was likely distributed along complex gradients of elevation, aspect and site water balance. Forest and riparian tree species likely included: ponderosa pine, western white pine, western larch, Douglas fir, lodgepole pine, grand fir, aspen, and black cottonwood (DeVries and Featherstone 2012). Salmonids were found in a wide distribution in the watershed as recently as 1970 (Kinkead and Aripa 2005, unpublished).

Anthropogenic impacts have greatly altered the Sheep Creek watershed since the 1940's. Dryland farming with an extensive drainage tile system, grazing within the riparian areas and silvicultural activities throughout the watershed have altered channel morphology and riparian composition, resulting in impaired fish habitat. Cattle have been excluded from the study reach for over ten years and restoration to the reach below began with removal of drainage tiles in 2008, and a design to reconnect the stream and its floodplain as part of BPA Project 2001-032-00 (Interfluve 2008).

Site inspection by DeVries and Featherstone of R2 Resource Consultants, Inc. (2012) found the forest floodplain relatively intact in the sub-reach above Sheep Creek Road and only required conventional restoration techniques such as introduction of rootwads to facilitate aggradation and pool forming processes. Downstream of the culvert on Sheep Creek, they stated "the riparian zone is less intact, and key needs and opportunities for floodplain restoration are found within this reach. The Sheep Creek channel appears to be entrenched with a width:depth ratio narrower than would be expected from a more classic alluvial channel. The entrenched state is inferred to have been the result of the aforementioned land use practices". Relict floodplain channels are evident in the LiDAR data mostly in the lower half of the reach. R2 corroborated with Hardin-Davis (2005) and Herrera (2011) to determine that floodplain inundation was restricted to flows higher than estimated for a representative alluvial channel. R2 described the substrate; "Spawning gravels are available for redband rainbow trout throughout the reach and upstream. However, gravel was observed upstream of all beaver dams, and appears to be within the appropriate size range for spawning. Cleaning of fine sediments associated with redd construction would render all gravels suitable for spawning throughout the reach."

Present riparian conditions were described by R2; "Although riparian forests throughout the lower Sheep Creek drainage are all degraded or absent to a significant degree relative to historic conditions with reed canary grass dominating, existing remaining riparian vegetation can be used as a reference system upon which to base the vegetation composition of the restoration design. Currently, the Sheep Creek riparian corridor supports forest fragments of Ponderosa pine, western white pine, black cottonwood, gray alder, Douglas fir, black hawthorn, lodgepole pine, aspen, and grand fir. Shrub species include snowberry, Pacific ninebark, ocean spray, spirea, red osier dogwood, mountain alder, and willows. Wetland herbaceous species include slender sedge, lenticular sedge, small-winged sedge, Nebraska sedge, beaked sedge, Baltic rush, common rush, daggerleaf rush, slender rush, and small-fruited bulrush."

Picture 11. Sheep Creek, tributary of Hangman Creek. Channel and riparian conditions

Description of Treatment

The objective of the treatment is to stabilize banks with native riparian plants capable of supporting beaver activity and providing canopy cover. Potted hardwoods and willows were planted in Allotment 336 using the same techniques used in 2009 (Kinkead and Firehammer 2012). 204 five-gallon pots of alder, 75 aspen, 26 black cottonwood, 25 coyote willow, along with 25 Drummond willow poles and 225 Mackenzie willow shoots were planted in 2010. Protective cones were placed on all hardwood trees and thirty hog panel enclosures were constructed to give protection from high flows and wildlife. First-year survival rates ranged from 88-100% and third year survival rates ranged from 59–80% (Table 17). Maintenance was required from high flows by re-staking cones and cleaning hog panels of grass.

Table 17. Summary of riparian enhancement in Sheep Creek during 2010.

Sheep Cr: Summary of Riparian Enhancement & Survival Rate of Various Plants

2010	# Planted	% Survival 1st Year	% Survival 3rd Year
Alder (5 gallon)	200	96.0	59.0
Aspen (5 gallon)	75	88.0	60.0
Cottonwood (5 gallon)	26	96.0	55.0
Coyote Willow (5 gallon)	25	100.0	80.0
2011	# Planted	% Survival 1st Year	
Willow shoots (Dummond)	125	*	
Willow shoots (MacKenzie)	125	*	

Comparing first-year survival rates of trees protected with cones and hog panel enclosures and those only protected with cones did not reveal any significant difference. However, ruminant browsing prompted a second survey in spring of 2013 to look at current survival rates. Results indicate a qualitative difference between hog panel protected trees versus those not protected (Table 18). Vegetative survival surveys in the future will reflect the need to separate the two protective methods to determine if a statistical significant difference exists.

Table 18. Comparison of protection methods, cones and hog panels versus cones, using first and third year survival rates of various species planted in 2010 along Sheep Creek.

Comparison of Survival rates with and without hog panel enclosures

	Sheep Creek Allotment 336 1st Year Survival Rates			
	Aspen 5 gal	Cottonwood 5 gal	Alder 5 gal	Coyote Willow 5 gal
2010 (inside enclosures)	95	100	100	100
2010 overall	88	96	96	100

	Sheep Creek Allotment 336 3rd Year Survival Rates *			
	Aspen 5 gal	Cottonwood 5 gal	Alder 5 gal	Coyote Willow 5 gal
2010 (inside enclosures)	90	95	87	90
2010 overall	60	55	59	80

** survey completed in Spring 2013*

7.6 Hardwood Clippings Provided to Beaver (Multiple Locations)

Project Location:

Sub-Watershed: Mission Creek
River Mile: 3.8 RM

Legal: T44, R 5W, Sect 26 SW ¼ - NE ¼
Lat: 47.103236°N   Long: -116.940031°W

Site Characteristics:

Slope/Valley gradient: 1.3%
Valley/Channel type: C5
Bkf Discharge (cfs): unknown

Aspect: S
Elevation: 2,715 ft.
Proximity to Water: In channel and riparian
Drainage Area: (4.9mi²)

Other: *This 4th reach of Mission (MI04) begins above crossing with King Valley Road and passes thru CDA Tribal Allotment A632.Planned treatments include support poles for beaver dams and riparian enhancement, along with aspen cuttings as described in this contract period.*

Project Location:

Sub-Watershed: Sheep Creek
River Mile: 0.8 RM

Legal: T44N, R4W, Sec 36
Begin: Lat 47.11345°N   Long -116.77966°W

Site Characteristics:

Slope/Valley gradient: 0.8%
Valley/Channel type: F5
Bkf Discharge (cfs): 80.6

Aspect: S
Elevation: 2,706 ft.
Proximity to Water: In channel and riparian
Drainage Area: (7.2mi²)

Other: *This 2nd reach of Sheep (SH2) begins above the bridge at HWY 95 and continues until the culvert on the Benewah County road. Reach passes thru CDA Tribal Allotment A336/340.*

Project Location:

Watershed: Hangman Creek	Legal: T44N, R4W, Sec 28 NW ¼
River Mile: 11.9 RM	Lat: 47.130289°N Long: -116.834803 °W

Site Characteristics:

Slope/Valley gradient: 0.5%	Aspect: NW	Elevation: 2,605 ft.
Valley/Channel type: C5	Proximity to Water: Riparian	
Bkf Discharge (cfs): 423	Drainage Area: (39.9mi²)	

Other: *Hangman Reach 11 (HA11).Reach lies within CDA Tribal Trust land 1030 and commonly referred to the "Sweatlodge Area". Riparian enhancement was initiated in 2005 and has been ongoing with different treatments and plant protection methods.*

Problem Description:

All three locations (Figure 17) have active beaver populations who do not have access to adequate hardwoods in order to build stable dams. Beaver surveys summarized in this report indicate that mud, grass, and hawthorn are often used for building materials without incorporating any large materials as a foundation. The first stable dams found in the watershed were in the spring of 2010 in Sheep Creek. Reed canary grass dominates the riparian area with a minimal amount of alder. Aspen and cottonwood are nonexistent prior to riparian enhancement associated with the restoration project. Hangman Creek (HA11) has deeply a incised channel with little connection between the stream and riparian area. Sheep Creek (SH02) has moderately incised channels where peak flows occasionally spill out into the floodplain. Mission Creek (MI04) lies within an extensive beaver dam complex with a wide floodplain filled with side channels caused by beaver activity. However, it has been noted by Herrera (2011) that inadequate supplies of hardwood and willow exist.

Description of Treatment

Hardwood clippings consisting of mostly aspen along with some cottonwood and alder were cut and placed at existing beaver dams in 2011 to supplement food and building supplies. A total of 6,100 ft^3 of dam building materials were provided in 3 general locations, with 3 specific dam locations on each stream reach (Picture 12). This amounts to an equivalent of 1,151 pieces of 2 inch diameter by 10 feet long, roughly enough materials to build twenty dams four feet high, ten feet long, and fifteen feet wide. Materials were offered on Mission Creek R4, Sheep Creek R2, and Hangman Creek R11 (Figure 17). Brush offerings were made in May, July and September of 2011. The initial offering disappeared the first night on Mission and Sheep Creek with all sizes utilized. A 6 foot tall dam was repaired on Sheep Creek within 24 hours of the offering. Utilization of brush by beavers in July and September were more selective with all pieces <2" diameter taken within 48 hours, while the larger pieces 2 – 4" diameter were picked up within 2 weeks

Picture 13). Most of the clippings appeared to be used for food rather than dam building.

Picture 12. Hardwood clipping left on Sheep Creek to supplement beaver food and dam building supplies in 2011.

Picture 13. Beaver utilizing aspen cuttings left on bank on Sheep Creek.

7.7 Project SH_0.8: Sheep Creek LWD Addition Design

Project Location:

Sub-Watershed: Sheep Creek	Legal: T44N, R4W, Sec 36
River Mile: 0.8 RM	Begin: Lat 47.11345°N Long -116.77966°W

Site Characteristics:

Slope/Valley gradient: 0.8%	Aspect: S	Elevation: 2,706 ft.
Valley/Channel type: F5	Proximity to Water: In channel and riparian	
Bkf Discharge (cfs): 80.6	Drainage Area: (7.2mi²)	

Other: *This 2nd reach of Sheep (SH2) begins above the bridge at HWY 95 and continues until the culvert on the Benewah County road. Reach passes thru CDA Tribal Allotment A336/340.*

Problem Description:

Historically, the Sheep Creek valley was likely a mosaic of open stands of conifers, wet meadows and stream corridor riparian forest. Forest composition and structure would have been maintained by frequent fires. A compositionally diverse, deciduous/coniferous forest was likely distributed along complex gradients of elevation, aspect and site water balance. Forest and riparian tree species likely included: ponderosa pine, western white pine, western larch, Douglas fir, lodgepole pine, grand fir, aspen and black cottonwood (DeVries and Featherstone 2012). Salmonids were found in a wide distribution in the watershed as recently as 1970 (Kinkead and Aripa 2005).

Anthropogenic impacts have greatly altered the Sheep Creek watershed since the 1940's. Dryland farming with an extensive drainage tile system, grazing within the riparian areas and silvicultural activities throughout the watershed have altered channel morphology and riparian composition, resulting in impaired fish habitat. Cattle have been excluded from the study reach for over ten years and restoration to the reach below began with removal of drainage tiles in 2008, and a design to reconnect the stream and its floodplain as part of BPA Project 2001-033-00 (Interfluve 2008).

Site inspection by DeVries and Featherstone (2012) found the forest floodplain relatively intact in the sub-reach above Sheep Creek Road and only required conventional restoration techniques such as introduction of rootwads to facilitate aggradation and pool forming processes. Downstream of the culvert on Sheep Creek, they found "the riparian zone is less intact, and key needs and opportunities for floodplain restoration are found within this reach. The Sheep Creek channel appears to be entrenched with a width:depth ratio narrower than would be expected from a more classic alluvial channel. The entrenched state is inferred to have been the result of the aforementioned land use practices". Relict floodplain channels are evident in the LiDAR data mostly in the lower half of the reach. R2 corroborated with Hardin-Davis (2005) and Herrera (2011) to determine that floodplain inundation was restricted to flows higher than estimated for a representative alluvial channel. R2 described the substrate; "Spawning gravels are available for redband rainbow trout throughout the reach and upstream. However, gravel was observed upstream of all beaver dams, and appears to be within the appropriate size range for spawning. Cleaning of fine sediments associated with redd construction would render all gravels suitable for spawning throughout the reach."

The Sheep Creek riparian plant community is currently in a degraded state as a result of historic land clearing, channel entrenchment, and resulting decoupling of the historic floodplain from annual flooding. The Sheep Creek active floodplain is currently dominated by reed canary grass which actively excludes most native shrubs and trees, whereas the adjacent terraces and hillsides are under-stocked with conifers.

Description of Treatment

R2 Resource Consultants (R2) was contracted to develop designs emulating or enhancing the effects of beaver dams on floodplain inundation and restoration for an approximately 0.48 mile length of Sheep Creek upstream of Highway 95. The affected reach flows through Tribal Allotments A336 and 340. Landowners of these two allotments have given permission to the Coeur d'Alene Tribe to improve channel and riparian conditions for fisheries resources, without degrading the value of the land or its timber resources. Beaver are currently active in the reach and redband rainbow trout use beaver ponds in the reach as habitat. This reach was identified as a priority location for initial restoration efforts in the watershed (Herrera 2011).

Tribal objectives for restoring the reach as part of this project include:

- Restore stable channel and floodplain geometry;
- Reestablish native plant communities;
- Use natural materials to minimize risk of erosion and provide habitat diversity within stream and floodplain areas;
- Enhance wetland habitat and improve off-channel water sources;
- Optimize instream habitat for redband rainbow trout; and
- Create conditions that support and enhance current beaver activity.

In addition, a key landowner objective is to not inundate the floodplain to the point that evergreen tree growth is adversely affected.

To achieve these goals, R2 proposed a similar approach could be applied in Sheep Creek as has been implemented in Benewah Creek for the Coeur d'Alene Tribe BPA Project 1990-044-00, involving ecosystem engineering attributes of beaver. The design proposed will work toward improve the ability of beaver to build a greater proportion of stable dams large enough to increase floodplain inundation, and to include the current practice of supplying hardwood clippings until the availability of woody material suitable for dam building is available. The design is intended to accelerate re-vegetation of the riparian zone and floodplain by assisting beaver dam construction more directly, and by constructing in-channel structures that emulate the hydraulic effects of beaver dams during floods to increase the frequency and extent of floodplain inundation during the critical spring period. LIDAR imagery was used to identify relic channels and identify strategic wood structure locations that would increase floodplain inundation frequency.

Proposed Conceptual Design

There are three types of beaver dam oriented prescriptions proposed at eight specific locations.

1. **Log-Constructed Flow Choke Structures** are proposed at three locations. The in-channel structures emulate flow obstruction effects of natural wood jams and beaver dams, allowing for more frequent and extensive floodplain connection during annual floods. Locations are selected strategically to facilitate connection of floodplain swales during high flows, and/or reduce erosive forces on streambanks. One structure (BD-8) is designed to flood a relic channel just upstream in an area where existing dam building materials would not permit a natural dam to form sufficiently in order to increase floodplain connectivity. The lowest in the reach, (BD-1) lies in an area of active bank erosion, and is designed to back up water into a relic floodplain channel and relieve pressure on the eroding bank. The 3rd choke structure (BD-3) is located downstream of the second largest existing beaver dam in the reach, and combined with measures to stabilize the dam, should create a large beaver pond complex with significant overbank flow into the same major floodplain swale that empties above BD-1.

2. **Beaver Assist Poles** are proposed for four locations to reinforce existing beaver dams. This technique is based on work performed recently in the John Day River basin ("RED" structures, Pollock et al. 2011). It is a simple, cost effective approach that involves installation of vertical poles spaced across the channel. Beaver use the poles as a framework for dam construction. Two of the dams (BD-4 and BD-7) are substantial in size and persistence, where installation of supporting poles will help beaver dams

maintain their present size. The other two dams (BD-2 and BD-6) are small in size at locations where their presence appears to be relatively regular based on previous surveys, but they may be transient because of flood damage. Installation of poles would provide a more stable framework for dam building. In all four cases, it will be necessary to continue supplying beaver with cut branches for dam building material on the riverbank.

3. **Beaver Assist Logs** are proposed for one location (BD-5). An existing in-channel log is to be attached to two large logs and braced with vertical support poles to assist beaver with future dam construction. The wood would also provide fish habitat cover and structure in the interim.

Riparian Design

R2 proposed using existing remaining riparian vegetation as a reference system upon which to base the vegetation composition of the restoration design. Currently, the Sheep Creek riparian corridor supports forest fragments of Ponderosa pine, western white pine, black cottonwood, gray alder, Douglas fir, black hawthorn, lodgepole pine, aspen and grand fir. Shrub species include snowberry, Pacific ninebark, ocean spray, spirea, red osier dogwood, mountain alder and willows. Wetland herbaceous species include slender sedge, lenticular sedge, small-winged sedge, Nebraska sedge, beaked sedge, Baltic rush, common rush, daggerleaf rush, slender rush, and small-fruited bulrush. The overarching vegetation restoration goal is to establish a compositionally diverse floodplain and riparian forest plant community along the stream corridor over 5-10 years, one that will develop over the next 50-100 years into a mature riparian forest ecosystem. Riparian species will consist heavily of willows, Pacific ninebark and black cottonwood.

A primary strategy we are proposing for the Sheep Creek restoration is the utilization of black cottonwood's unique life history characteristics to rapidly "flip" or change the current degraded riparian ecosystem into a diverse self-sustaining riparian forest. Although black cottonwood's regenerative strategy (seedling establishment on bare alluvial substrates and branch fragment vegetative propagules) likely resulted in it historically playing a non-dominant role in these riparian forests, its life history characteristics make it ideal for rapidly establishing a complex riparian forest. These characteristics include: vegetative propagation, very rapid growth rate (approximately 50-60 feet in 15 years on floodplain site), and flooding tolerance. Establishment of cottonwood components of the riparian forest along the Sheep Creek floodplain and stream banks will provide exceptional hydrologic, biogeochemical and plant and animal habitat functional lift within 5-10 years as well as control the trajectory of ecosystem development over next 100+ years. Dense plantings of willow, red osier dogwood and cottonwood will supply local beaver populations with ample future dam building materials facilitating local backwater flooding of adjacent floodplain wetlands. These hydrologically restored areas will support a diverse emergent, scrub-shrub and forested wetland plant community (DeVries and Featherstone 2012).

The riparian enhancement design includes zone specific prescriptions including species, and density:

- **Terrace and Hillslope Riparian Forest (Zone A):** Upper banks; Ponderosa and Aspen
- **Steep Streambank Shrub Stabilization (Zone B):** Sheared banks stabilized with dogwood poles and Pacific ninebark *(Physocarpus capitatus)*
- **Floodplain to Terrace Bank Revegetation (Zone C):** Transitional zone planted with wide variety consisting of willows, dogwood, and shrubs.
- **Reed Canary grass Floodplain Restoration (Zone D):** Lower bench; canary grass eradication and planted with willows, dogwood, ninebark and sedge plugs.

7.8 Project BU_0.6: Bunnel Creek Culvert Replacement

Project Location:

Sub-Watershed: Bunnel Creek	Legal: T44, R 3W, Sect 33
River Mile: 0.6 RM	Begin: Lat: 47.113073°N Long: -116.725478 °W

Site Characteristics:

Slope/Valley gradient: 6.0%	Aspect: SW	Elevation: 3,312 ft.
Valley/Channel type: B4	Proximity to Water: In channel and riparian	
Bkf Discharge (cfs): 40	Drainage Area: (0.5mi²)	

Other: *Reach ID:BU02. Culvert on the Sanders-Imida Road that was identified as a fish passage barrier due to slope and was undersized to handle peak flows.*

Problem Description:

The culvert on the Sanders-Emida Road at Bunnel Creek was identified as a fish passage barrier for juveniles as well as adults by Kinkead and Firehammer (2012). Measurements were taken and analyzed using methods described by Hendrickson et. al (2008). The culvert was considered inadequate to carry high flows. In addition, the slope and outlet drop were limiting fish passage.

Culvert Slope: 6.0% Culvert Dia: 36” Outlet Drop: 1.5 ft. Culvert Length: 70ft.

The Sanders-Emida road had poor drainage and road fill frequently ran directly into Hangman Creek 0.5 miles downstream of Bunnel Creek. Consequently, a drainage culvert was needed half way down this portion of the Sanders-Emida road. Idaho Department of Lands surveyed the existing culvert and recommended a 6ft pipe to accommodate the watershed above (Idaho Dept. of Lands 2009).

Description of Treatment

The combination of the two problems outlined above led to a partnership by the Coeur d’Alene Tribe, Benewah Conservation District, and Benewah County. The three agencies were awarded a 319 Grant to replace the culvert on Bunnel Creek along with installation of a new drainage pipe 0.3 miles downstream of the Bunnel Creek crossing. Administration of the grant was done by the Benewah County Conservation District. Benewah County supplied the 6 ft pipe and heavy equipment to complete pipe installation. Installation was done at a 4% gradient to aid fish passage but channel work was needed downstream to prevent a repeat of the outlet drop that previously existed. Coeur d’Alene Tribe personnel provided erosion control and a water pump to divert water during installation. Tribal personnel then used erosion control matting on the raw banks and built a series of step pools backing water into the culvert. A fish ladder design was supplied by the Idaho Dept. of Lands (Figure 20). The fish ladder was welded into 10 foot sections and bolted together on site. Once bolted to the inside of the culvert, cobble was placed in the rebar rings welded onto the steel angles (Picture 14).

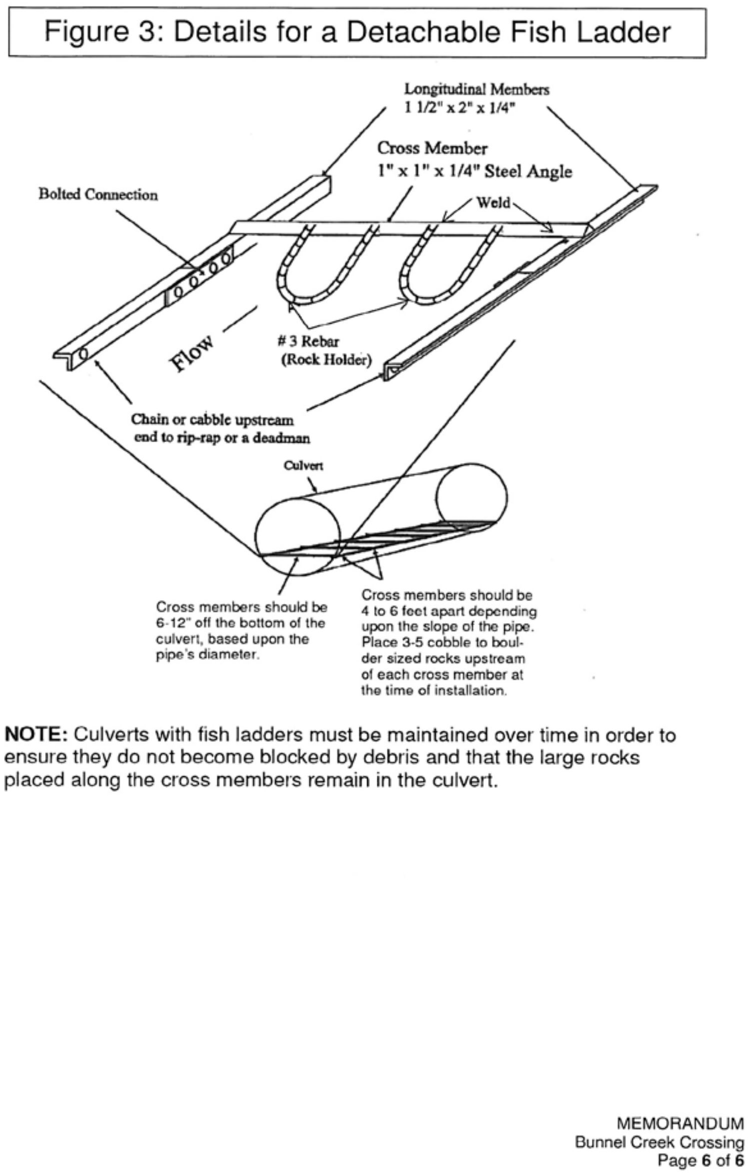

Figure 20. Diagram of an existing design of culvert fish ladder supplied by Idaho Dept of Lands using steel angles and rebar.

Picture 14. Bunnel Creek culvert replacement. 24" pipe (left panel) replaced with a 60" pipe, and LWD structures to facilitate a step pool sequence below the culvert (right panel). Rebar rings and rock were incorporated to facilitate fish passage through the culvert (bottom panel).

7.9 Summary and Conclusions

The project has thus far completed small pilot projects in restoration in which we have learned moderately impaired tributaries of Hangman Creek can be enhanced with simple restoration including hand placed large woody debris and riparian and upland enhancement. However, main-stem and tributary habitat with severely incised channels require too much effort to enhance the riparian habitat without first completing intensive channel work to re-connect the stream and its floodplain. The design for choke structures on Sheep Creek will be implemented in 2012 and we will use the lessons learned on this project to proceed with larger scale projects on the main-stem of Hangman Creek where recent purchases through Avista mitigation funding has given us access to a 3 mile section of stream.

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10. APPENDICES

A. Linear Regression Output

Table 19. Linear regression model based on the relationship between single and multiple pass electrofishing.

Standard Error	2.02
Observations	75.00

ANOVA

	df	*SS*	*MS*	*F*	*Signif. F*
Regression	1.00	13218.11	13218.11	3238.10	0.00
Residual	73.00	297.99	4.08		
Total	74.00	13516.10			

	Coefficients	*S. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.58	0.32	-1.79	0.08	-1.22	0.07
X Variable 1	1.32	0.02	56.90	0.00	1.28	1.37

B. Repeated Measures Analysis Output

Table 20. Repeated measures statistical analysis showing a significant difference between treatment and control groups (p-value of 0.063) and no significant differences within treatment or within control groups (p- value of 0.621 and 0.680).

Source	SS	df	MS	F	P
TREAT$	310.083	1	310.083	14.479	0.063
Error	42.833	2	21.417		

Source	SS	df	MS	F	P	G-G	H-F
a	63.500	2	31.750	0.539	0.621	0.539	0.621
a*TREAT$	50.167	2	25.083	0.426	0.680	0.581	0.680
Error	235.667	4	58.917				

C. Water Quality Results

Table C-1. Summary of water quality in Hangman Creek collected in June and August 2010-2011.

	Hangman-Stateline						
Date/Time	**TSS (mg/l)**	**Turbidity (NTU)**	**DS ft³/sec**	**D.O. mg/L**	**Temp (C)**	**pH**	**Cond**
6/8/10 17:30		49.50	3.718	7.04	14.93	6.64	74.86
8/23/10 20:00		4.22	<0.3	3.14	17.69	7.48	169.90
6/27/11 16:00	11.00	7.47	1.164	6.68	19.74	8.15	91.10
8/23/11 15:15		2.78	0.448	4.16	18.86	8.02	181.50

	Hangman-Buckless						
Date/Time	**TSS (mg/l)**	**Turbidity (NTU)**	**DS ft³/sec**	**D.O. mg/L**	**Temp (C)**	**pH**	**Cond**
6/8/10 16:25		12.70	48.508	8.70	13.90	6.78	49.84
8/23/10 16:10		2.58	0.230	6.26	18.96	6.93	65.41
6/27/11 15:15	5.00	6.96	6.168	7.50	17.38	7.20	38.40
8/23/11 14:45		2.50	0.348	5.60	20.32	6.81	62.61

	Hangman-SF Road						
Date/Time	**TSS (mg/l)**	**Turbidity (NTU)**	**DS ft³/sec**	**D.O. mg/L**	**Temp (C)**	**pH**	**Cond**
6/8/10 12:55		12.00	3.936	9.22	9.93	6.62	42.57
8/23/10 15:35		3.27	0.066	6.74	13.77	6.79	51.60
6/27/11 14:45	4.00	5.57	1.462	8.59	13.61	6.69	30.24
8/23/11 14:10		3.64	0.399	7.20	16.98	6.78	43.76

	Hangman-Forest						
Date/Time	**TSS (mg/l)**	**Turbidity (NTU)**	**DS ft³/sec**	**D.O. mg/L**	**Temp (C)**	**pH**	**Cond**
6/8/10 10:45		9.48	3.560	10.25	7.34	5.80	39.53
8/23/10 14:00		2.32	0.141	8.10	10.44	6.81	46.38
6/27/11 14:30	5.00	4.06	1.235	9.23	10.53	6.80	27.24
8/23/11 13:45		2.92	0.396	8.56	12.99	6.44	40.93

Table C-2. Summary of water quality in Hangman Creek during 2010 – 2011.

		Mission-Desmet					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/27/11 11:15	4.00	9.57	1.155	7.60	17.20	7.55	76.80
8/22/11 11:25		1.31	0.060	0.95	13.74	6.58	314.60
6/7/10 16:45		27.40	5.585	7.59	16.45	7.57	71.90
8/23/10 18:00			0.000				

		Mission-King Valley					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
8/23/10 18:10		2.65	0.013	3.90	13.80	6.89	135.70
6/27/11 10:50	8.00	15.80	0.811	8.01	12.45	6.73	48.11
8/22/11 10:25		2.47	0.036	4.17	10.96	6.18	139.90

		Mission-MF					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/10 13:15		17.50	1.025	10.38	8.22	5.49	32.26
8/23/10 18:45		4.49	0.009	7.55	12.20	6.78	41.24
6/27/11 9:15	4.00	10.70	0.295	9.99	8.37	6.07	24.18
8/22/11 8:40		4.87	0.026	7.62	11.95	6.05	38.02

		Mission-EF					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/27/11 9:55	<2	13.20	0.173	8.57	8.98	6.09	28.37
8/22/11 9:40		6.70	0.003	5.84	10.87	5.90	54.42
6/7/10 13:45		19.60	0.680	9.60	8.85	5.90	36.22
8/23/10 19:15			0.000				

		Mission-WF					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/10 14:35		30.70	0.700	9.04	10.68	6.23	51.21
8/23/10 19:30		6.72	0.012	4.17	13.41	6.39	70.67
6/27/11 8:00	4.00	13.60	0.254	9.41	8.63	6.08	34.87
8/22/11 10:55		7.28	0.006	6.20	11.88	6.09	60.60

		Sheep-HWY 95					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/10 11:50		41.70	10.056	8.19	11.21	6.12	62.93
8/23/10 17:40		1.20	0.010	4.34	13.86	6.62	119.80
6/27/11 12:45	6.00	9.72	0.837	7.81	14.00	6.36	34.15
8/22/11 13:00		8.73	0.110	3.42	13.16	6.11	93.66

		Sheep-Upper					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/10 11:00		8.57	1.108	11.36	8.07	5.51	28.31
8/23/10 17:15		2.18	0.069	8.16	11.65	6.78	30.97
6/27/11 12:15	2.00	4.29	0.531	10.11	9.53	7.55	20.11
8/22/11 11:50		2.61	0.037	8.55	12.67	6.49	30.59

Table C-3. Summary of water quality in Hangman Creek during 2010- 2011.

Nehchen-Lower

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 15:45		9.51	12.474	9.30	11.08	6.17	34.42
7/16/10 10:45			0.476				
8/23/10 16:00			DRY				
6/28/11 9:10	2.00	5.35	1.088	9.17	10.21	6.04	28.43
8/23/11 9:00			DRY				

Nehchen-Upper

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 16:50		6.07	3.444	10.11	8.24	5.91	26.72
8/23/10 16:30		2.17	0.054	7.82	12.49	6.65	34.72
6/28/11 8:15	2.00	2.64	0.659	10.00	8.53	5.49	18.48
8/23/11 8:00		2.87	0.044	8.38	11.05	6.00	30.76

Indian Creek-Sanders

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
7/16/10 11:10			0.784				
8/23/10 13:10		2.01	0.316	7.87	13.48	6.70	46.95
6/28/11 10:45	5.00	4.08	3.072	9.09	10.94	6.33	23.04
8/23/11 11:20		2.91	0.398	8.04	14.82	6.42	38.34

Indian Creek-Pow Wow

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 13:55		7.79	7.730	10.22	7.99	6.20	30.90
8/23/10 12:40		1.46	0.270	8.93	10.43	5.85	38.90
6/28/11 10:10	3.00	2.77	2.620	9.74	9.69	5.99	22.47
8/23/11 10:50		1.81	0.361	9.08	12.86	6.17	36.01

Indian Creek-Upper

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 14:55		4.57	2.505	10.25	7.92	6.30	35.08
8/23/10 11:25		0.98	0.062	7.48	9.64	6.40	61.26
6/28/11 15:15	<2	1.95	0.697	9.02	10.31	6.52	29.59
8/23/11 10:00		1.15	0.138	7.72	11.51	6.41	56.01

Indian Creek-NF

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 14:35		3.96	2.682	10.57	7.87	5.72	22.74
8/23/10 11:45		1.15	0.252	9.61	9.44	4.96	24.25
6/28/11 15:40	<2	2.33	1.199	9.49	11.08	5.93	14.66
8/23/11 9:25		0.94	0.162	10.23	12.64	6.02	22.20

Indian Creek-EF

Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 15:15		4.59	1.868	10.12	7.60	6.00	38.86
8/23/10 10:50		0.92	0.034	7.85	9.40	5.92	49.44
6/28/11 15:00	4.00	2.19	0.223	9.79	9.43	6.48	26.84
8/23/11 10:25		1.53	0.047	8.19	11.18	6.23	43.32

Table C-4. Summary of water quality in Hangman Creek during 2010 – 2011.

		Smith					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/10 15:35		23.80	4.316	8.44	12.83	6.54	72.22
8/23/10 15:45			DRY				
6/27/11 13:20	6.00	7.71	0.863	8.11	15.34	7.72	60.65
8/22/11 13:50			DRY				
		SF Hangman-Lower					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 12:30		7.69	4.225	9.10	10.38	6.63	53.35
8/23/10 15:15		4.50	0.078	5.30	12.39	6.57	98.99
6/28/11 14:00	4.00	6.42	2.250	7.60	14.26	6.81	42.12
8/22/11 14:45		4.66	0.122	5.41	13.47	6.61	97.86
		SF Hangman-Upper					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/28/11 12:50	<2	3.59	0.273	8.03	10.93	7.15	39.32
8/22/11 14:05			0.000				
6/8/10 11:40		6.35	1.426	9.32	7.99	5.83	51.44
8/23/10 14:30			DRY				
		Conrad					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 12:10		5.69	0.386	8.60	11.00	6.61	42.50
8/23/10 15:10			DRY				
6/28/11 13:45	3.00	5.55	0.206	7.47	14.44	7.18	29.68
8/22/11 14:40			DRY				
		Martin					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 11:10		6.88	1.000	8.71	8.47	6.63	52.67
8/23/10 14:45		2.92	0.102	6.07	11.00	6.74	88.99
6/28/11 13:20	<2	4.06	0.314	7.51	11.70	7.11	45.93
8/22/11 14:25		3.30	0.103	6.33	12.45	5.74	91.84
		Bunnel					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 10:00		7.77	1.086	10.48	6.89	5.27	33.34
8/23/10 13:35		1.59	0.075	8.25	10.19	5.84	40.30
6/27/11 13:50	4.00	3.59	0.230	9.58	9.22	5.87	26.20
8/23/11 12:50		3.40	0.029	9.08	12.47	6.12	38.33
		Parrot					
Date/Time	TSS (mg/l)	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/10 10:20		17.90	0.236	10.87	6.31	5.64	37.69
8/23/10 13:55		2.77	0.008	6.34	10.61	6.71	77.77
6/27/11 14:10	4.00	8.72	0.052	9.01	8.85	6.16	33.68
8/23/11 13:25		3.06	0.018	7.08	11.51	6.40	69.61

D. Continuous Temperature Graphs

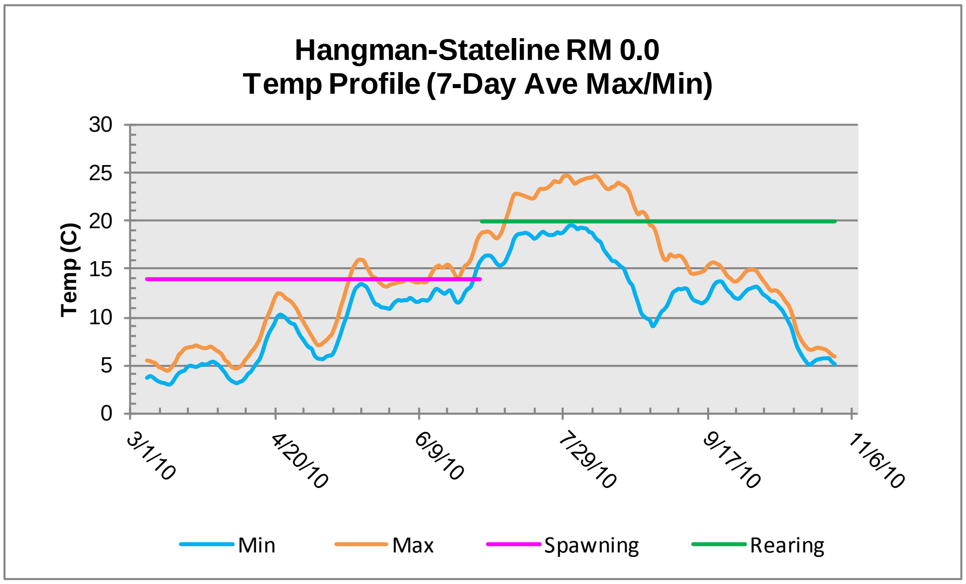

Figure D-1: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

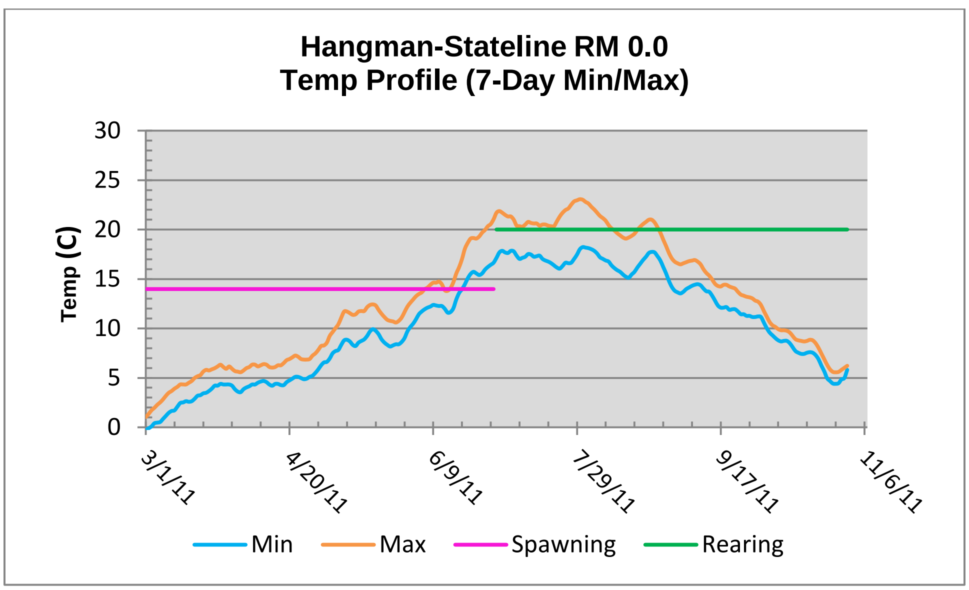

Figure D-2: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

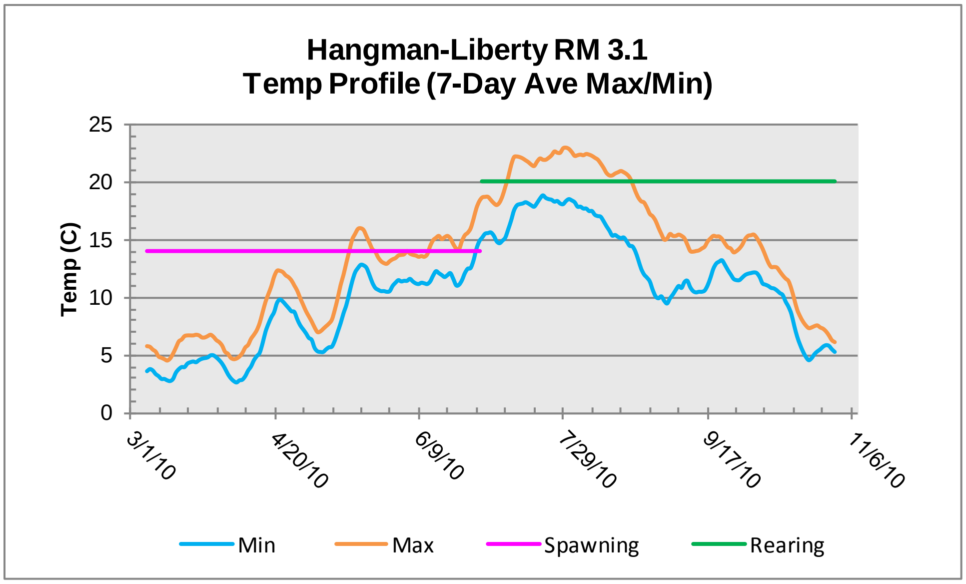

Figure D-3: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

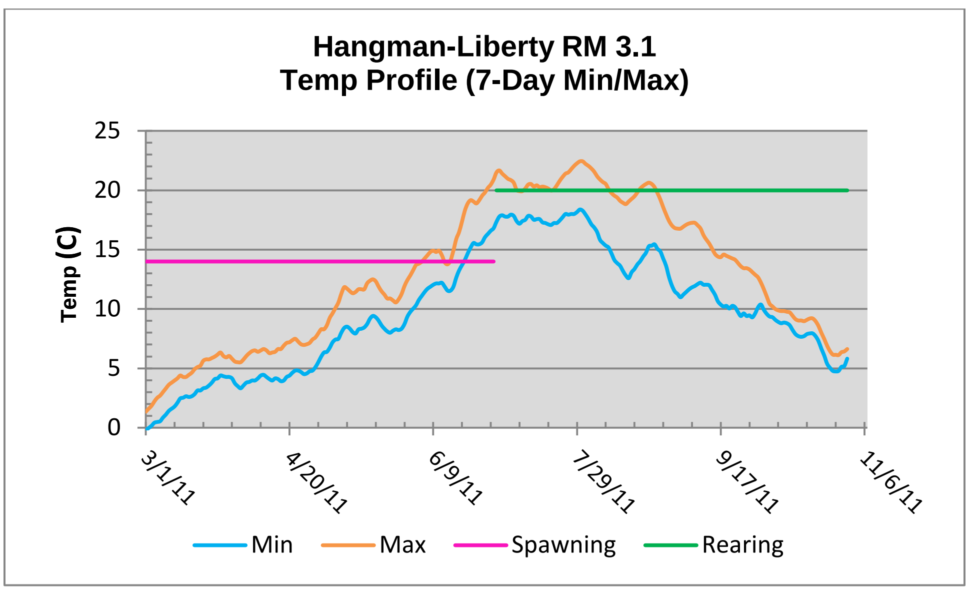

Figure D-4: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

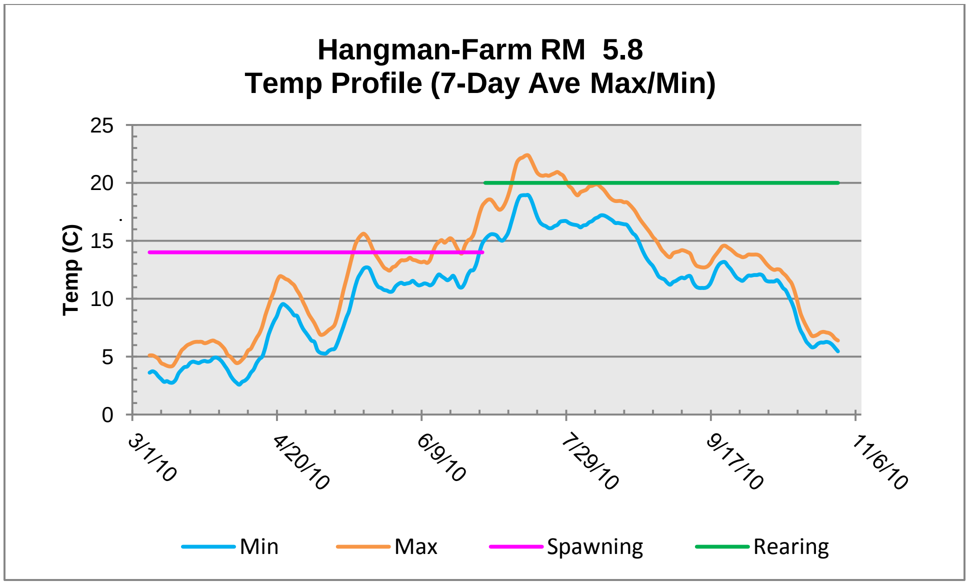

Figure D-5: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

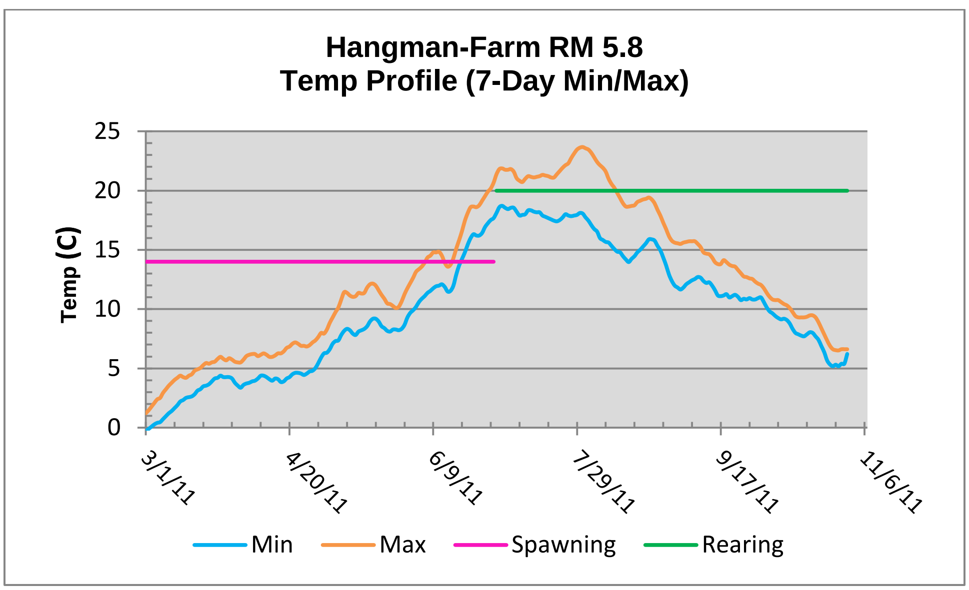

Figure D-6: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

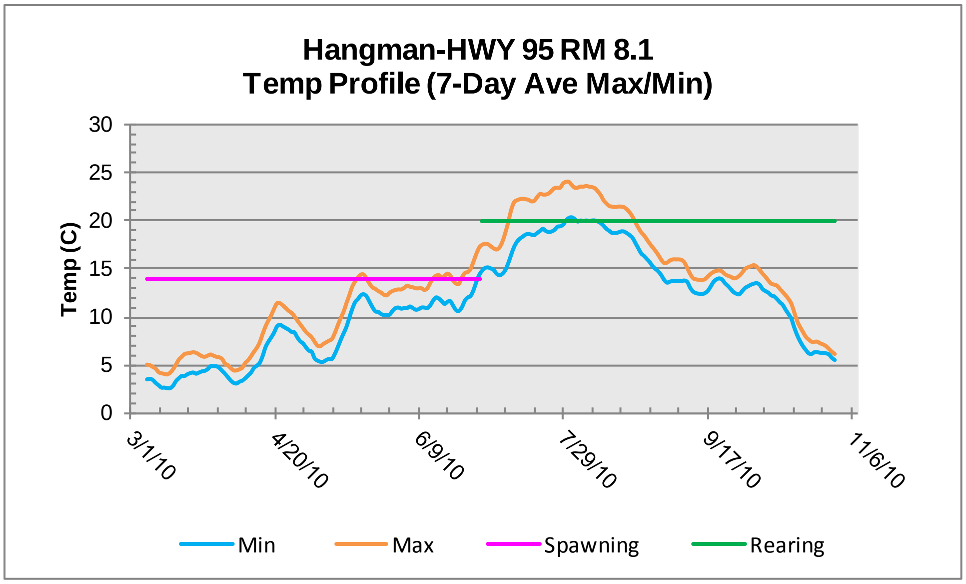

Figure D-7: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

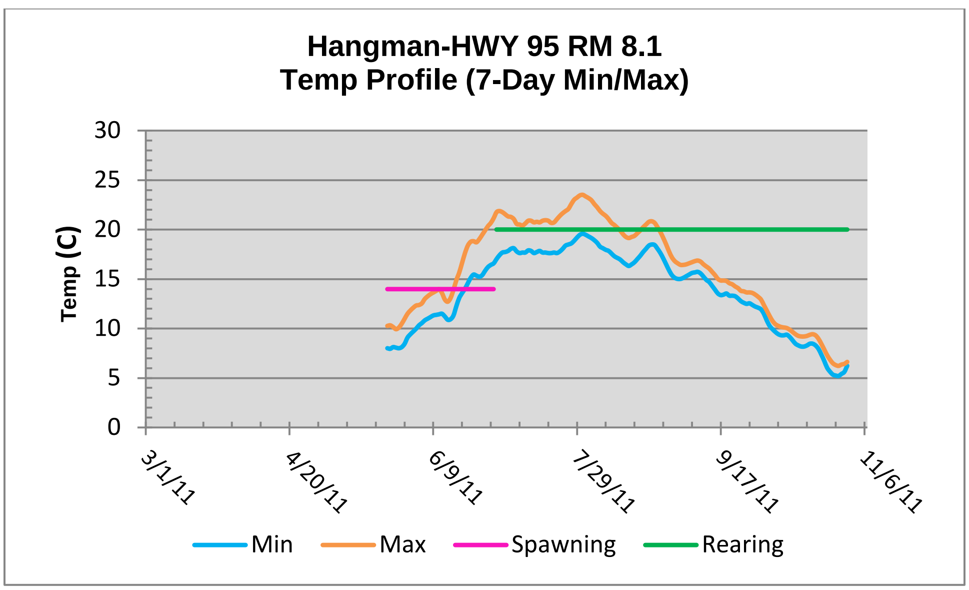

Figure D-8: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

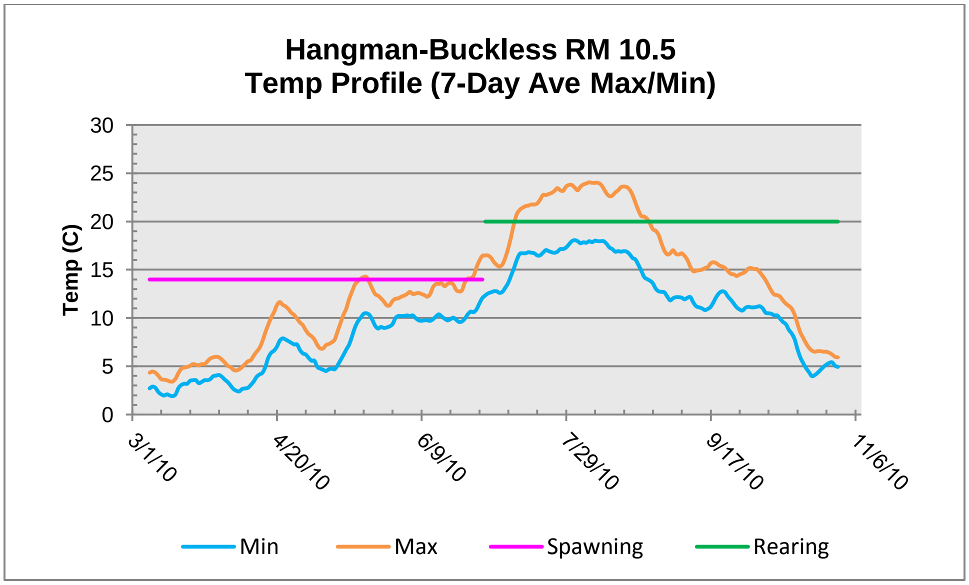

Figure D-9: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Buckless in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

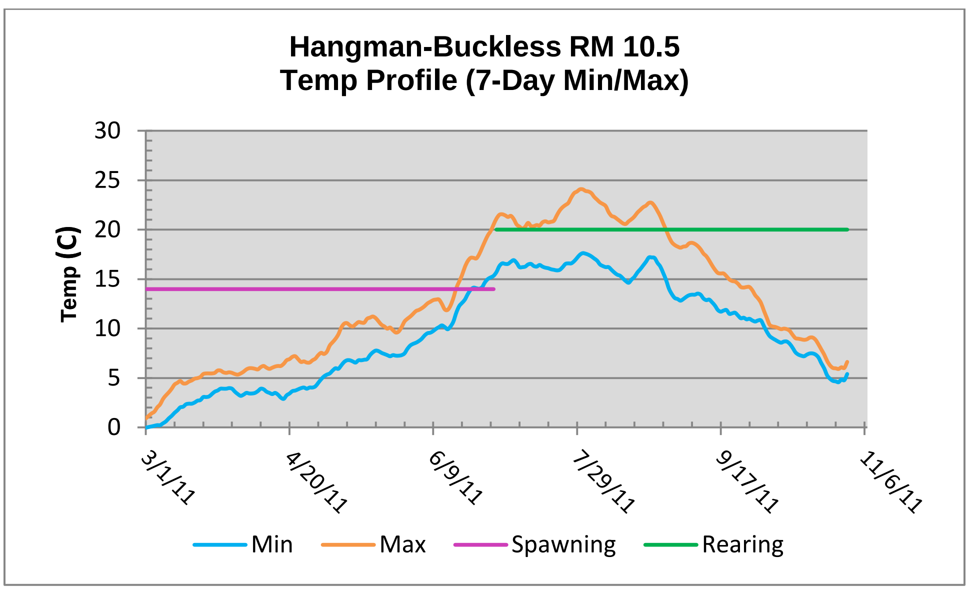

Figure D-10: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Buckless in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

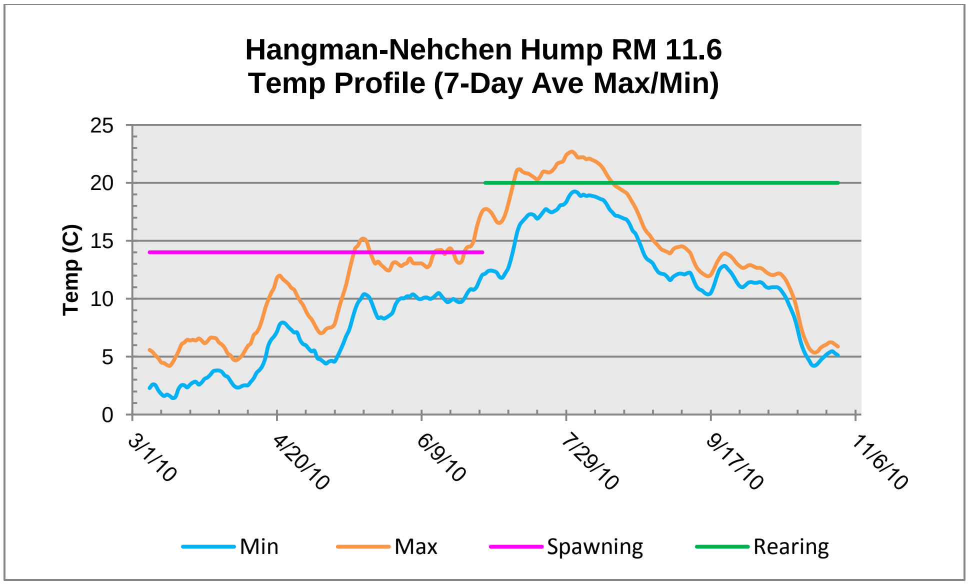

Figure D-11: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

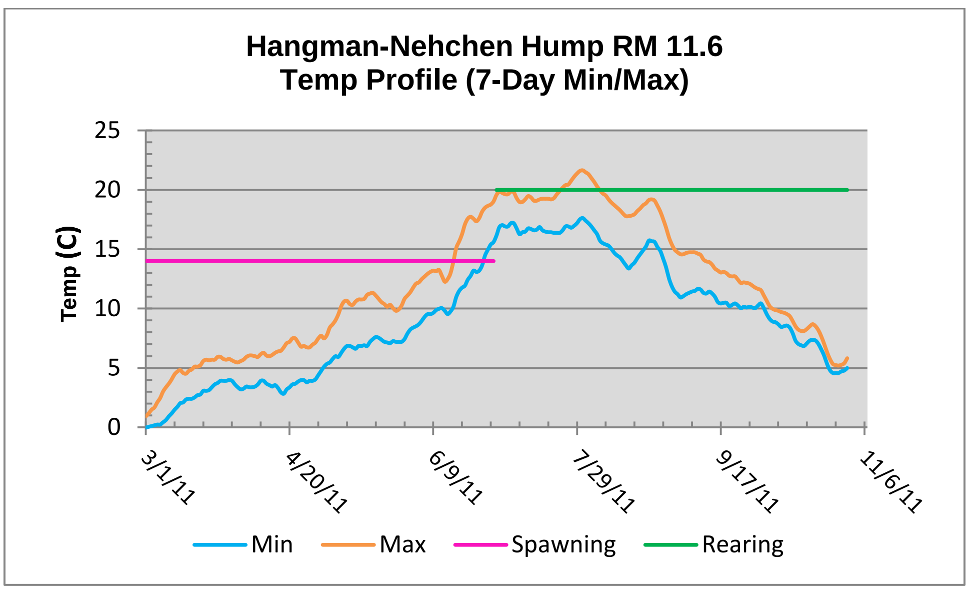

Figure D-12: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

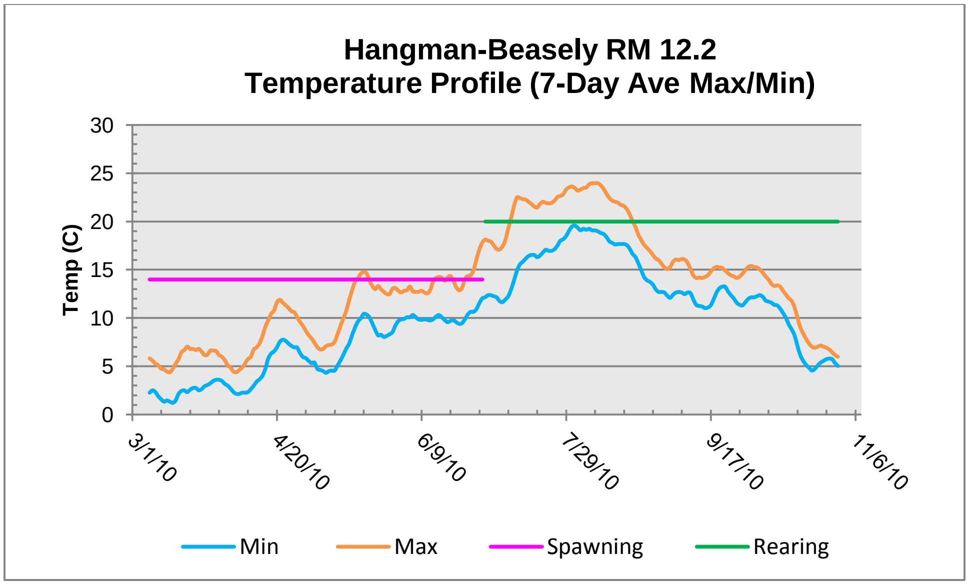

Figure D-13: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

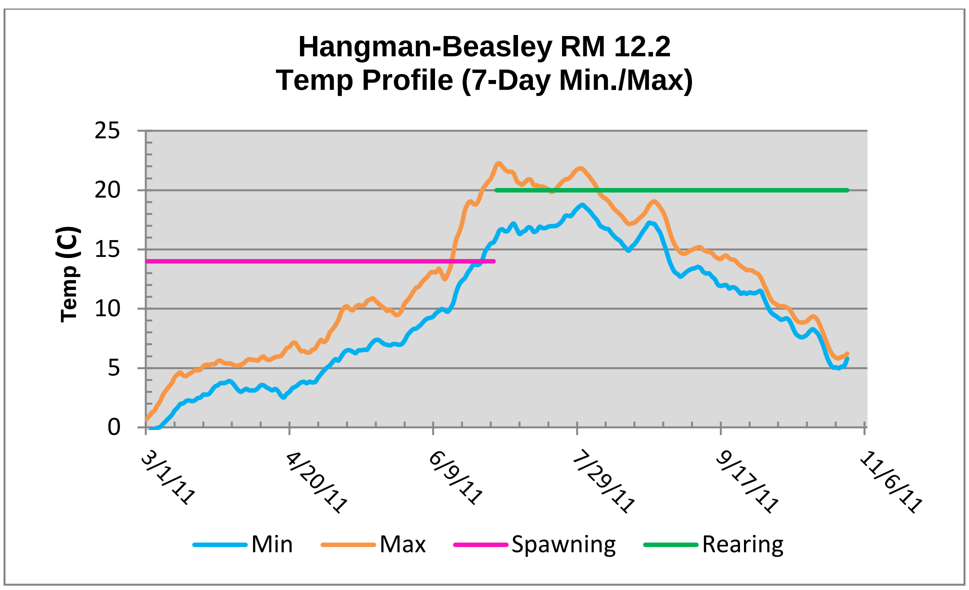

Figure D-14: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

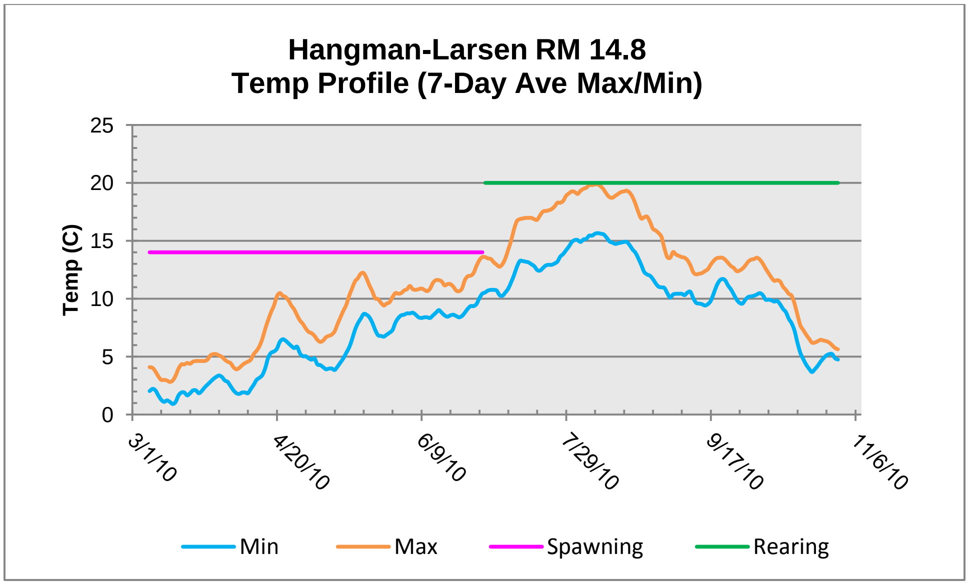

Figure D-15: Average weekly maximum/minimum temperature profiles of Hangman Cr.-Larsen in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

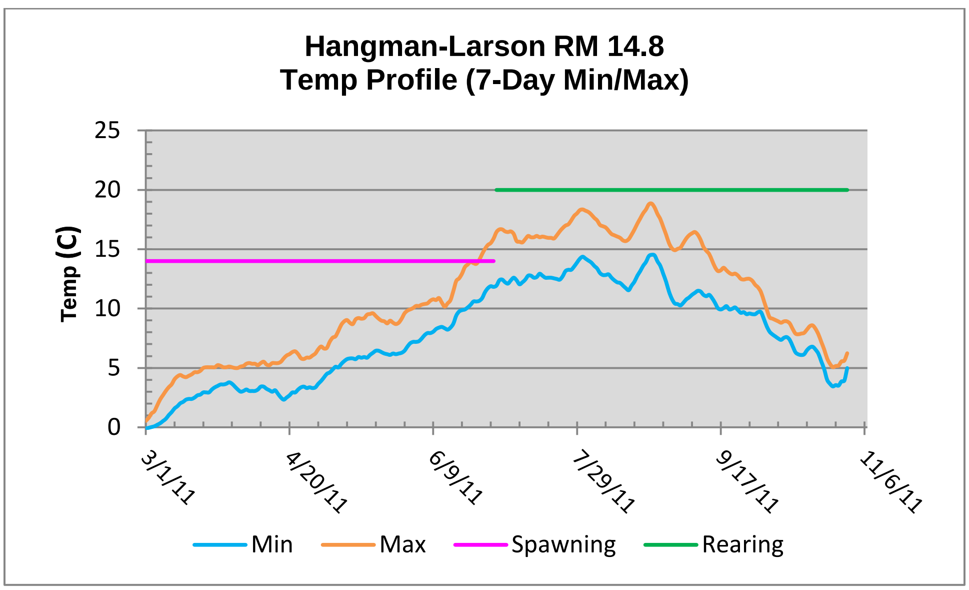

Figure D-16: Average weekly maximum/minimum temperature profiles of Hangman Cr. - Larsen in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

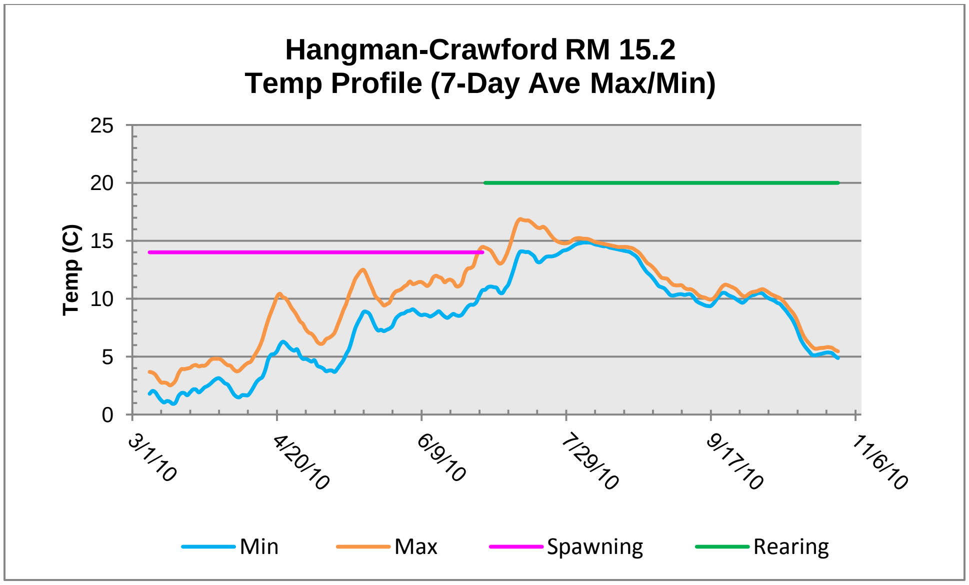

Figure D-17: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

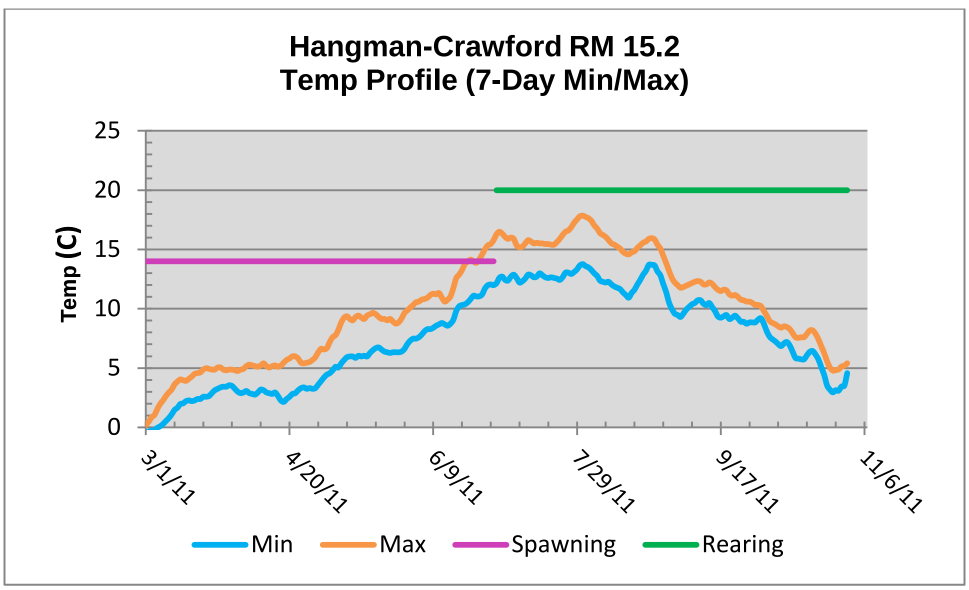

Figure D-18: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

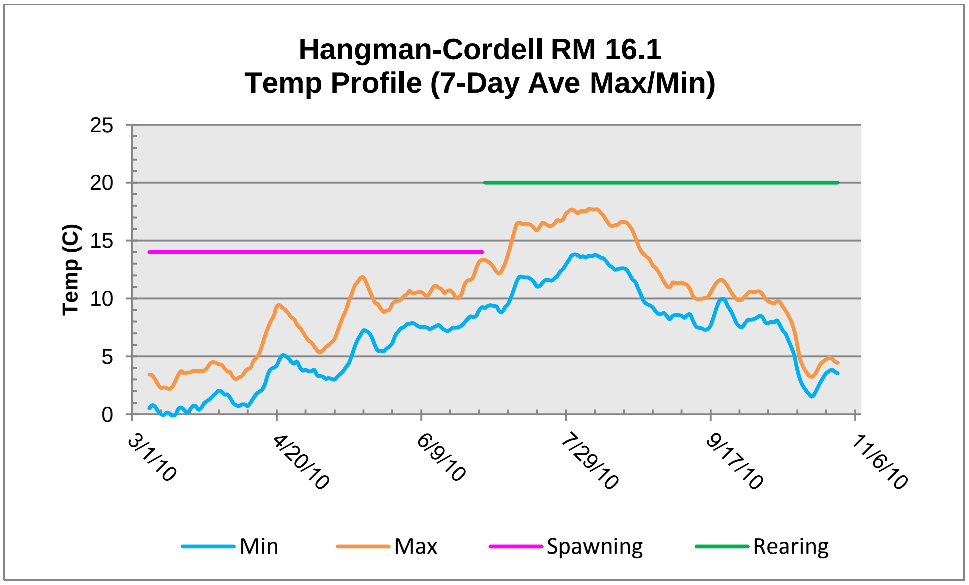

Figure D-19. Average weekly maximum/minimum temperature profiles of Hangman Cr. at RM 16.1 in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

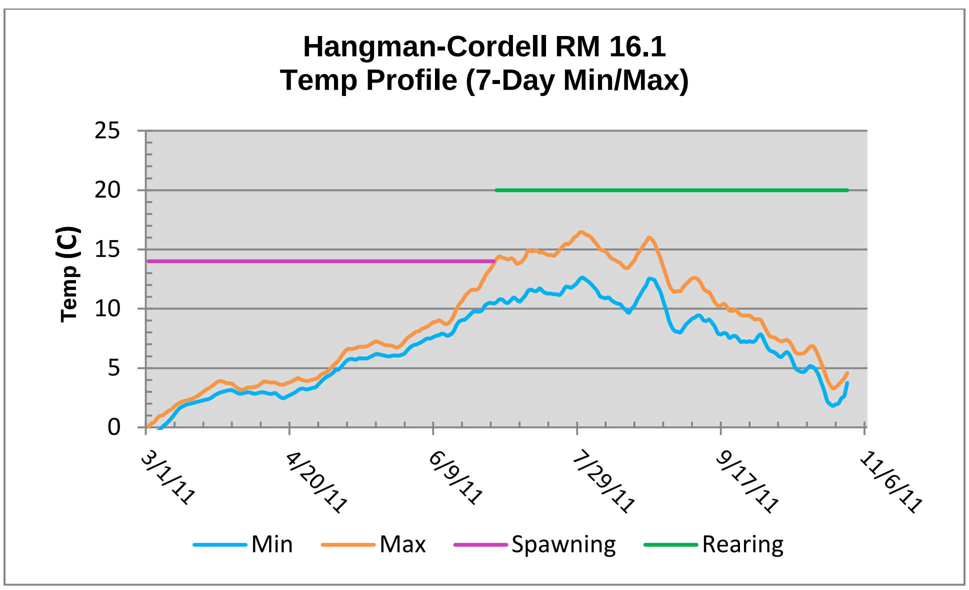

Figure D-20. Average weekly maximum/minimum temperature profiles of Hangman Cr. at RM 16.1 in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

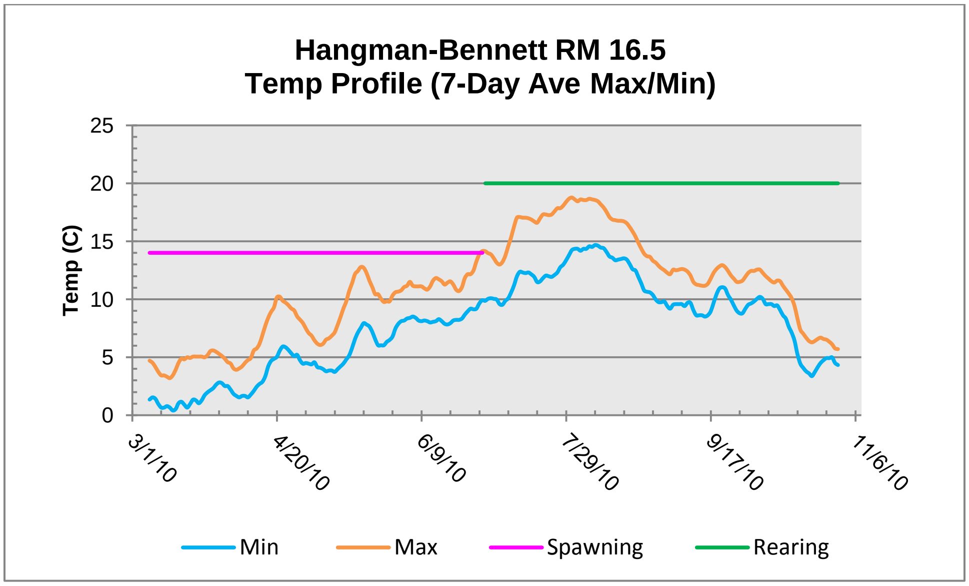

Figure D-21: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

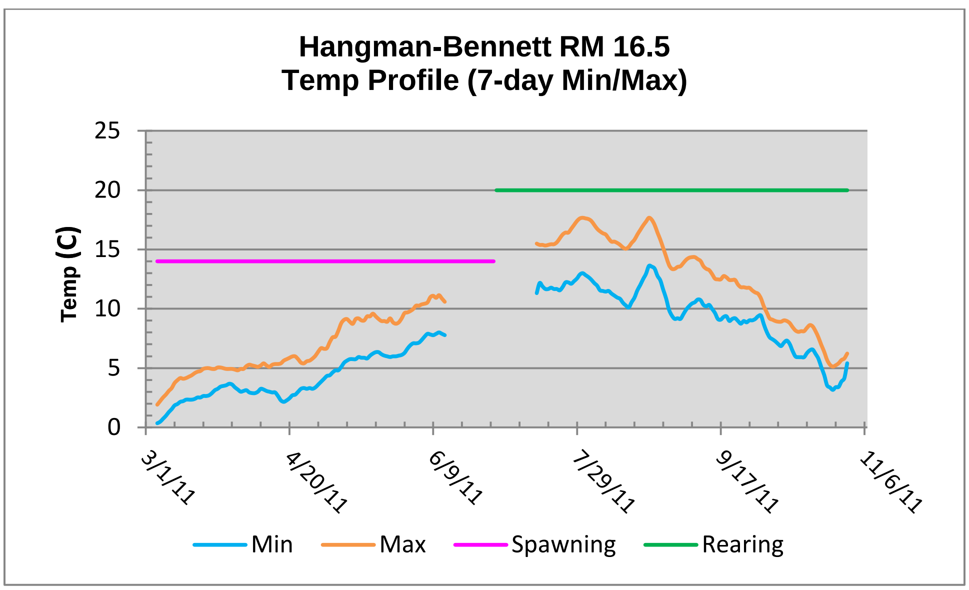

Figure D-22: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. *(Logger was out of the water June 15 – July 20th)*

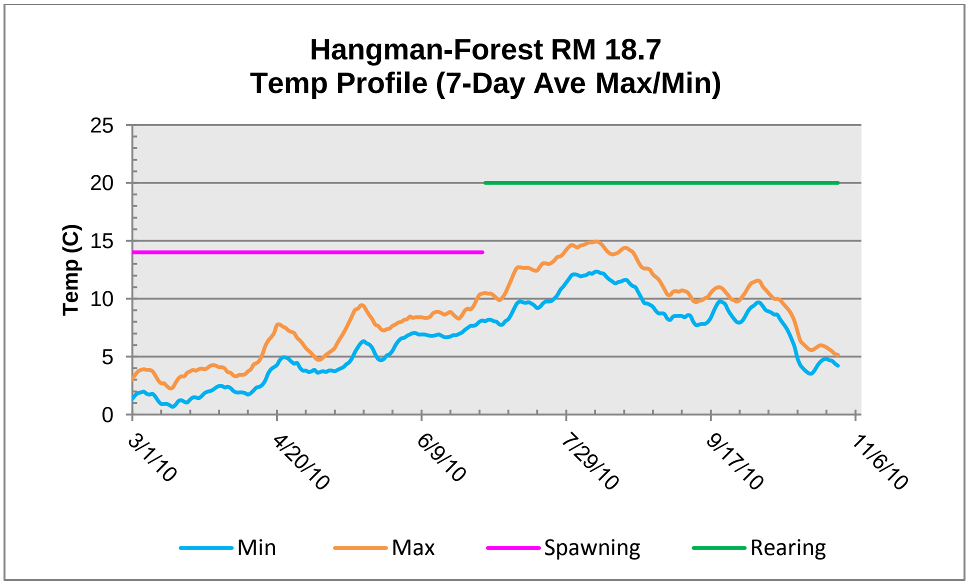

Figure D-23: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Forest in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

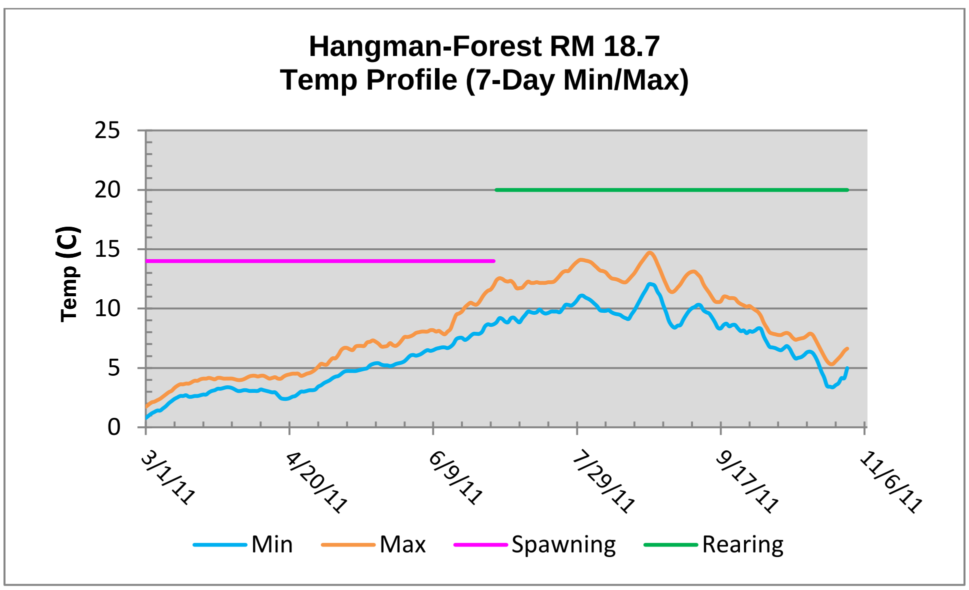

Figure D-24: Average weekly maximum/minimum temperature profiles of Hangman-Forest in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

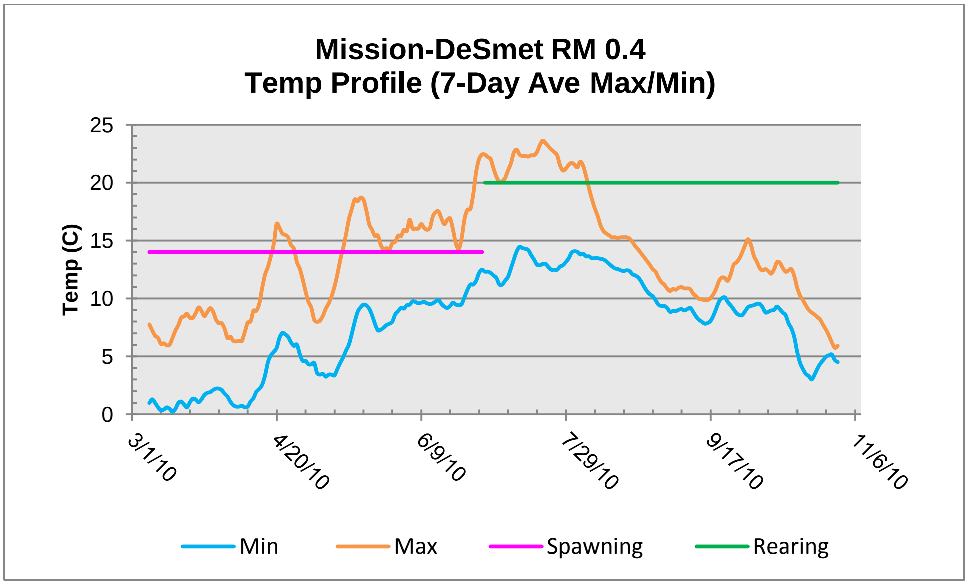

Figure D-25: Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

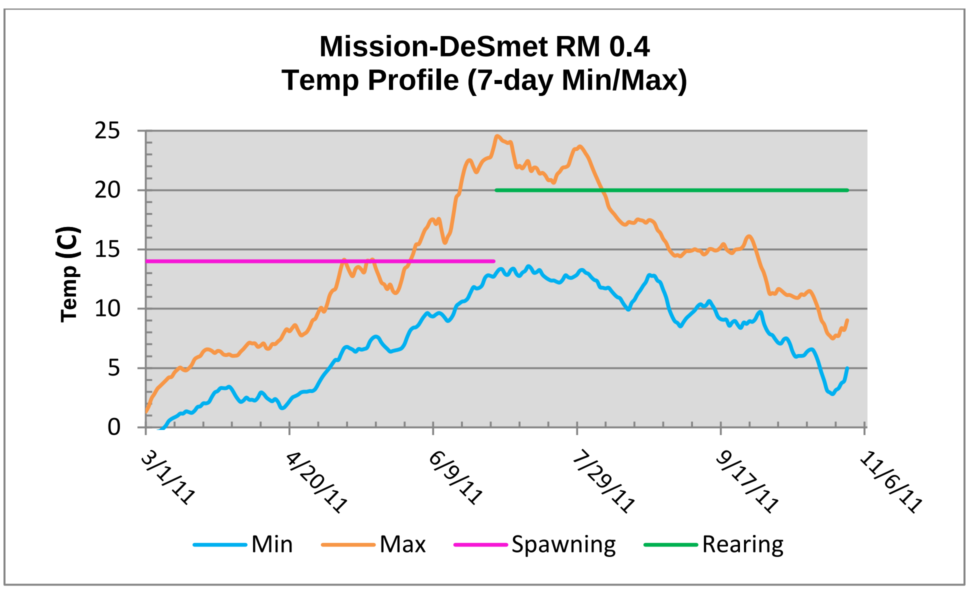

Figure D-26: Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

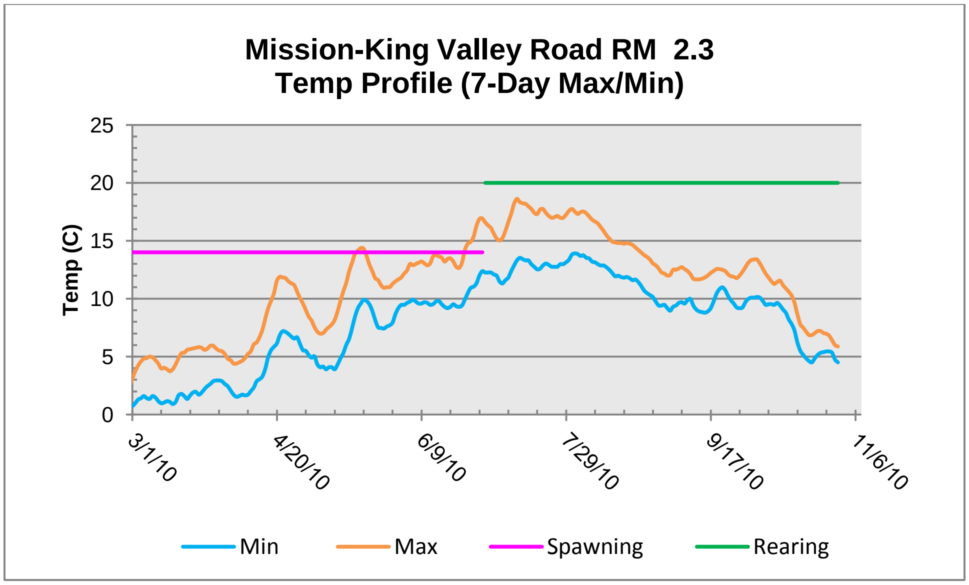

Figure D-27: Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

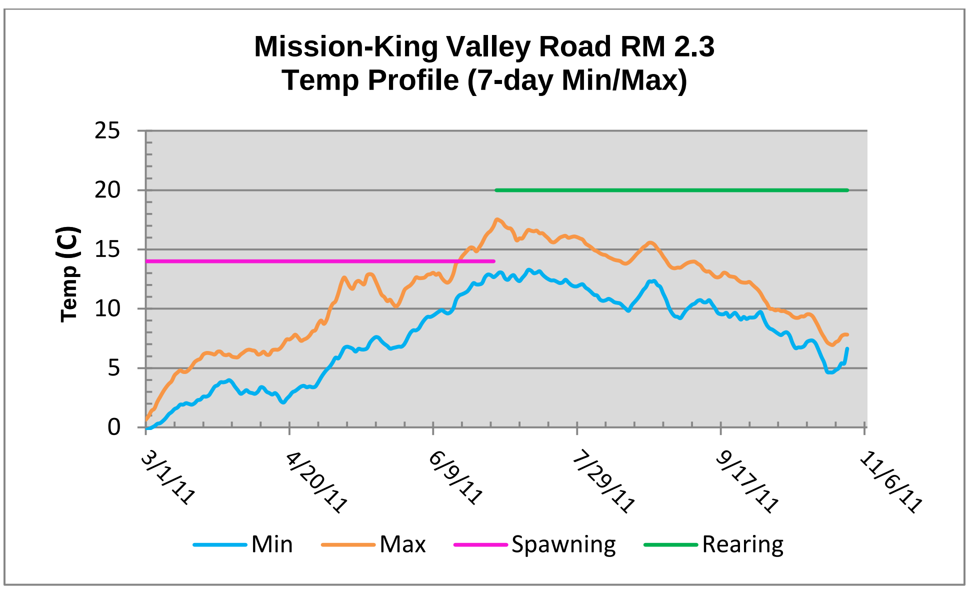

Figure D-28: Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

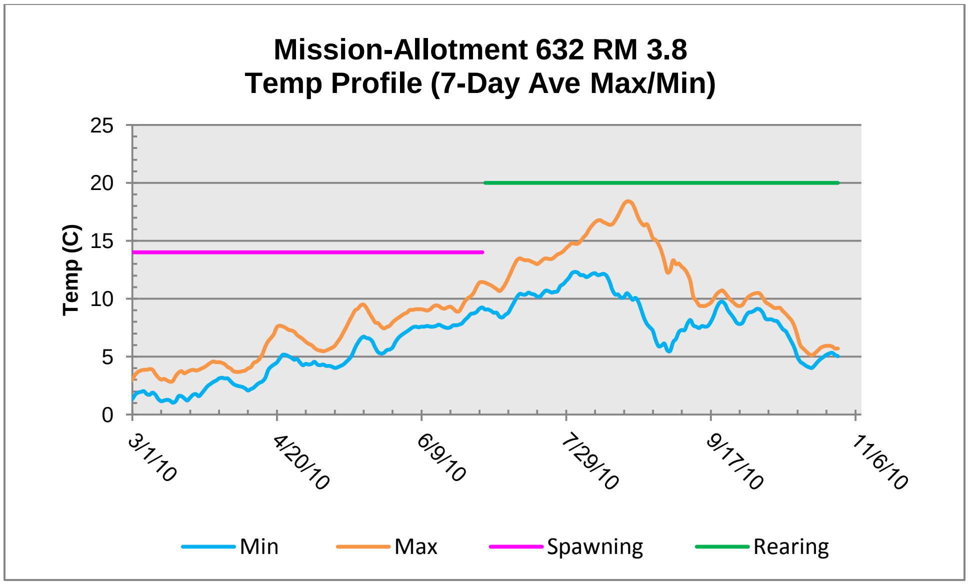

Figure D-29. Average weekly maximum/minimum temperature profiles of Mission Cr. Allotment 632 RM 3.8 in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

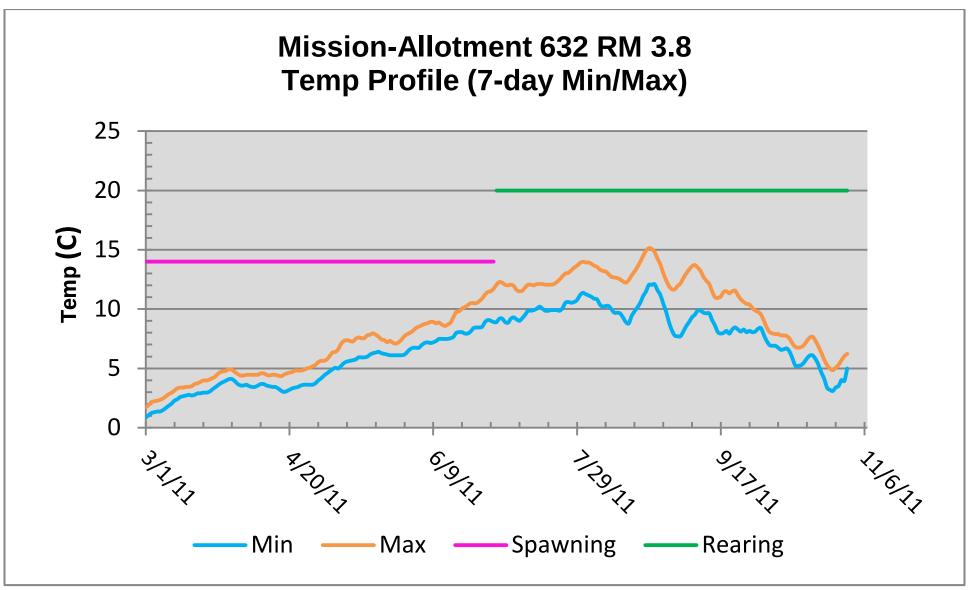

Figure D-30. Average weekly maximum/minimum temperature profiles of Mission Cr. Allotment 632 RM 3.8 in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

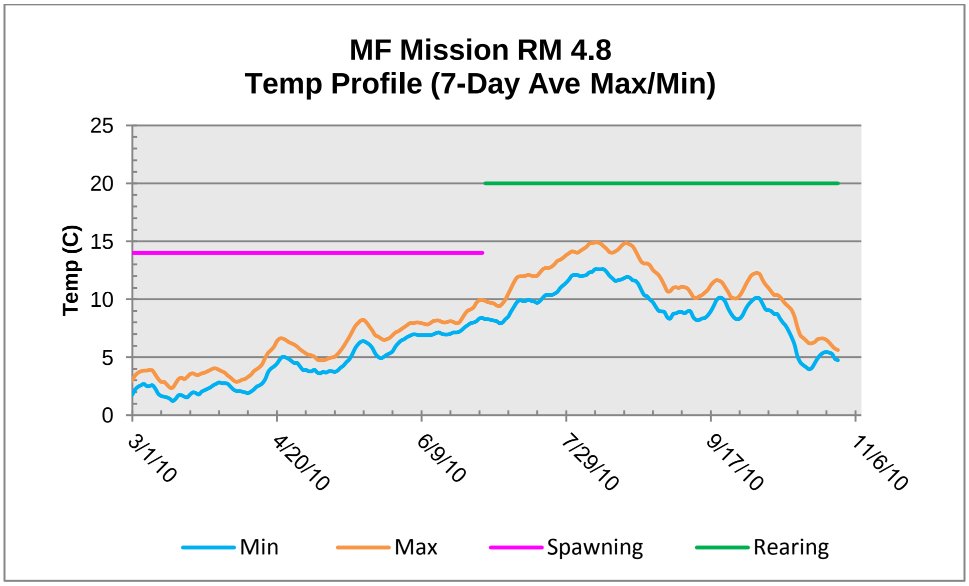

Figure D-31: Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

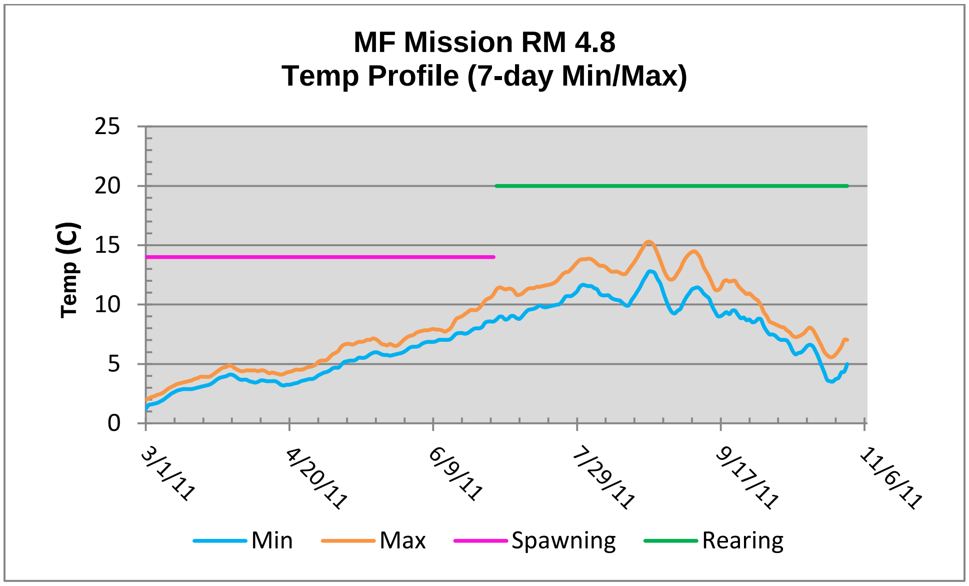

Figure D-32: Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

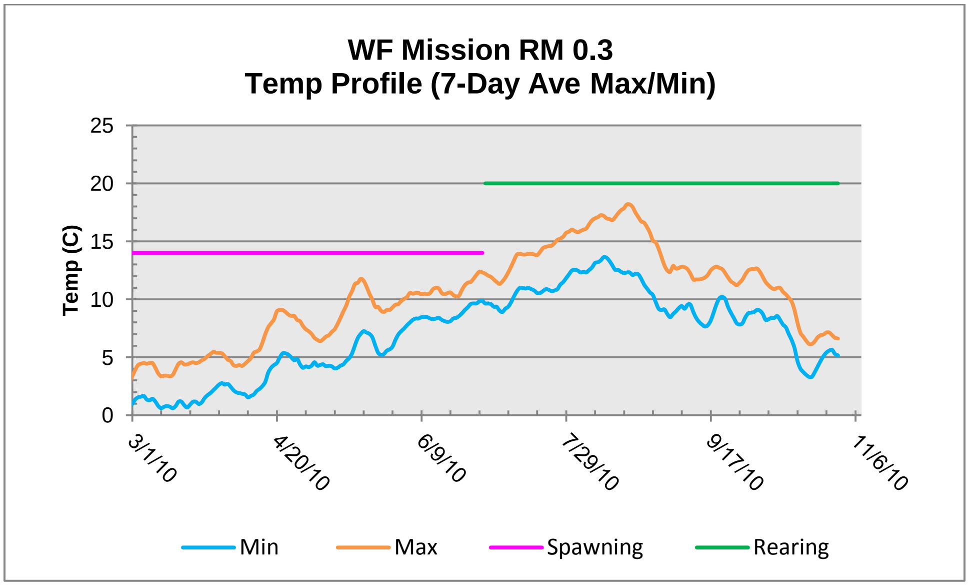

Figure D-33: Average weekly maximum/minimum temperature profiles of the WF Mission Creek in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

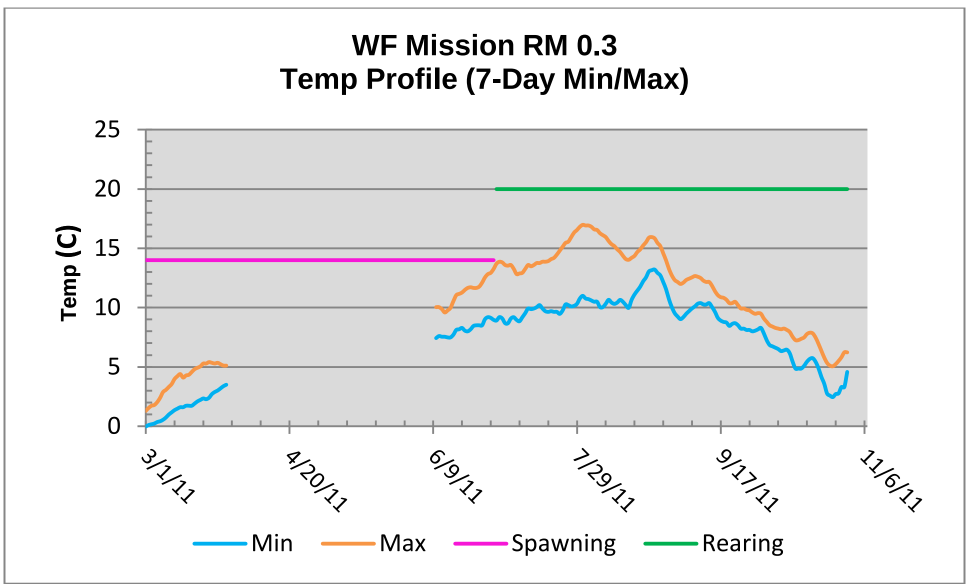

Figure D-34: Average weekly maximum/minimum temperature profiles of the WF Mission Creek in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

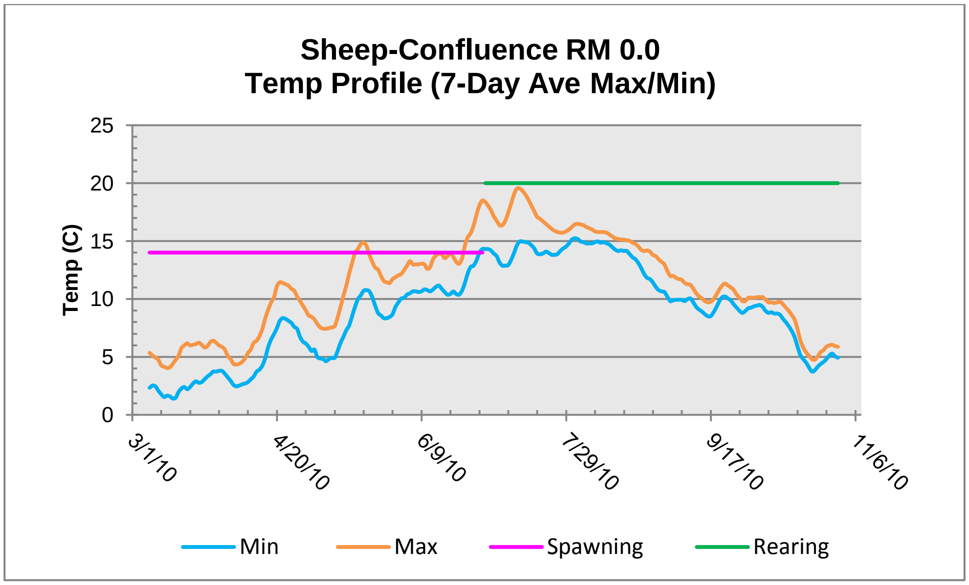

Figure D-35: Average weekly maximum/minimum temperature profiles of Lower Sheep Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

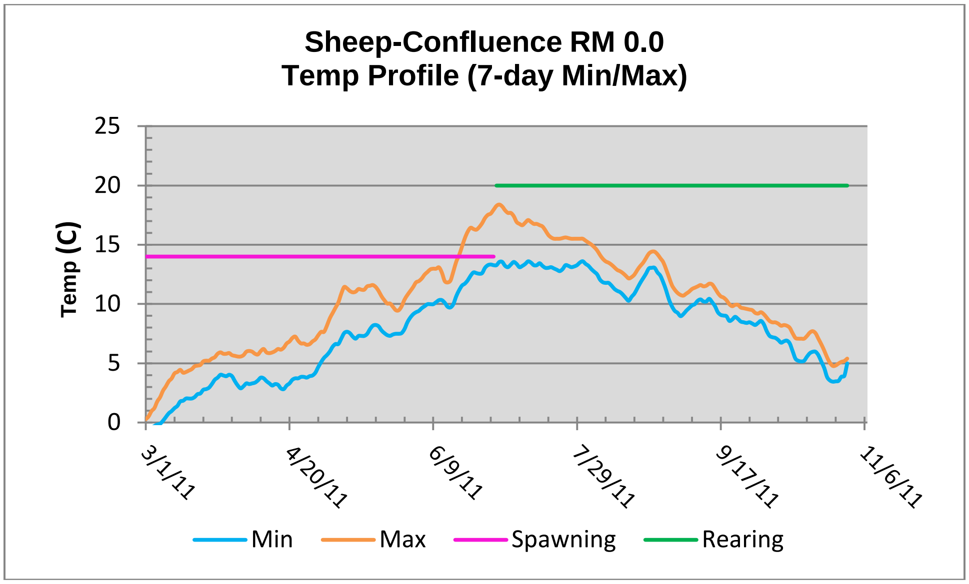

Figure D-36: Average weekly maximum/minimum temperature profiles of Lower Sheep Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

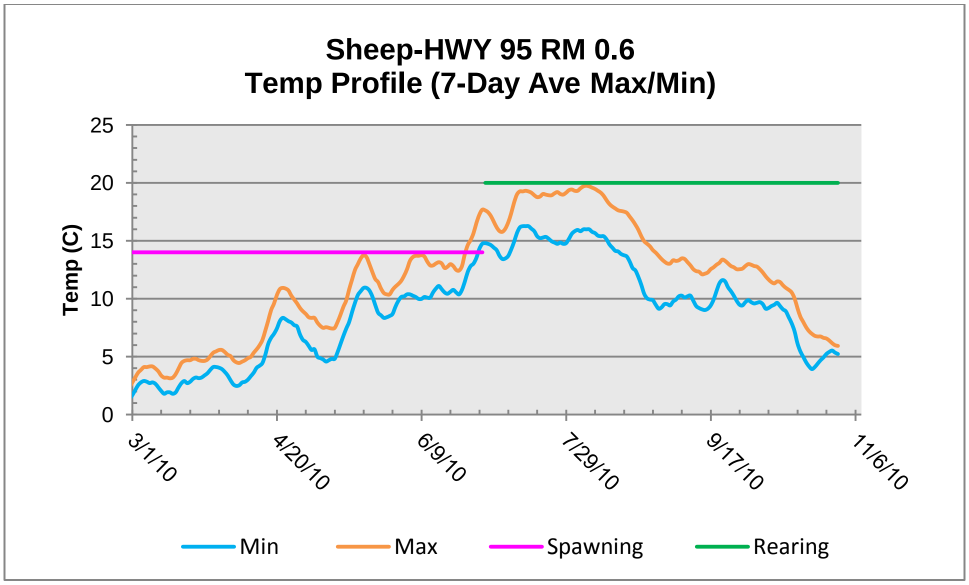

Figure D-37: Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

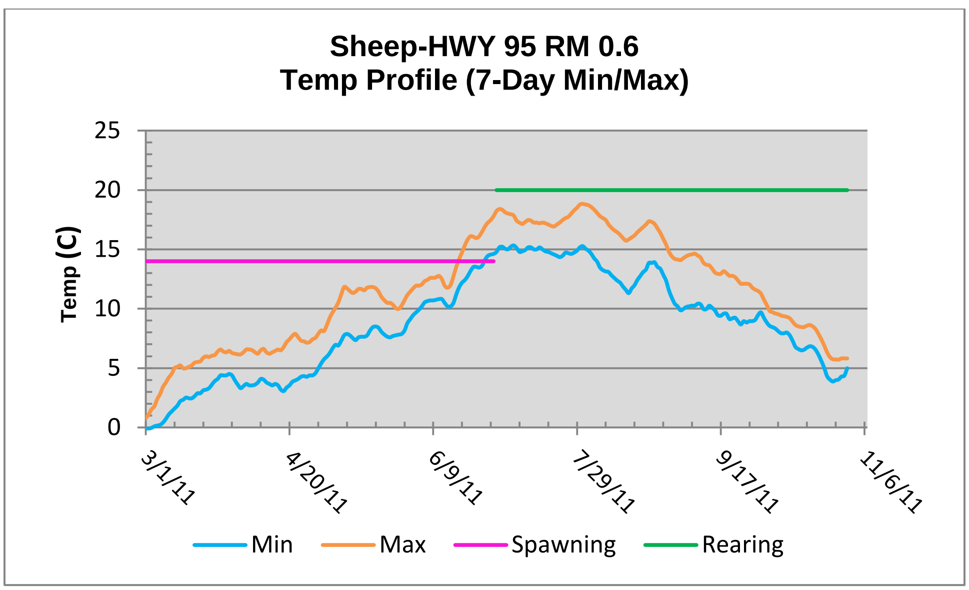

Figure D-38: Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

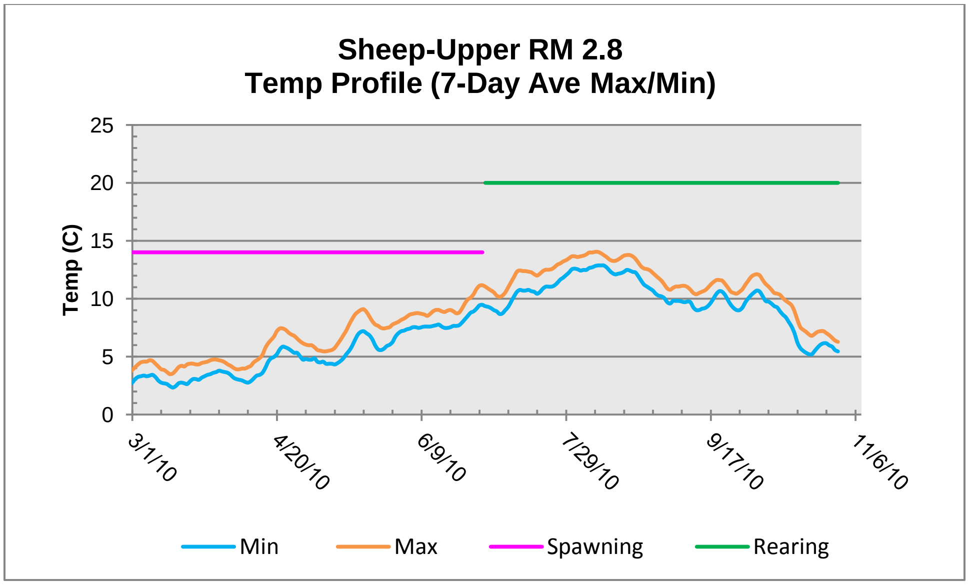

Figure D-39: Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

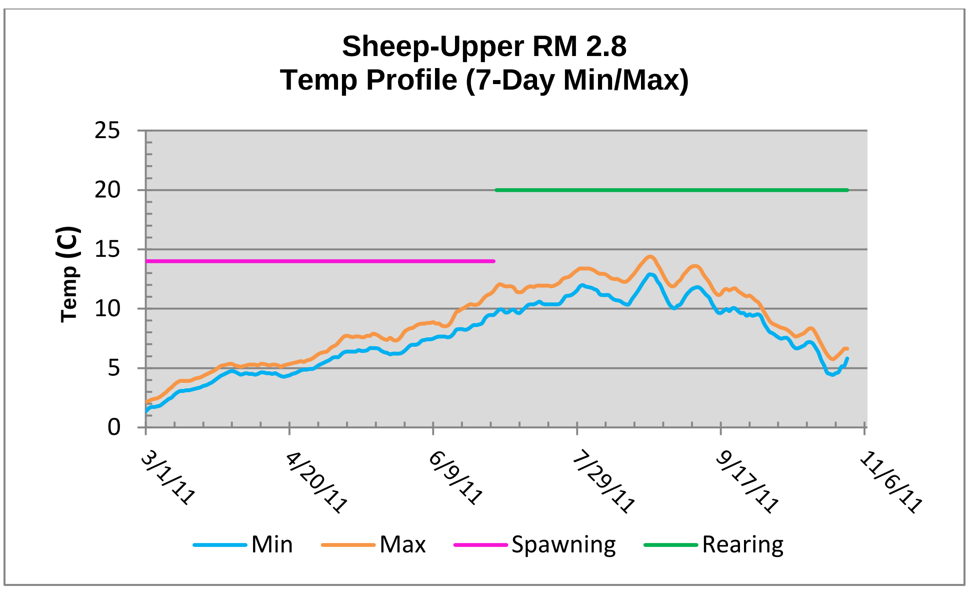

Figure D-40: Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

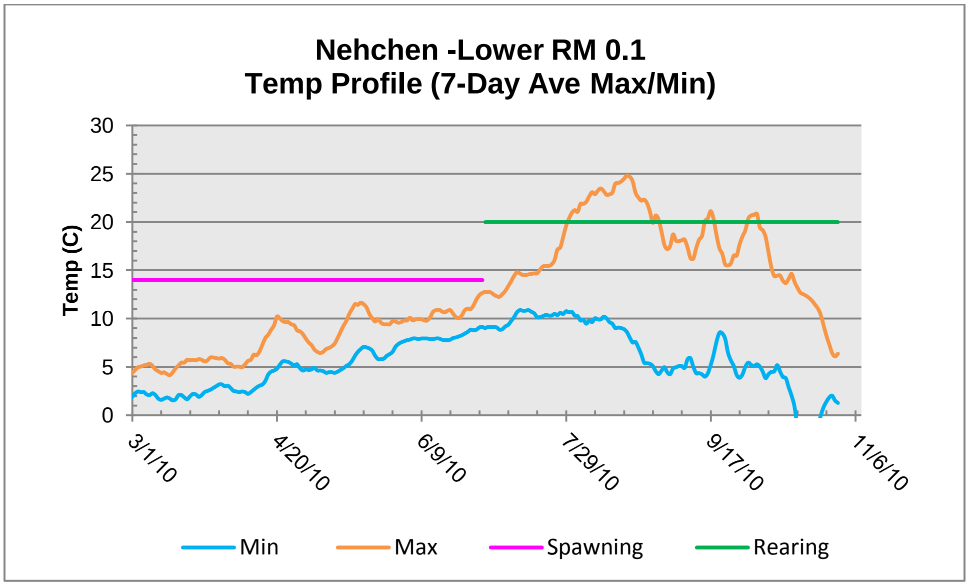

Figure D-41: Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.*(Dry channel after July 5th.)*

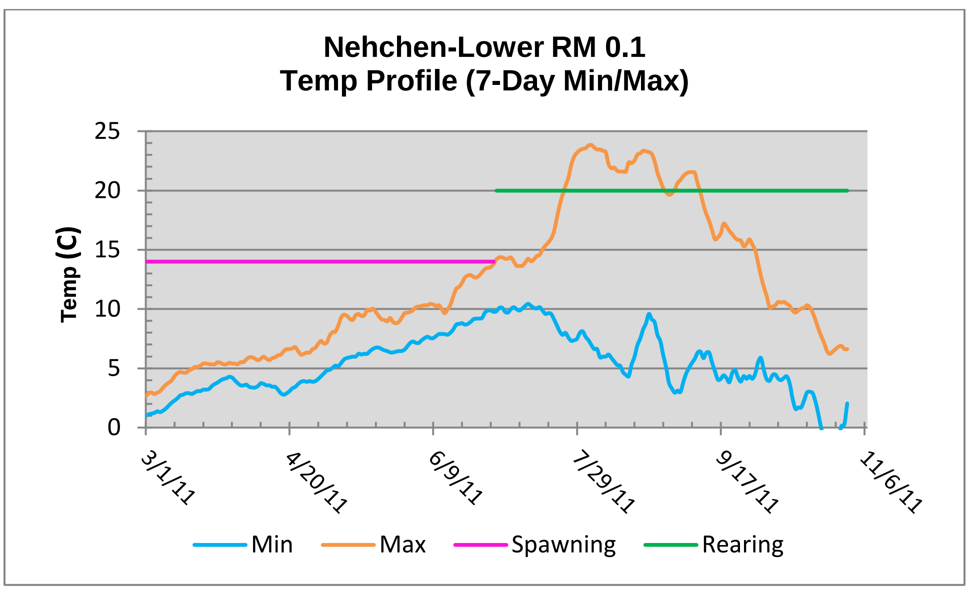

Figure D-42: Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. *(Dry channel after July 3)*

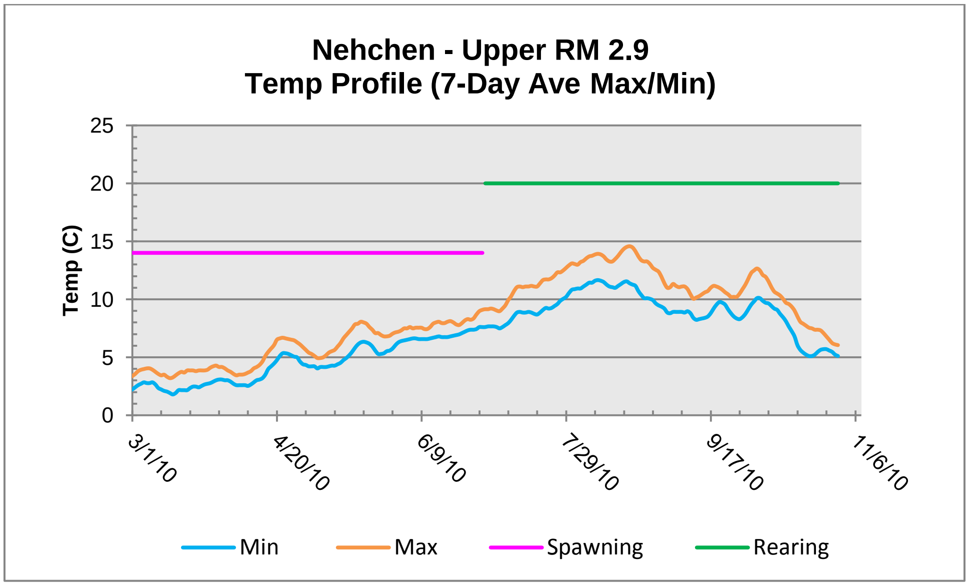

Figure D-43: Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

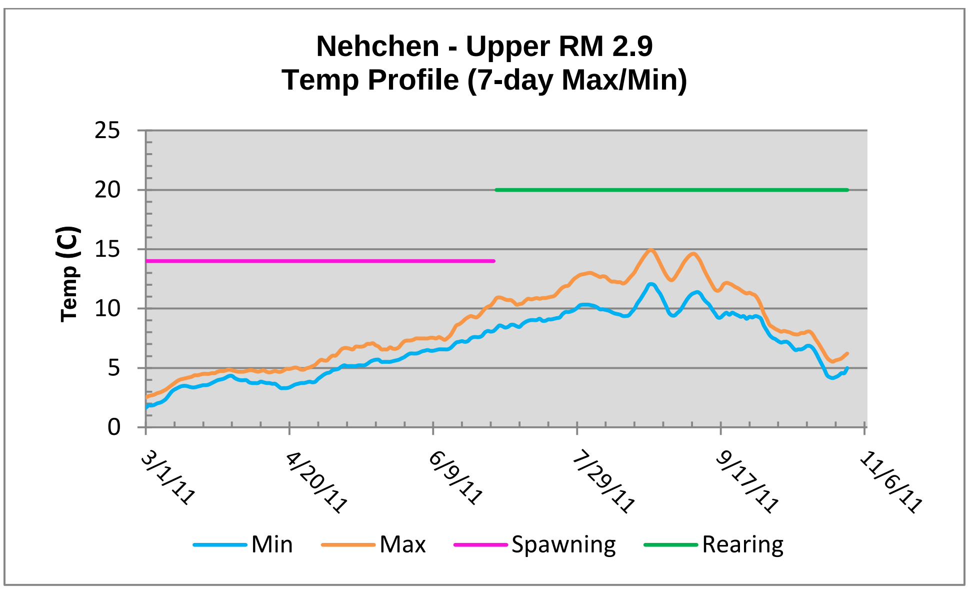

Figure D-44: Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

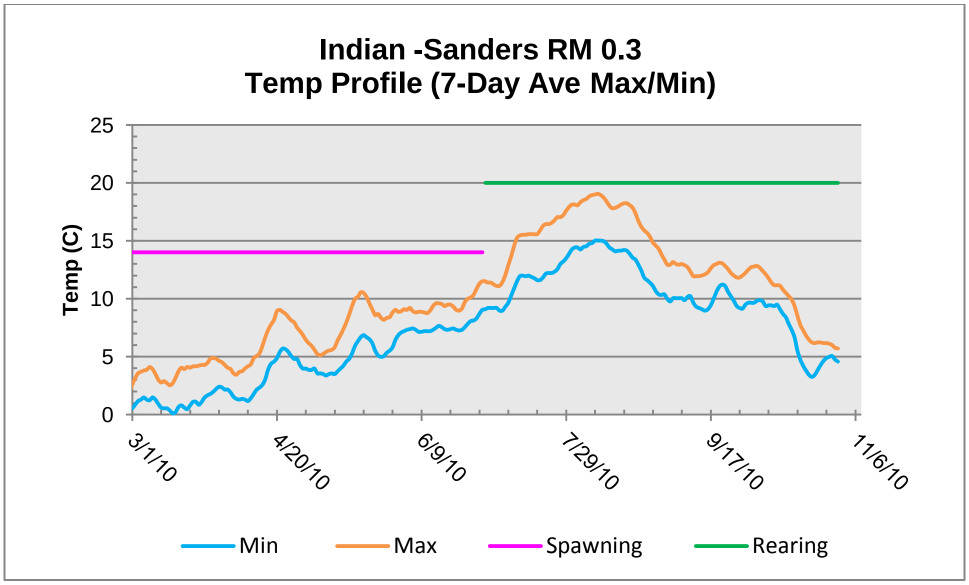

Figure D-45: Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

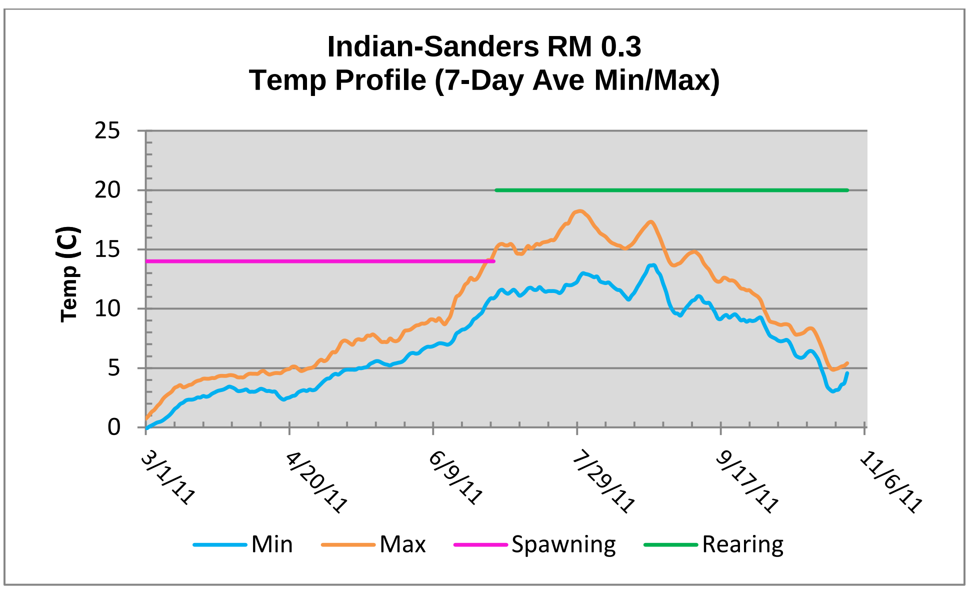

Figure D-46: Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

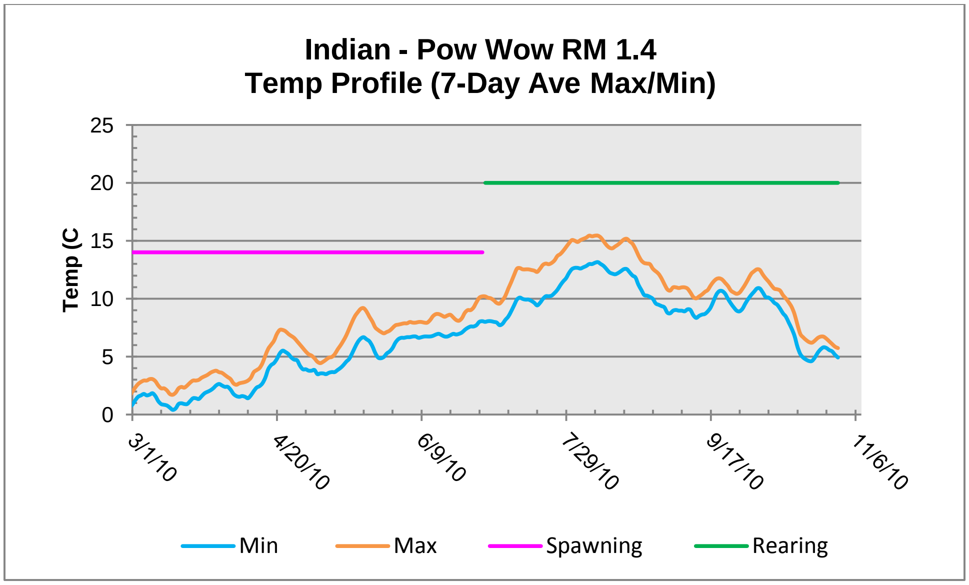

Figure D-47: Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

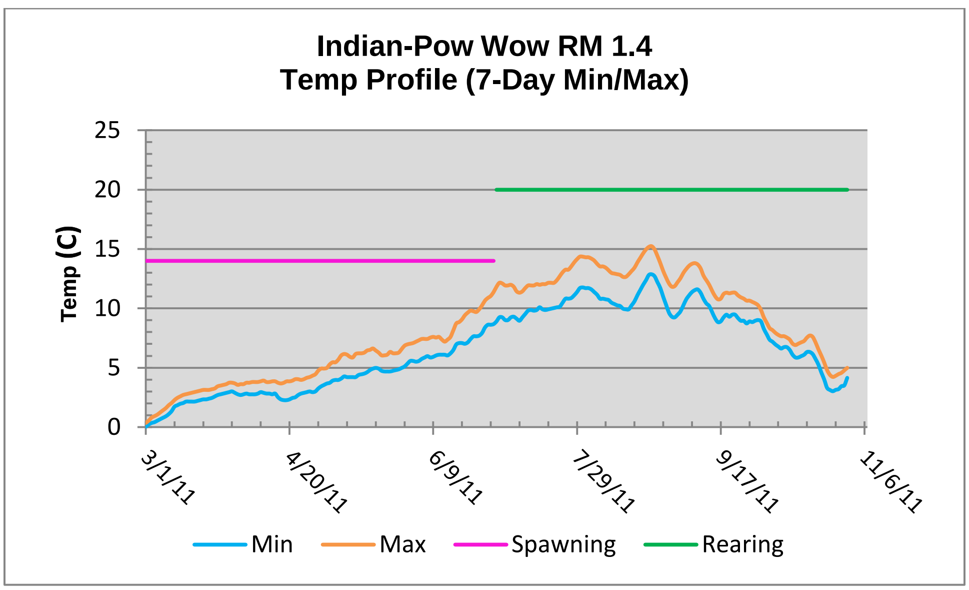

Figure D-48: Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow Grounds in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

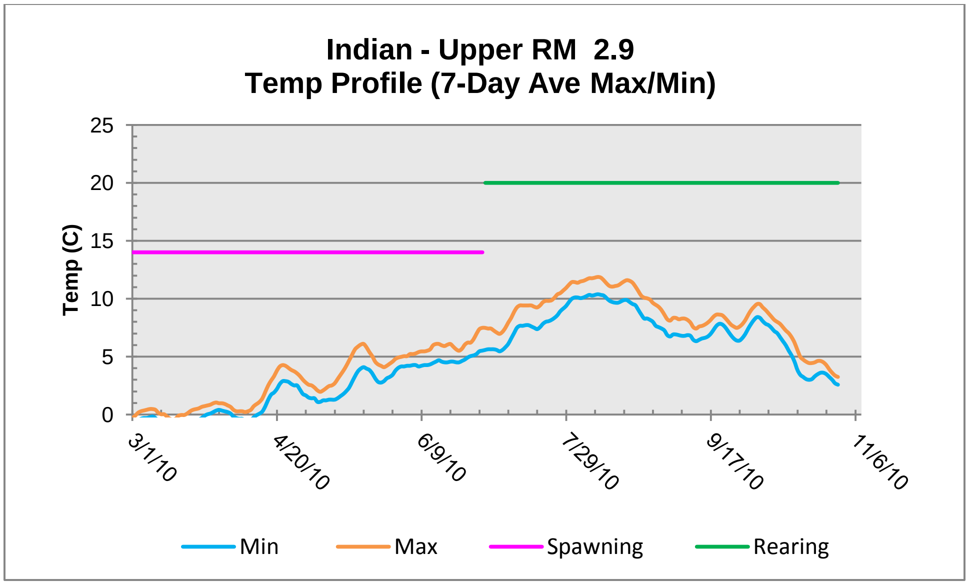

Figure D-49: Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

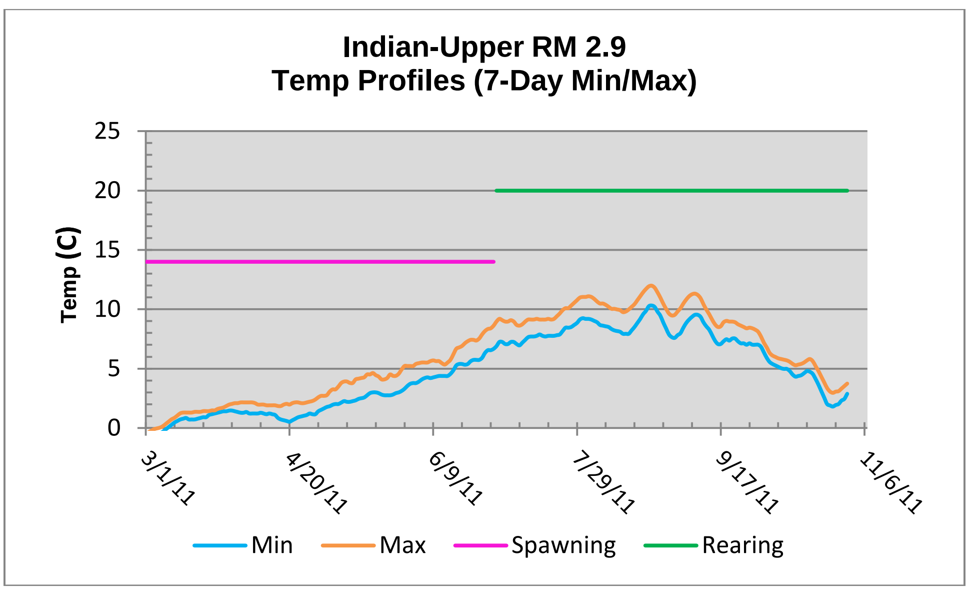

Figure D-50: Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

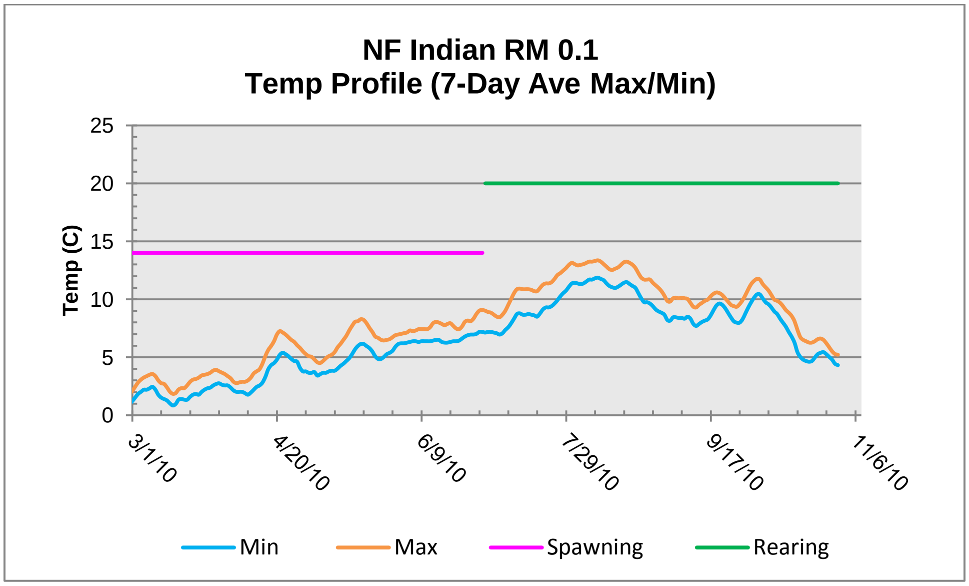

Figure D-51: Average weekly maximum/minimum temperature profiles of the NF Indian Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

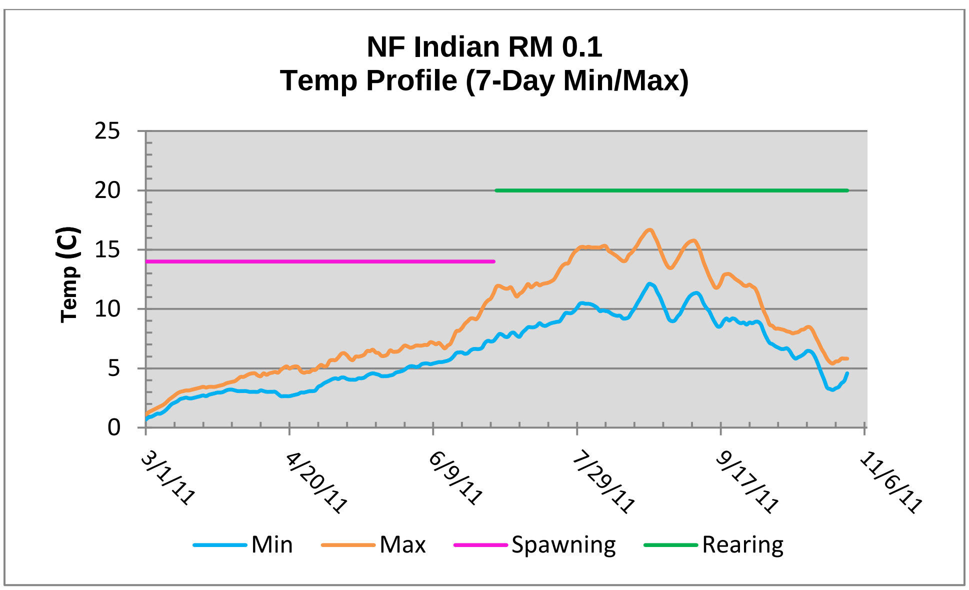

Figure D-52: Average weekly maximum/minimum temperature profiles of the NF Indian Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

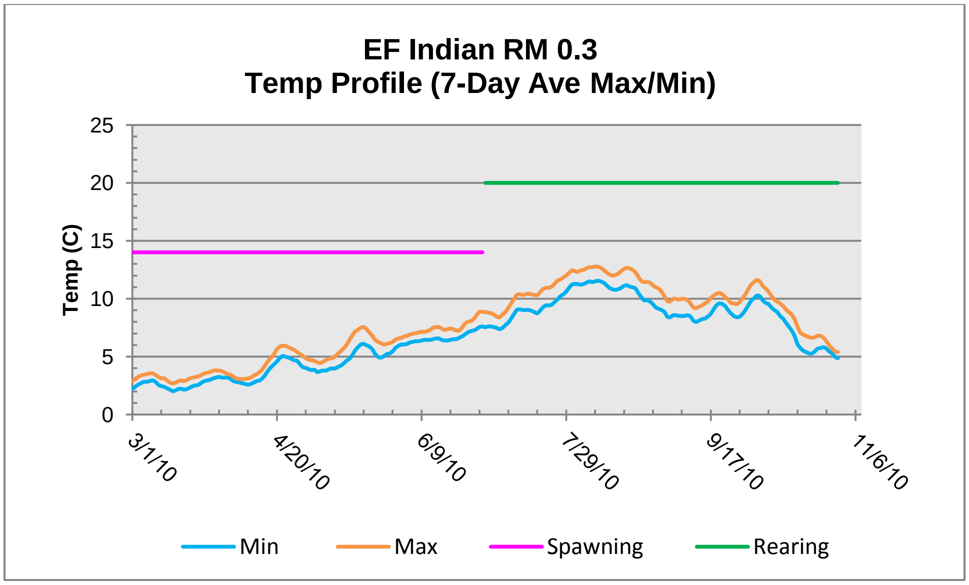

Figure D-53: Average weekly maximum/minimum temperature profiles of the EF Indian Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

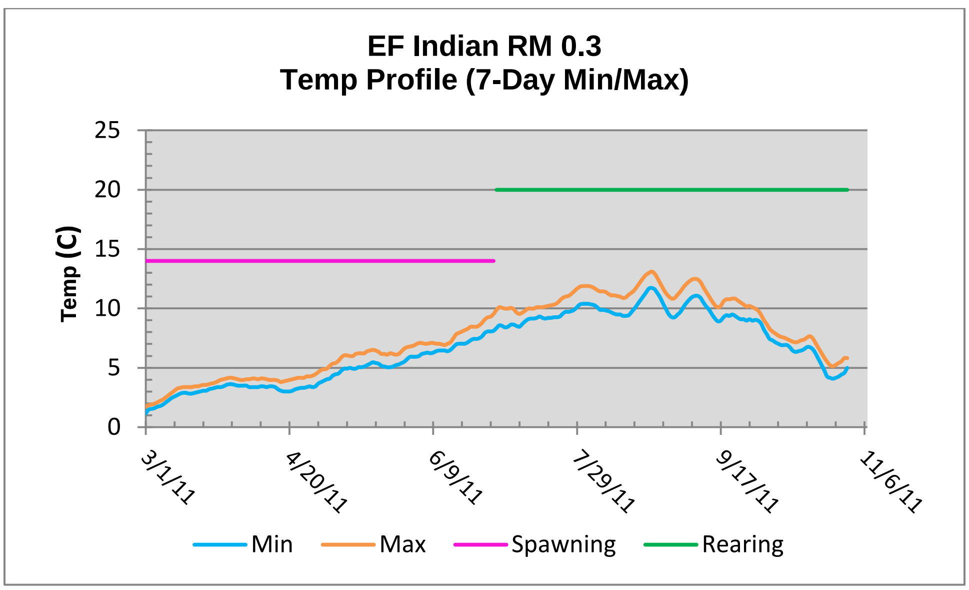

Figure D-54: Average weekly maximum/minimum temperature profiles of the EF Indian Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

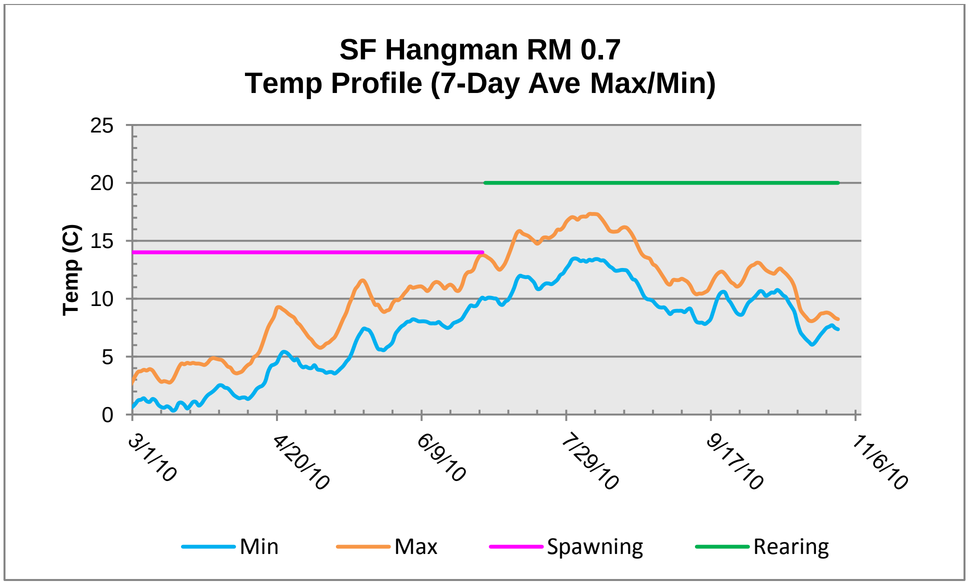

Figure D-55: Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

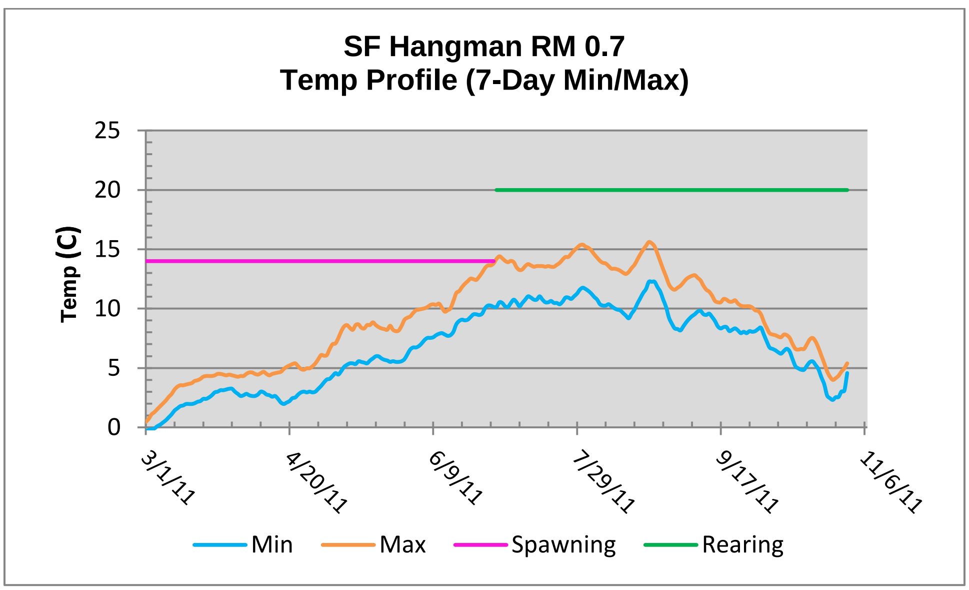

Figure D-56: Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

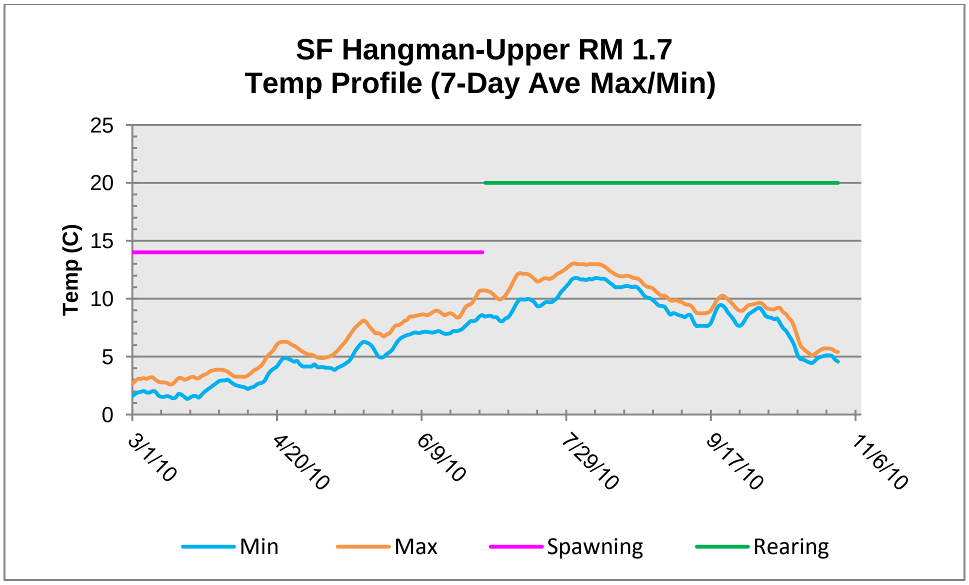

Figure D-57: Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

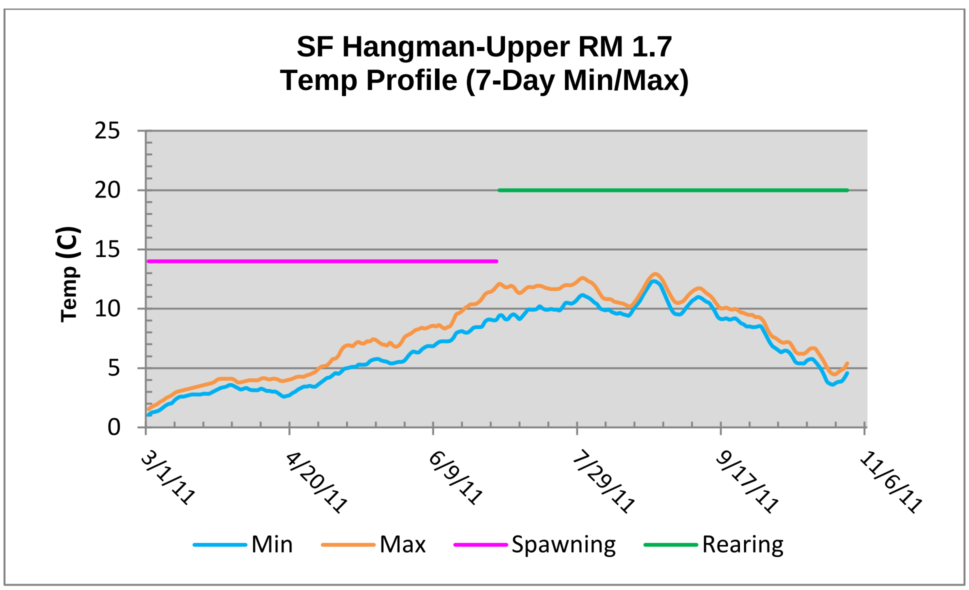

Figure D-58: Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

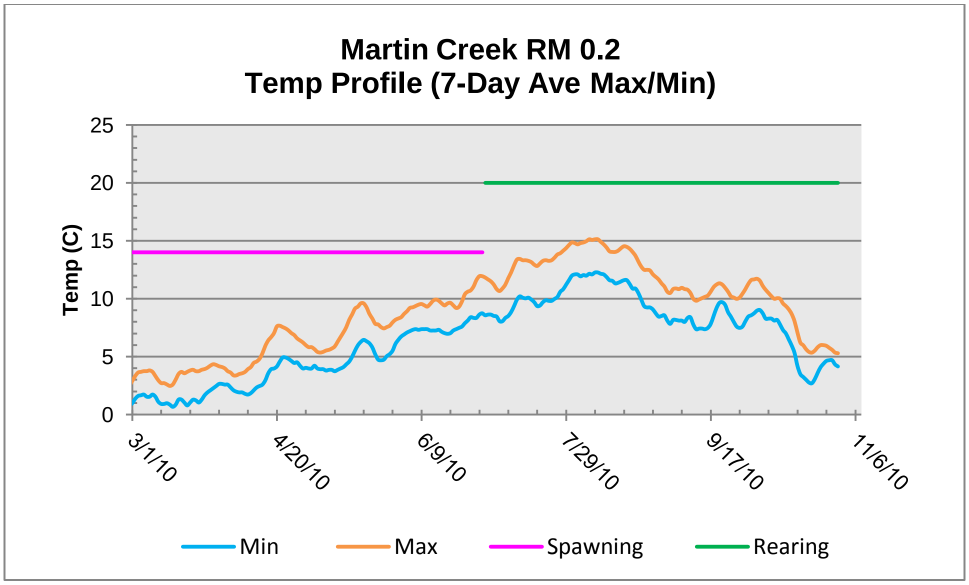

Figure D-59: Average weekly maximum/minimum temperature profiles for Martin Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

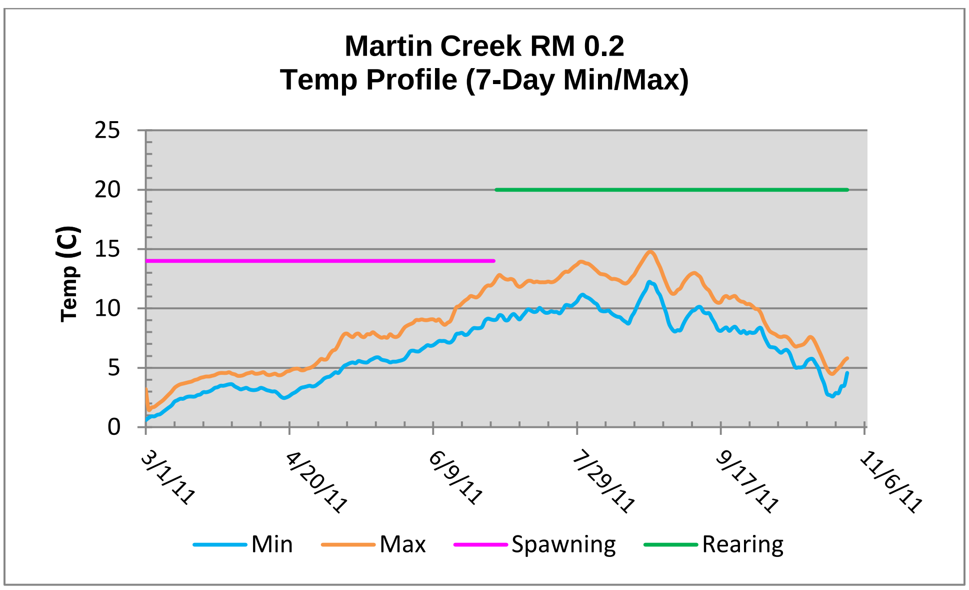

Figure D-60: Average weekly maximum/minimum temperature profiles for Martin Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

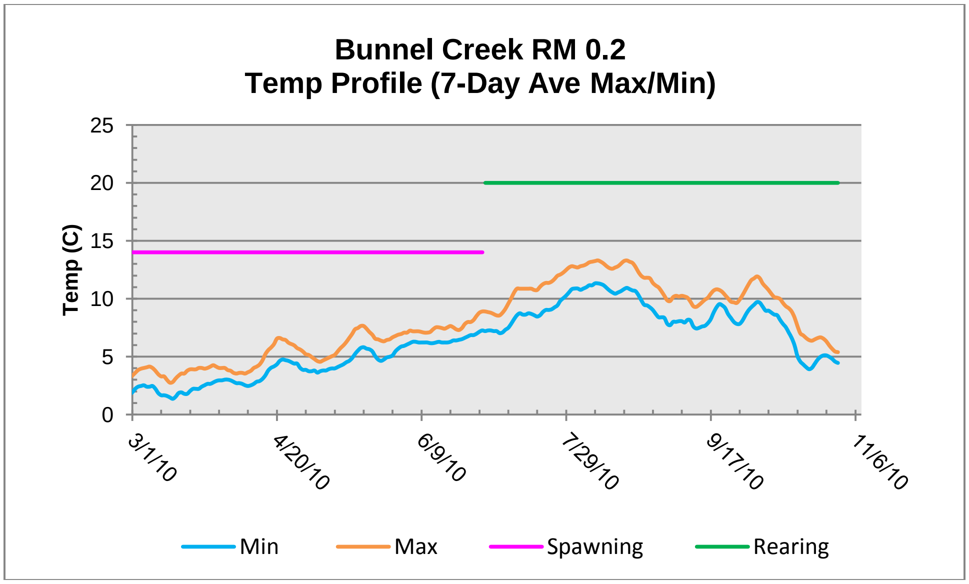

Figure D-61: Average weekly maximum/minimum temperature profiles for Bunnel Cr. in 2010 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

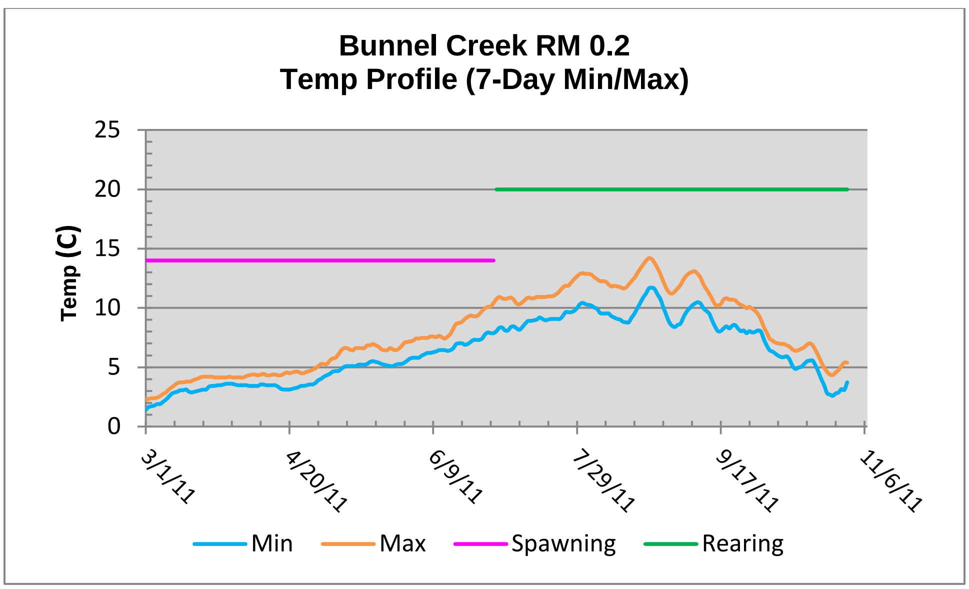

Figure D-62: Average weekly maximum/minimum temperature profiles for Bunnel Cr. in 2011 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

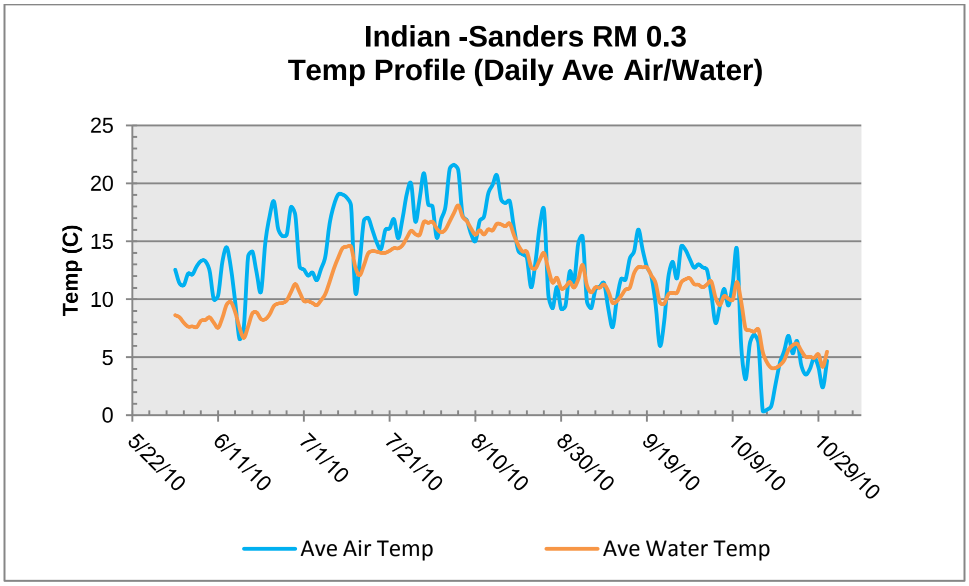

Figure D-63. Water and air temperatures at Indian-Sanders during 2010

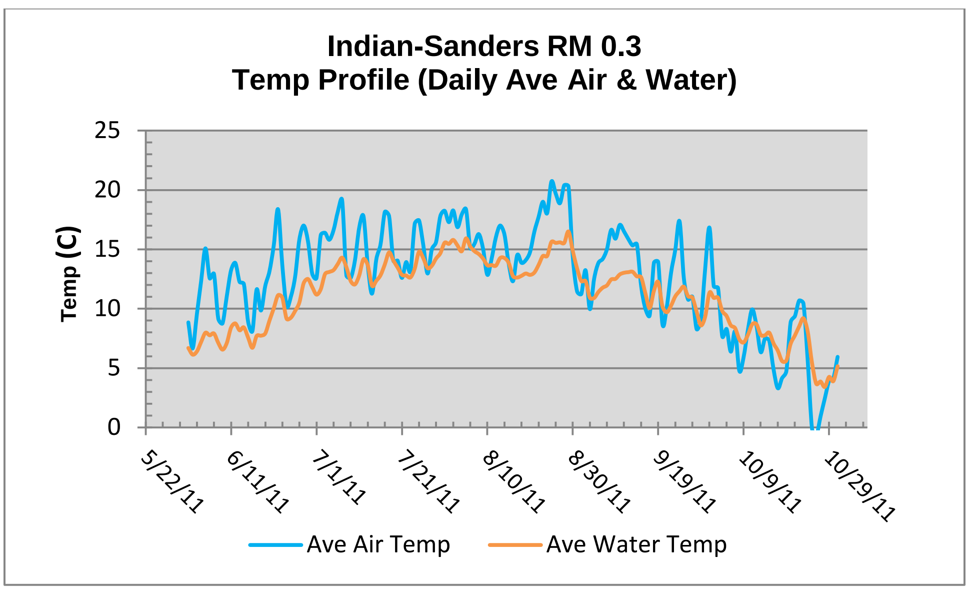

Figure D-64. Water and air temperatures at Indian-Sanders during 2011

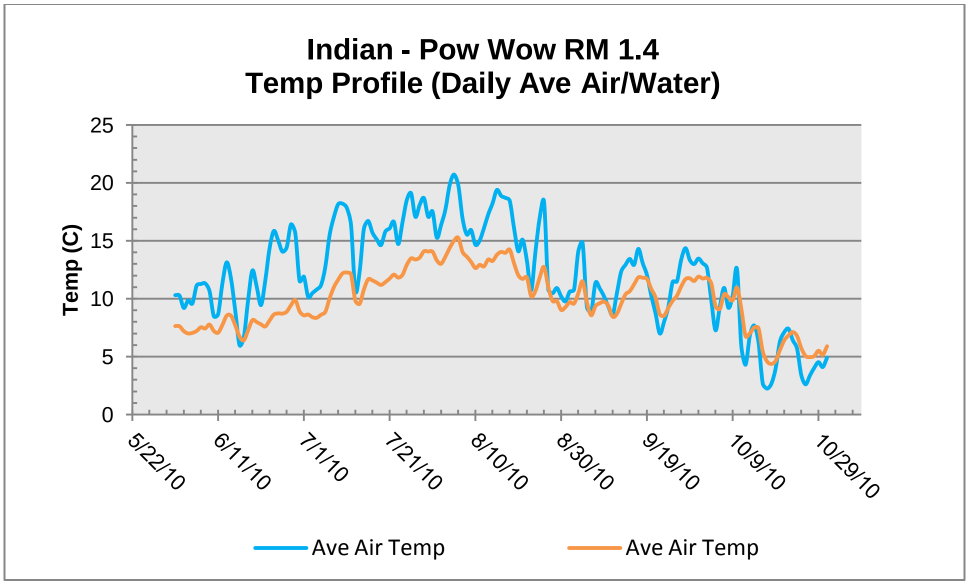

Figure D-65. Water and air temperatures at Indian-Pow Wow during 2010

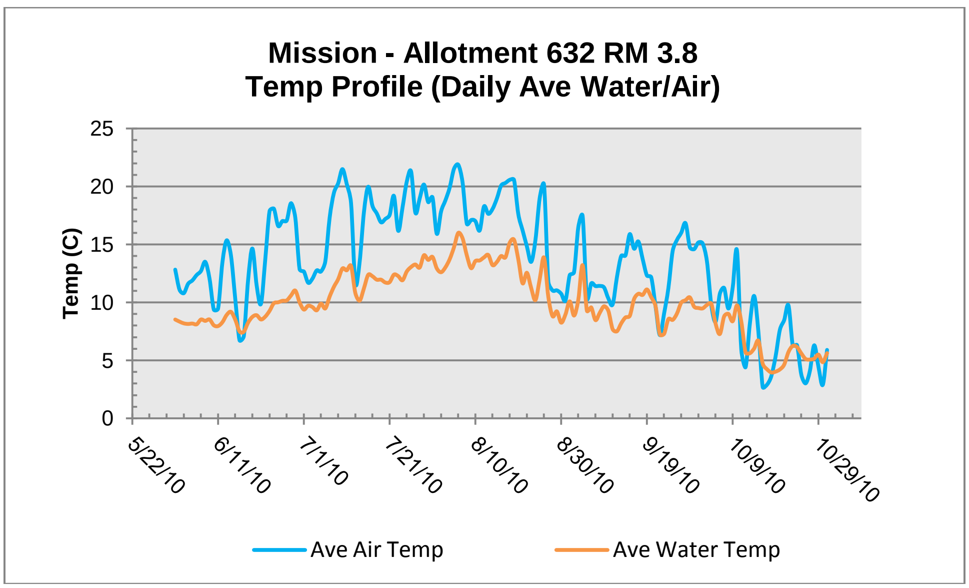

Figure D-66. Water and air temperatures at MF Mission Allotment 632 in 2010.

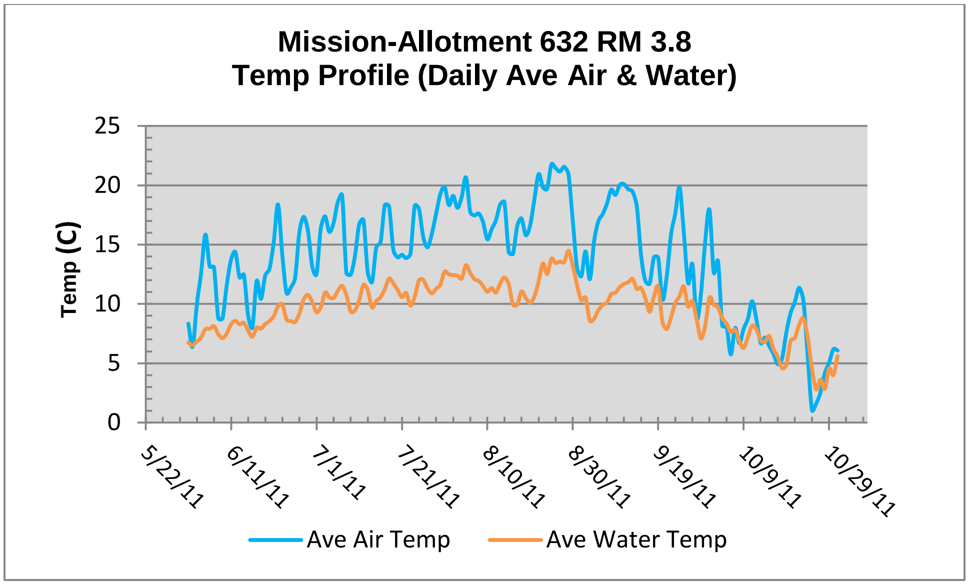

Figure D-67. Water and air temperatures at MF Mission Allotment 632 in 2011.