Upper Columbia Regional Application 2017

Thermal Refuge Assessment in the Upper Columbia

Sponsor Organization
Sponsor Address
Sponsor Contact Information
PRISM # 17–1241 PLN

Anticipated Request - SRFB:	$ 55,992
Anticipated Request - Tributary Committee:	$ 0
Anticipated Request for Proposal:	**$ 55,992**
Anticipated Other Funding/Contributions/Matches: (*Name Source, if applicable*)	$ 13,998
Anticipated <u>TOTAL</u> Project Budget:	**$ 69,990**

Comments

Use this section to respond to the comments received after the initial site visits and after submitting the final application.

Response to Site Visit Comments

1. *Please define what is meant by "complexity" if it is listed as one of the goals or objectives of the project. How will complexity be improved by the project and how could it be measured?*
One definition of habitat complexity is: the areal extent, number and diversity of habitat types and distinct ecological zones within a specified area. Reach-scale thermal diversity is a sub-category of habitat complexity and will be increased by the implementation of habitat projects identified in this assessment. Specifically, once implemented these projects (funded by future grants) will increase cold plume size, add woody debris to provide cover to an existing thermal refuge, or create new refuge. Monitoring of the project reach can depict an increase in thermal diversity, measured by an increase in the area and or frequency of cold pockets. This can be done by comparing pre/post conditions using TIR drone profiles, ground-based profiles, spot-checking with plume size measurements, and/or by installing a distributed temperature sensing (DTS) cable on the substrate.

2. *Please clarify the issues with the drone-based data collection and discuss alternate approaches for that type of data if needed for the project to succeed.*
Since the tour, CCNRD has found a path forward for drone-based TIR data collection. Two west-side consultants are available to do the work, one has a TIR/drone setup in house and the other has committed to purchasing one.

3. *Please detail your plan for data storage and sharing? There may be a large amount of data collected in this projects that others would like to use and access. How will that be accomplished? What is the cost for data storage and management and is that included in this proposal?*
Data will be stored on the UCSRB website as an interactive GIS-based portal (Figure 5). Layers will include temperature profiles, the raster FLIR layer, TIR drone data, cold spots with plume size and temperature differentials, prioritized restoration projects identified by the assessment, and other fish and land use data. Users will be able to toggle layers on and off as well as zoom in to a specific plume or out to view larger-scale temperature heterogeneity. ICF consulting firm quoted $6,000 to do the work.

4. *The interpretation of the MODIS data seems inaccurate. Please review the data set and the interpretation that the Entiat is a warmer tributary than the Wenatchee Basin as a whole. This apparent "result" may be an artifact of the extent of the data and how they were collected (i.e., there is much greater resolution of temperature monitoring in the Entiat than in the Wenatchee.) We would actually expect the Wenatchee River to be warmer.*

Figure 1 in the pre-proposal (unbeknownst to the project sponsor) depicted an archived data set and has since been updated with the most current model. In this updated Figure, the Wenatchee is warmer than the Entiat. Furthermore the root mean square error (RMSE) for this time period was 1.04°C in the Wenatchee and 1.4°C in the Entiat, which is greater than the temperature scale for the 8-day period depicted (1°C for January 1st, 2013). Although the map is still in Figure 1, it is mainly just to answer this

question and will not be depended on to understand winter patterns. Average RMSE for the MODIS model in the Wenatchee is 0.85°C, and is best for the summer outputs. Independent variables of the model are 8-day composite MODIS land surface temperature, Julian day and elevation. Temperature loggers are used to calibrate and fine tune the model, and the study found that temperature loggers in excess of 5 do not significantly improve model performance (Mcnyset et al 2015). Model authors do not think more Wenatchee temp logger data would result in a drastically different model. Project sponsor review of both the MODIS and NORWEST model (based on local knowledge of relative temperatures) suggest NORWEST is better at detecting cold tributary inputs. However, both the NorWeST and MODIS models likely do not have consistent error across the landscape, so using both models together will provide multiple lines of evidence for thermal heterogeneity.

	Questions	Answers	Information Resource
REGIONAL INFORMATION			
1	What Upper Columbia subbasin is the project in?	Wenatchee and Entiat	Wenatchee Entiat Methow Okanogan
2	What project category is your project?	Assessment	Restoration Design Only Restoration/Protection Protection Assessment Monitoring
3	What Assessment Unit is the project in?	Chiwawa, Little Wenatchee River, Nason River, Upper and Middle Wenatchee River, Lower and Middle Entiat	*Click Here for Assessment Unit names*
4	What rank restoration and/or protection priority is the assessment unit the project is located in?	Nason – 1, Up Wen – 2, Middle Entiat – 1, Lower Entiat - 2	*Click Here for table of Assessment Unit ranks*
5	What is the primary species the project will target?	Spring Chinook	Steelhead Spring Chinook Bull trout
6	What secondary species will the project will target?	Steelhead and Bulltrout	Steelhead Spring Chinook Bull trout Other (please name)
7	What regional PCSRF Metrics will be implemented with this project?	Total river miles assessed for thermal refuge is 85: Chiwawa: RM 0 – RM 7 Little Wenatchee River: RM 0 – RM 10 Nason River: RM 0 – RM 16 Upper and Middle Wenatchee River: RM 28 – RM 54 Lower and Middle Entiat River: RM 0 – RM 26	*Click Here for regional PCSRF Metric definitions*
8	What Primary Ecological Concern does the Project Address? (not required for protection projects)	Instream Complexity	*Click here for Ecological Concern definitions*
9	What other Ecological Concerns does the Project Address (not required for protection projects?	Temperature	*See above*
10	What is the rank priority of the primary ecological concern this project addresses in the assessment unit it occurs?	Upper Wenatchee – 1, Nason Creek – 4, Lower Entiat – 2, Middle Entiat - 3	*Click here for table of Ecological Concern ranks by assessment unit*

Regional Technical Team - Summary Information

Click here for complete RTT scoring criteria

	QUESTION	SUMMARY INFORMATION
1	In one sentence, what is the purpose of your project?	The purpose is to identify and provide a detailed assessment of the location, size, and quality of thermal refuge areas, along with recommended habitat projects to create or augment thermal refuge and increase survival and persistence of salmonids during temperature limiting periods of the year.
2	Location of the Restoration Project	In spring Chinook MaSAs with temperature TMDLs: Upper Wenatchee 35-54, Nason Creek (RM0-16), Chiwawa River (RM 0-7), Little Wenatchee (RM0-10) and in reaches with over-wintering spring Chinook: Lower and Middle Entiat (RM 0 – 26) , Middle Wenatchee (RM 28 – 35).
3	In one sentence, identify what you are going to do	Review available temperature data and models (loggers, NORWEST, MODIS, FLIR) and conduct supplemental field data collection (longitudinal profiles, spot checking cold seeps and small tribs, winter drone-based FLIR in Entiat and Wenatchee) to identify thermal refuge areas and prioritize related restoration projects to be shared with the region's Salmon Recovery community.
4	How long will it take for the benefits of the project to be realized and how long are they estimated to persist?	Benefits of this project will be realized within the first year of data collection. CCNRD will attend IT, WHSC, and other regional boards to share results and locations of thermal refuge areas located during the field season. These data sets will be openly shared to better plan Salmon Recovery in the basin and to aid in building restoration projects based on tangible fish-habitat relationships. Lessons learned will feed into the regions Climate Adaptation Strategy, and the completed Assessment (December 2019) will be shared and immediately aid sponsors across the region in building effective habitat projects that aid fish survival during critical temperature limiting periods of the year.
5	Benefits to Freshwater Survival or Capacity	Identified thermal restoration projects will increase survival of summer rearing juveniles and decrease pre-spawn mortality of summer holding adult spring Chinook by increasing capacity of thermal refuge areas when ambient stream temperatures exceed thermal limits. Projects identified from the winter inventory will increase winter-rearing survival of ESA-listed juvenile fish through increasing capacity of warm water refuge.
Protection Projects Only		
1	Project Protection Type?	(List one: Fee Simple or Conservation Easement)

Citizens Advisory Committee – Ranking Criteria and Summary Information For complete CAC ranking criteria click here	
CRITERIA	**SUMMARY INFORMATION**
Criterion 1: Benefits to Fish and Certainty of Success (60 pts. as a weighted percentage based upon RTT score)	
Is the project consistent with the Recovery Plan Implementation Strategy?	Yes. The RTT has drafted a new data gaps list that has not yet been tiered. This assessment addresses two data gaps. 1.location and quality of thermal refuge areas and 2. The effects of thermal profiles on fish distribution and movement is unknown. The assessment was developed with UCSRB to use with reach assessments in project implementation to address a tier 2 data gap on the old list "…mitigate for increased water temps". It also includes Tier 1 and 2 assessment units in both the Entiat and Wenatchee basin.
Is the project/assessment based on proven scientific methods that will meet objectives?	Yes. Assessment methods are based on Torgersen et al 2012. Thermal Refuge assessement in progress or completed in the lower Columbia and Klickitat county also provide a model. Development of proposed habitat actions will draw projects done in Oregon, the lower Columbia and on Kurylyk et al 2014.
Are there any obstacles that could delay the implementation of this project or study (e.g. permitting, design)?	No. This assessment does not require any permits.
Criterion 2: Project Longevity (30 points)	
Who has the responsibility to manage and maintain the project? What is the responsibility of current or future landowners?	CCNRD staff will manage the assessment. There are no landowners involved in any step of the gathering and compiling of assessment information.
Has the sponsor successfully implemented projects in the past?	CCNRD has a long history of managing assessment, design, construction and planning projects with a multitude of funding agencies including RCO and Tributary Committee.
Are the benefits associated with the project in perpetuity? *Will the project last only a few years?	The ultimate goal of this assessment is to build better projects that incorporate the need for thermal refugia in the Wenatchee basin. These projects can reduce prespawn mortality of spring Chinook and improve survival of all ESA-listed species and lifestages when ambient stream temperatures reach thermal limits. Therefore, the benefits of the assessment will not only last but will increase over time as more projects identified in the assessment are built.
Is there a high risk of failure associated with this project?	No. These methods are approved and encouraged in peer-reviewed literature. CCNRD has tested these methods in the Kahler reach of Nason Creek and have found them successful in locating cold spots and guiding restoration design.
Criterion 3: Project Scope (15 points)	
How much habitat is being protected or gained?	84 river miles of the Wenatchee and Entiat basin spring Chinook major spawning areas (MaSAs) will be assessed. Reaches have TMDL listings for impaired temperature (Wenatchee) or documented exceedances (Entiat).
Are threats imminent?	Yes. We know that water temperatures will increase in the future and therefore thermal refugia will be critical to the survival and recovery of our listed species. This project would be the first step toward protecting and enhancing these critical areas.
Is the scale of the proposed action appropriate?	Yes. Adult spring Chinook, since they hold in freshwater in the summer before spawning, are particularly susceptible to warming water temps and have experienced an average of 50% prespawn mortality above Tumwater Dam. Thus, it is appropriate to focus on spring Chinook MasAs with temperature

	limitations. Reaches also are major rearing habitat for steelhead and Chinook.
Criterion 4: Community Support (25 points)	
*Has there been public outreach about this project to assess the level of community support? *Does the project build community support for salmon recovery efforts? *Is there any community outreach planned during and/or after implementation?	Part of the goals of the assessment work is to disseminate the information to the public during Wenatchee Habitat Subcommittee and public meetings. All data will be available to the public on the UCSRB website as an interactive GIS portal. Public meetings will focus on education on the importance of thermal refugia to salmon recovery, an effort that is expected to build community support.
Has the project sponsor secured landowner participation or acceptance?	This assessment will not be conducted on private land. Access to reaches is expected to be via public access.
Will there be public access?	N/A
Will the project create benefits or raise concerns for particular groups or the community at large?	No community concerns are expected. This is an assessment to guide sponsors to build better projects, which should ultimately benefit the community.
What is the breadth and strength of the partnership supporting the project (technical support, financial, and in-kind contributions, labor)?	CCNRD has match secured from the Department of Ecology and Bureau of Reclamation. The UCSRB specifically asked sponsors to develop a project to map and characterize thermal refugia as part of a larger strategy to address climate change. This assessment has been developed with UCSRB guidance. WDFW, USFWS, Washington Department of Ecology, and the Climate Impacts group are project partners and will provide technical support and guidance.
Criterion 5: Economics (20 points)	
Does the project represent an opportunity for economic benefit?	The assessment will be used alongside reach assessments in order to build better projects that protect and enhance thermal refugia. Therefore, it will result in salmon recovery dollars better spent.
Will this project help the region move closer to delisting or reduce regulatory intervention?	Yes. We know that water temperatures will increase in the future and therefore thermal refugia will be critical to the survival and recovery of our listed species. This project would be the first step toward protecting and enhancing these critical areas.
Is the project budget clearly defined and reasonable?	Every task and step in the process towards the completed assessment and online portal are elucidated in the budget table on page XXX. The budget is based on staff costs doing similar work in Kahler, WDFW input on time to survey included reaches, consultant quotes, and equipment quotes.
How much benefit does the project create for the dollars invested?	Total project cost is $66,864 which is relatively low compared to the breadth of information that will be garnered by the effort. This information will include location of cold water refugia that is crucial to salmonid survival during periods of elevated temperature (standards are exceeded in all reaches) and winter temperature data that can be used with winter juvenile distribution data. Without this information, restoration may be misguided. The assessment will include recommended habitat actions to increase thermal refuge to ensure that these important areas are taken into account when planning restoration in the future.

Project Number	17-~~1201~~ 1241 P
Project Name	Thermal Refuge in the Upper Columbia
Sponsor	Chelan County Natural Resources Department
Planning Type	Assessment

List all related projects previously funded or reviewed by RCO:

Project # or Name	Status	Status of Prior Phase Deliverables and Relationship to Current Proposal?
16-1784 P	Not funded	N/A

Differences from the last proposal include 1. The addition of the Entiat river. 2. Winter drone FLIR flights in the Entiat and Middle Wenatchee. 3. The use of MODIS model and NORWEST model, in addition to 2001- 2003 FLIR (which we propose to georeference into a raster layer), to streamline data collection in reaches with specific life-stage temperature limitations. 4. Online data portal for assessment sharing.

1. Project brief. This project will identify and provide a detailed assessment of the location, size, and quality of thermal refuge areas in reaches that are temperature limiting to ESA listed salmonids. The assessment is the first step in UCSRBs climate change adaptation strategy and will be a collaborative effort that will also include recommended habitat actions to create or augment thermal refuge to increase survival and persistence of salmonids during temperature limiting periods of the year.

2. Project location. This project is located in the spring Chinook Major Spawning Areas (MaSAs) of the Wenatchee and Entiat basins that exceed Washington Department of Ecology (Ecology) temperature standards. This includes reaches in the Entiat River, Wenatchee River, Chiwawa River, Nason Creek, and little Wenatchee Rivers.

3. Problem statement. Currently there is no information available to sponsors about thermal refugia, locations or opportunities for restoration. Without this information, and other information that can help establish fish- habitat relationships, habitat restoration projects may be misguided. We know that water temperatures will increase in the future and therefore thermal refugia will be critical to the survival and recovery of our listed species. This project would be the first step toward protecting and enhancing these critical areas. Specific problems that highlight the need for this information are below:

1. Available data indicates that stream temperature in all reaches included in this assessment exceed Washington Department of Ecology (Ecology) 7-day average daily maximum (7-DADMs) temperature criteria for core spawning areas (17.5°C). NORWEST A1B climate change models show temperatures could increase an additional 2 deg C by 2040 and further constrict ESA-listed salmon habitat (Isaak et al, 2011). Elevated water temperatures in the Wenatchee and Entiat basins are due to the cumulative effects of land-use activities, such as water withdrawals and riparian development (i.e. logging, agriculture, and roads) and ongoing climate change. The proposed assessment will help mitigate for increasing water temperatures by identifying opportunities to restore and protect thermal refugia. Thermal refugia are cold spots, or deviations from a downstream warming trend ("heterogeneity"), that can provide refuge and

promote survival when ambient stream temperatures approach or exceed thermal limits of cold-blooded fishes (Kurylyk et al, 2014). The 2016 NOAA status review identified habitat degradation and the lack of complex, cold water refuge as continuing to threaten the survival and recovery of many populations.
2. Average pre-spawn mortality (PSM) of spring Chinook is around 50% above Tumwater Dam (Andrew Murdoch, personal communication). In major spawning areas currently experiencing high pre-spawn mortality, an increase in cool water refugia should increase pre-spawn survival (Andrew Murdoch, personal communication).
3. Drought conditions in 2015 resulted in elevated stream temperatures throughout the Upper Columbia – Ecology's stream gage indicates Nason Creek reached 24°C that year. ESA-listed juveniles were observed using small cold pockets (Jennifer O'Neil, Natural Systems Design, personal communication) .High temperatures, in addition to other factors, likely contributed to low abundance at smolt traps the following spring (Bryan Ishida, Yakama Nation, personal communication). An increase in thermal refuge could help ameliorate low survival of juvenile salmonids when stream temperatures are elevated.
4. Over-wintering survival of juvenile spring Chinook in the Wenatchee and Entiat Rivers is low (Truscott et al 2016, Grote and Desgroseillier 2015). Winter fish-habitat relationships are major data gaps in both basins (Truscott et al 2016, Grote and Desgroseillier 2015). This project proposes drone-based Winter FLIR data in both basins to be used with distribution data. This data will help address the data gap concerning what drives juvenile spring Chinook winter distribution (Jeremy Cram and Tom Desgroseillier, personal communication).

4. List the fish resources present at the site and targeted by the project.

Species	Life History Present (egg, juvenile, adult)	Current Population Trend (decline, stable, rising)	Endangered Species Act Coverage (Y/N)
Spring Chinook	Adult, juvenile	Stable	Y
Bull trout	Adult, juvenile	Declining/Stable	Y
Steelhead	Adult, juvenile	stable	Y

5. Describe the limiting factors and limiting life stages (by fish species) that the project expects to address. The region has drafted an updated data gaps table to replace the current list of regional data gaps, which is out of date (2008) ~~and the region is working to develop an updated list for the 2017 SRFB process (~~sSee question 9B for information on how this project addresses ~~current and emerging~~ data gaps~~)~~. ~~This assessment addresses pre-spawn adult spring Chinook –~~ rRecent data show pre-spawn mortality (PSM) is elevated (50%) above Tumwater Dam, indicating this life stage is may be limiting. Data also indicates improved cold holding habitat in spring Chinook MaSAs addressed in this assessment would improve pre-spawn survival (Andrew Murdoch, personal communication). Winter rearing habitat is a limiting life-stage in the Wenatchee and Entiat (Truscott et al 2016, Grote and Desgroseillier 2015) and will be addressed in the proposed winter drone-based FLIR data collection~~.~~ Projects resulting from this assessment will increase instream complexity (see response to comments question 1), which is the number 1 ecological concern (limiting factor) in the Upper Wenatchee River, number 4 in Nason Creek, 2 in Lower Entiat and 3 in Middle Entiat (UCRTT 2014). This assessment also identifies refugia for protection in 4 tier 1 assessment units for protection projects – Nason Creek, Upper Wenatchee, Chiwawa River and Middle Entiat (Little Wenatchee River and Lower Entiat are tier 2). The entire Wenatchee watershed has a TMDL listing for temperature and temperature is a data gap in the Upper

Wenatchee (Andonaegui 2001). Temperature is a water quality of concern in the Entiat (USFS, 2013). Enhanced thermal refugia will also improve survival of rearing juvenile spring Chinook and all life stages of steelhead and bull-trout when ambient stream temperatures reach thermal limits to survival. Juvenile rearing habitat is the primary ecological concern in Nason Creek (UCRTT 2014). Information on thermal refugia and fish – habitat relationships are emerging data gaps. This project will address the latter by using winter FLIR data alongside winter distribution data. In addition to providing an invaluable data set, this assessment will identify restoration projects that will increase the total area of thermal refuge in our basin and remove ecological tradeoffs from existing refugia (i.e. add cover) and therefore provide more opportunities for salmonids to safely thermoregulate during temperature limiting times of the year.

6. Project goals and objectives.

A. What are the project's goals?

Identify and map thermal refuge within spring Chinook MaSAs of the Wenatchee and Entiat where there are known summer temperature limitations and where there is the potential for overwinter thermal refugia for ESA-listed spring Chinook and Steelhead.

Identify and prioritize habitat actions to create or augment thermal refuge.

Work in collaboration with several partners and stakeholders across the region in all stages of Assessment development.

B. What are the project's objectives?

1. Map and characterize thermal refuge in 50 river miles of spring Chinook MaSAs with temperature TMDL listings (Nason Creek RM 0 - 15, Chiwawa River RM 0 – 7, Upper Wenatchee River RM 36 -54, Little Wenatchee River RM 0 -10) during the hottest time of the year in 2018 and 2019. Cold-water areas that meet temperature differential criteria of at least 1.5°C will be measured and mapped, displaying location, plume size, and habitat quality.

2. Collect FLIR via drone during the winter of 2018 within ~~52~~ 34 river miles where recent studies have documented spring Chinook use as over-winter habitat (Entiat River 0-26 and Wenatchee River RM 28-~~54~~36). This data will be used with winter juvenile distribution data to address an emerging data gap related to over-winter distribution and limiting factors.

3. Identify site-specific restoration projects to augment winter and summer thermal refuge areas. Projects will be prioritized according to how well they address current and emerging life-cycle bottlenecks (i.e. PSM, juvenile over-winter survival, and over-summer survival under climate change) and included in a report and on an interactive online viewer with thermal refuge data by December 2019.

4. Facilitate three meetings throughout the life of the grant with the Implementation Team to review Methods, Data Collected and project identification.

7. What are the assumptions and constraints that could impact whether the sponsor achieves the objectives? *N/A*

8. Project details.

A. Provide a narrative description of the proposed project. This assessment is the first step in our region's climate change adaptation strategy, which is currently under development (UCSRB, personal comm)~~.~~ The proposed assessment will include thermal refuge location, source, habitat quality, plume extent and prioritized opportunities for restoration. Nason Creek, lower Chiwawa River, Upper Wenatchee River, and Little Wenatchee River, all spring Chinook MaSAs that also have TMDL listings for temperature exceedance, will be included in the assessment. The assessment will also cover winter refugia in the Upper/Middle Wenatchee River and the Entiat River – areas where over-wintering ESA-listed juvenile distribution studies are ongoing and where related fish –habitat relationships is an emerging data gap. Below is a list of the data sets and model outputs that CCNRD staff will review. Data review will serve two purposes 1. Help identify potential cold tributaries and seeps to ground truth via spot-checking 2. Identify key temperature limiting reaches to perform longitudinal profiling. (Table 1) ~~CCNRD staff will review the following data sets and model outputs to guide subsequent data collection:~~

- *MODIS model* – South Fork Research (SFR) center developed water temperature models for every 8 days from 2001 -2015. The model is based on Land Surface Temperature data collected by the MODIS satellite. Currently available datasets include daily mean water temperature that is both spatially (1 km scale) and temporally (every 8 days) continuous across the Wenatchee and Entiat basin (Figure 1). ~~Carol Volk of SFR is a partner to this proposal and is currently using this data to analyze life-stage and reach specific temperature limitations in the Wenatchee. Once the output of this modeling effort is complete, CCNRD will target temperature limiting reaches for longitudinal profiling and spot-checking (Table 1, see below for field methods).~~

-*NORWEST model* – Available data includes spatially continuous (1 km) shapefiles of the 10 year average (1993-2011) of August daily mean stream temperature, and future August temperature means under the A1B climate warming trajectory (Figure 2 and 3). ~~CCNRD staff will use this data to pinpoint cold tributary inputs to be validated in the field.~~

2001-2003 FLIR data – Ecology's Thermal Infrared Aerial surveys ("FLIR") are available for all reaches except the Entiat. Data represents spatially continuous (10 pixel) surface temperature on one August day. As part of this proposal, Quantum Spatial will geo-rectify and create continuous mosaics of the thermal imagery collected in the Wenatchee basin. This data can then be overlaid with other layers in GIS (redds, winter-distribution, topographic, etc). The data will then be used to locate potential ground water seeps, cold alcove or side-channel habitat, and cold tributaries to be validated in the field. The raster data set could also help in addressing fish – habitat relationships.

Stream temperature logger data – A complete network is available in the Entiat through the CHAMP IMW, and will be used to understand general reach scale patterns in temperature. Seasonal data is also available through Ecology stream gages, WDFW loggers, and CCNRD loggers. Additional loggers will be deployed as part of this proposal.

Temperature monitoring methods proposed are adapted from and generally follow: Primer to Identify Cold Water Refuges to Protect and Restore Cold Water Diversity in Riverine Landscapes (Torgersen et al 2012). Cold spots that meet a temperature differential of at least 1.5°C will be recorded as thermal refugia. *The following three methods* will be used to conduct temperature monitoring:

1**)** CCNRD staff will conduct ground-based longitudinal temperature profiles in select reaches in Nason Creek, Little Wenatchee, Upper Wenatchee River ~~-~~and Chiwawa (see 8a)~~.~~ ~~This method will be used in reaches that MODIS models indicate have life-stage temperature limitations.~~ Staff will walk or float the reach while dragging two Solinst levelogger Edge units – quick response temperature loggers that also record water depth. One probe will follow the bottom of the stream to identify any deep, cold, ground water sources and the other will stay on

the surface. Data will be collected on a clear summer day, between 2 and 6 pm when stream temperatures are at or near their yearly peak. A GPS Garmin will simultaneously acquire a continuous track of points in order to geo-reference temperature readings. A fixed temperature logger will be installed within the reach to enable the temporal element of temperature change to be subtracted from the profile. Expected time to complete the full 32 miles of profiles is 18 hours per summer (scope includes time for project manager and 1 hired field staff), which includes time to float in an inflatable kayak (larger streams) or walk reach length, round trip drive time, and time to turn on equipment.

2) Microhabitat scale sampling or "spot checking" will occur on stream margins with a thermal probe at locations where 2001-2003 FLIR data documented cooler surface temperatures. Staff will also survey cool tributaries indicated in NORWEST and MODIS models. This is likely to be 5 -10 % of the total survey area (roughly 5 miles). CCNRD staff will use a fast-response, hand-held thermocouple with instantaneous temperature readout to search for cold spots. When found, the cold spot will be photographed and the following data will be collected: temperature, depth, channel unit type (i.e. pool, glide), plume extent in two dimensions, fish cover, and GPS location.

3) CCNRD will hire a consultant with a TIR/drone setup (ICF and Cramer Sciences)~~Sitka technologies~~ to perform FLIR winter drone flights in the Entiat and Upper/Middle Wenatchee Rivers. This will serve two purposes – to share with region biologists to use with over-winter distribution data to develop fish-habitat relationships, and to assess the accuracy of 2001-2003 FLIR to current conditions in the middle and upper Wenatchee.

Using GIS, CCNRD staff will make several maps that overlay a subset of the following layers – Thermal refuge location with plume size and temperature differentials; spring Chinook spawning concentrations, channel unit type, land use, and topography. Using these maps and collected data, cold spots will be prioritized for augmentation projects according to specific criteria:

- Size of plume in two dimensions.
- Distance from plume to spring Chinook spawning concentration.
- Distance up and downstream to identified thermal refuge.
- Percent of the year reach is temperature limiting, and expected increase under climate change.
- Document feasibility - High: easy equipment access without wet crossings and removal of mature riparian vegetation. Medium: access presents some challenges but projects can be implemented. Low: Adjacent infrastructure like home, bridge, highway, power poles, would make implementation low likelihood.
- *High functioning, high capacity and fish use refugia will be listed with **"protection"** projects and the appropriate regulatory/management agency will be notified.*

Restoration techniques may include – increasing the plume size of a tributary confluence (Figure 4), creating hyporheic flow using structure to induce hydrologic forcing and gravel augmentation to effect porosity (a new method developed by Cramer sciences), adding structure and cover to an existing refugia to remove an ecological tradeoff (i.e. thermal regulation can expose fish to predators if the refuge does not have adequate cover). CCNRD has reached out to biologists in other basins (lower Columbia, Puget Sound) who are currently doing this work and testing different techniques. Staff will continue these conversations to develop projects.

Data will be disseminated in an online data sharing portal developed by an experienced consultant (see Figure 5 and response to comments, question 3). The portal will be on the UCSRB website so that data can be easily used in conjunction with Reach Assessments by project sponsors to develop projects. Deliverables will also include a report documenting methods, results, discussion, thermal refuge maps and recommended habitat actions. See Figure 2 and

Table 2 for a hypothetical layout of recommended projects. ~~Information will be disseminated~~ CCNRD staff will also present information to the Wenatchee Habitat Subcommittee,UCRTT and other interested parties ~~so that data can be used in conjunction with Reach Assessments by project sponsors, and presented to UCRTT and other interested parties~~ to better plan for salmon recovery in the basin. The assessment will also be shared in other basins in the region including the Okanagan and Methow, for potential replication and to promote climate change resilience across the Upper Columbia.

B. **Provide a scope of work and detailed list of project deliverables.**

CCNRD STAFF TASKS (2 staff indicates Project manager and hired field staff)	timeline	hrs	cost/hr	total
Review of existing temperature models and data ~~to identify life-stage specific temperature limiting reaches, cold tributary inputs, and potential surface and groundwater coldwater sources.~~	January - April 2018	80	43.16	3452.8
Meetings with partners ~~to discuss results of temperature limiting reaches per life stage analysis (Carol Volk, SFR), winter distribution and redd data~~ to prioritize data collection	January - April 2018	15	43.16	647.4
Deploy and manage temperature data loggers in mainstem reaches and cold tributaries (2 staff)	May - October 2018 and 2019	40	33.43	1337.2
Longitudinal temperature profiles ~~during hottest time of year in reaches that pose temperature limitations mid and lower Nason Creek, Upper Wenatchee, lower Chiwawa, and lower little Wenatchee.~~ (2 staff)	July - September 2018 and 2019	72	33.43	2406.96
Conduct spot-checking ~~of significant ground water seeps identified in FLIR data and tributary inputs from temperature models.~~ Measure plume size and habitat metrics. (2 staff)	July - September 2017 and 2018	80	33.43	2674.4
Snorkel largest cold plumes in each reach. (2 staff)	July - September 2017 and 2018	30	33.43	1002.9
In collaboration with partners and the IT, develop prioritized habitat actions for augmentation projects	September 2018 - November 2019	80	43.16	3452.8
Create and compile maps (including plume extents and potential augmentation), output graphics and photo documentation into an assessment report	September 2018 - November 2019	120	43.16	5179.2
Coordinate, implement, and facilitate meetings with partners and local and regional boards~~, WHSC, EHSC, IT, RTT, MaDMC and interested parties both within the Upper Columbia and outside the region to work toward a regional climate change strategy.~~	January 2018 - December 2019	30	43.16	1294.8
Disseminate report and findings in presentations at several local committees.	September 2018 – December 2019	30	43.16	1294.8
Chief Accountant and Director Tasks	January 2018 - December 2019	106	58.39	6189.34
EQUIPMENT PURCHASES, CONTRACTED HELP, MILEAGE:		unit	cost/unit	
Solinst levellogger and barologger	January - April 2018	2	581	1162
15 hobo data loggers	January - April 2018	15	129	1935
~~Quantum Spatial, LLC~~ create continuous mosaics of thermal imagery (FLIR) collected in Wenatchee Basin	January - April 2018	1	15426	15426
~~Sitka Technologies, LLC~~ Drone based FLIR ~~TIR~~ flights - Wenatchee RM 28-56, Entiat RM 0 -26	Nov~~December~~ - March 2018 and/or 2019	2	~~5000~~6000	~~10000~~12000
Develop online portal	Sep 2018 – December 2019	1	6000	6000

mileage		3600	0.565	2034
Spatial analyst (GIS extension)	January - April 2018	2500	1	2500
TOTAL GRANT REQUEST				~~61~~69,990

C. Explain how the sponsor determined cost estimates.

Staff costs are hourly rates including benefits and indirect for CCNRD staff (2 staff is the average between the hired field tech and project manager). The numbers of hours to drive, perform longitudinal profiles, spot check, review data and write the report was derived from similar work conducted in the Kahler reach of Nason Creek. Based on their experience conducting redd surveys, WDFW also provided input on time to do longitudinal profiles. ~~(redd surveys likely take a bit longer since surveyors must stop and record redd data, whereas we will float or walk continuously).~~ Cost to create thermal mosaics of FLIR ,~~and~~ perform drone ~~TIR~~ FLIR flights, and create the online portal were developed from quotes from Quantum Spatial and ~~Sitka Technologies~~ICF.

D. How have lessons learned from completed projects or monitoring studies informed the project? CCNRD staff have developed and implemented methodologies for this type of longitudinal profiling and microhabitat sampling for work on the Nason Creek Kahler Design Project (SRFB 2014) beginning in 2013. Similarities in the 2013 and 2015 longitudinal profiles of the Kahler reach of Nason creek revealed the method produces repeatable patterns in stream temperature. CCNRD staff used the "spot checking" method between RM 7.4-6.0 and was able to ground –truth cold seeps indicated in 2001-2003 FLIR images approximately 70 percent of the time. Results at Kahler were used to develop elements of restoration design (Figure 6). ~~4).~~ Additionally, spot checking in CCNRD restoration sites has proven to be an effective method of finding refugia and these areas usually include aggregates of juvenile salmonids, when ambient stream temperatures exceed 17C and the refugia is 2°C cooler . CCNRD staff has previously applied these methods in tributaries of the Willamette River as part of master's degree work, where it was learned that this method works to identify cold spots and that adult spring Chinook preferentially held in cold areas within the profile (Roumasset 2012).

9. If the project includes an assessment or inventory

A. Describe any previous or ongoing assessment or inventory work in your project's geographic area and how this project will build upon, rather than duplicate, the completed work.

Numerous assessments and inventories have been completed in the project tributaries and new restoration planning efforts are in process. The project will provide more detailed data and recommendations that can be incorporated into these existing assessments and planning efforts. CCNRD has worked with UCSRB in the development of this assessment, and they are supportive of this proposal to address ~~current and emerging~~ data gaps and better plan for salmon recovery in the basin (please see Response to 9B for specifics on how this project meets data gaps).

As described in question 8a, there is a vast amount of temperature data and models that describe current and future stream temperature conditions (Ecology FLIR, MODIS and NORWEST models, stream temp loggers). All point to temperature limitations to ESA-listed fish and further habitat constrictions due to increased temperature in future warming scenarios. To date, no one has used this data to systematically plan for climate change with on the ground solutions. ~~This proposal will leverage on this data to support thermal refugia and~~ create habitat resiliency under climate change. Ground-truthing and data collection can locate areas that currently serve as cold

holding areas for ESA-listed adult spring Chinook and areas that can be augmented to serve this purpose and aid WDFW's effort to understand the mechanisms and reduce pre-spawn mortality. Juvenile winter survival and distribution studies are occurring in the Wenatchee and Entiat. This Assessment will support these studies by providing fine-scale temperature data (FLIR) that can aid in developing fish-habitat relationships.

The RTT is in the process of updating the current Biological Strategy. This will include a re-prioritization of projects. Data on the riverscape scale was called out at the WHSC as a need that would support this effort. This proposal will provide temperature data on the riverscape scale that can be matched to the scale of fish movement and distribution in freshwater.

~~Reach~~ Assessments and Tributary Assessments are available for the lower 14 miles of Nason Creek (BOR 2009 and 2010), the Upper Wenatchee (Yakama Nation 2012) and the Middle and lower Entiat (BOR 2009, 2013 and 2012). The Lower Chiwawa has had many years of fish inventory work funded by Chelan Public Utility District and is now part of a 75,000-acre US Forest Service planning area looking at fire resilience, fuel loading, road issues, and aquatic conditions. This planning area will likely result in timber harvest, road abandonment and other actions to treat changes in landscape condition. This assessment will also merge well with other CCNRD ~~is also starting on a~~ projects, including LIDAR expansion, road inventory, and the Nason TMDL project to address ~~the Nason TMDL (Ecology funding) with the goal of identifying and treating~~ issues linked to water quality degradation (sedimentation) and temperature. ~~as well as a road inventory project (SRFB funding) in Nason Creek.~~

The proposed assessment will include temperature data on the riverscape (longitudinal profiles) and reach (spot checking) scale that can be overlaid with geomorphic data from completed assessments, proposed action areas in forest planning projects, and road inventory information to expose processes that control refugia and identify areas needing protection and/or restoration. This will provide a landscape scale assessment to complement existing assessments and inventories and help prioritize future planning for restoration and protection and is supported by UCSRB.

B. If a design is NOT a deliverable of this grant, please describe how this project meets all of the required criteria for filling a data gap that are list in Section 2 of Manual 18.

The current list of regional data gaps is out of date (2008) and ~~the region is working to develop an updated list for the 2017 SRFB process~~ a new data gaps list has been drafted. ~~Within the existing 2008 list~~, ~~The~~the most closely aligned data gap in the 2008 list states: "Study the effects of climate change on the water temperature of the Okanogan, Methow, Entiat, and Wenatchee Rivers and *ways to mitigate for increase water temps*." (UCRTT 2014). This project also addresses two ~~emerging~~ data gaps ~~that are expected to rank high on the new data gaps table~~in the new list (USCRB, pers. comm.): 1) ~~Location, distribution, and opportunities to restore thermal refuge areas~~ Location and quality of thermal refuge areas is unknown 2) ~~WDFW stated in their annual report that "The distribution, habitat preference, capacity and survival of juvenile salmonids in non-wadable rivers are major data gaps" (Truscott et al 2016).~~The effects of thermal profiles on fish distribution and movement is unknown. Both these gaps address fish survival and bottlenecks and if left can result in misguided habitat projects (i.e., high priority).

a. Currently there is no information available to sponsors about thermal refugia (either locations or opportunities). We know that water temperatures will increase in the future and therefore thermal refugia will be critical to the survival and recovery of our listed species. This project would be the first step toward protecting and enhancing these critical areas. WDFW noted habitat preference of over-wintering fish as a "major data gap" (Truscott et al, 2016). This project will assess whether temperature is a driver of habitat preference and help establish

fish-habitat relationships. "Without these relationships, habitat restoration projects may be misguided" (Truscott et al, 2017). The~~Once the~~ ~~Wenatchee~~ thermal refugia mapping will address data gap 1 above and all information, including identified projects, will be displayed in a GIS portal on the UCSRB website. ~~and assessment is completed,~~ Projects will be developed based on methods in Kurylyk et al 2014 and those developed by parties outside the basin (see d below).~~the Implementation Team, Watershed Action Team and other partners will use it to develop future projects.~~ The RCO, UCSRB and RTT have communicated with sponsors the importance of these projects and their priority in the region. This assessment is the first step in our region's climate change adaptation strategy, which is currently under development.

b. The proposed assessment will help mitigate for increasing water temperatures by identifying opportunities to restore and protect thermal refugia. Protection and restoration of thermal refugia is thought to be one of the most important actions needed to increase resiliency to climate change. The need for such an assessment was specifically called out at the 2016 Upper Columbia Science Conference and reiterated at the March 2016 Implementation Team meeting on climate change adaptation. The UCSRB specifically asked sponsors to develop a project to map and characterize thermal refugia as part of a larger strategy to address climate change. The hope is to use this project in the Wenatchee as a pilot project that could eventually cover the Entiat, Methow, and Okanogan as well.

In addition to the above, this project will fit into a larger context through work with the Climate Impacts Group to study the effects of climate change across the Columbia Basin. It will also fit into WDFW research on high pre-spawn mortality of spring Chinook above Tumwater dam, as well as research in both the Wenatchee (WDFW) and Entiat (USFWS) concerning over-winter juvenile survival and habitat metrics that drive un-even distribution.

c. Funding for climate change adaptation and assessment is difficult to secure. Few entities fund these types of assessments and because of the clear link of results to future SRFB projects, this funding source is a great fit.

d. As part of the proposed assessment, thermal refugia will be mapped and characterized. Each refugia area will be evaluated based on the criteria in the bulleted list under question 8A. These criteria will help determine the priority of different refugia for either protection or enhancement projects. Through the development of this proposal (2016 and 2017) ~~and work with the Climate Impacts Group in Seattle~~, CCNRD staff have ~~formed relationships to~~consulted ~~biologists~~ who are at the forefront of developing and implementing techniques to identify, enhance and create thermal refugia ~~with organizations in other basins~~ (i.e. The Estuary Partnership, Lower Columbia EPA, Cramer Sciences, Klickitat County~~)~~. ~~who are at the forefront of developing techniques to identify, augment and create thermal refugia projects.~~ Once sponsors have the location and priority of existing refugia areas they can easily develop projects based on these techniques and those elucidated in Kurylyk et al 2014 (i.e. Figure 4)~~-~~. The schedule for such projects will be laid out in the regional Implementation Schedule that is annually updated by the Wenatchee Watershed Action Team and the Implementation Team.

C. Will you apply for permits as part of this project's scope? No
No permits should be required for data review and collection.

11. Explain why it is important to do this project now instead of later. The 2016 NOAA status review identified several key findings, one of which was that habitat degradation and the lack of complex, cold-water refuge continue to threaten the survival and recovery of many

populations. Thus, it is important to look at ways to support thermal refugia in stream reaches that present temperature limitations to survival. In 2015, low snowpack resulted in record summer low flows and high stream temperatures in the Wenatchee basin. 2015 may be a glimpse into future conditions under climate change (Higgins et al 2016). Roughly 200 Adult ESA-listed species were observed using a single thermal refuge in the Wenatchee River at the mouth of Chiwakum Creek during 2015 summer (Russ Rickets, Native Fish Society, personal communication). There are likely other tributary confluences that, like this one, could be restored to increase habitat capacity (Figure 4) or quality (i.e. large wood to provide cover) to improve ESA-listed survival at all life-stages. Juveniles were also observed using small cold pockets in the Wenatchee River during the drought summer of 2015 (Jennifer O'Neil, Natural Systems Design, personal communication. Pre-spawn mortality of spring Chinook above Tumwater dam is estimated at 50 %). The location of adult spring Chinook holding areas and cold refugia in temperature limiting spawning reaches is unknown (Andrew Murdoch, personal communication). This assessment would identify functioning thermal refuge and opportunities to augment cold spots to improve their fish capacity and reduce the threat of pre-spawn mortality. As noted above (9b), without the information on thermal refugia and factors driving juvenile over-wintering distribution, habitat projects may be misguided as to the actual life-cycle bottlenecks that impede recovery. With ongoing climate change, the current lack of salmon recovery work associated with supporting thermal refugia and the 2016 NOAA finding mentioned above, it is important to begin this process immediately.

12. If the project is a part of a larger overall project or strategy, describe the goal of the overall strategy, explain individual sequencing steps, and which of these steps is included in this application for funding.

CCNRD has discussed integrating our local climate change planning strategy with the Climate Impacts group (Seattle) and they have been receptive to providing technical review and data access. The proposed assessment strives to promote ESA-listed salmonid resilience to warming stream temperatures under climate change, and is part of a larger regional strategy. This project can have mutual benefit in a program developed to increase monitoring/data collection for management and analysis, and to support analysis designed to improve both sampling strategies for monitoring and the subsequent management.

This project responds to a lack of comprehensive data on temperature and the role it plays during summer peaks, and is being proposed as an additional assessment tool in the middle of the implementation phase of the recovery process. This assessment addresses a tier 2 data gap to study the effects of climate change on water temperature and ways to mitigate for increased water temperature (Appendix F of Recovery Plan) and has been developed with the support of UCSRB.

Though many projects have been implemented or are in development in Nason Creek, the remaining tributaries within the project have had very few projects implemented at this time. Data from this project will be useful for sponsors designing restoration projects, prioritizing in-stream flow opportunities and prioritizing protection activities. Additionally, the data could be very useful for future planning/development efforts and even for amendments to existing regulations governing critical areas in Chelan County.

13. Describe the sponsors experience managing this type of project. CCNRD staff has developed a robust post-construction and pre-design data collection program. This includes a variety of techniques and collaboration with a wide range of partners. Stream flow, temperature, groundwater wells, topo survey, fish use and plant survival are routinely included with this work. CCNRD has a long history of managing assessment, design, construction and planning projects with a multitude of funding agencies including RCO and Tributary Committee.

.**14. List all landowner names.** N/A

15. List project partners and their roles and contributions to the project.

WDFW (Andrew Murdoch and Jeremy Cram) – Technical advice for assessment priorities and how it can benefit the development of a spring Chinook life-cycle model

USFWS (Tom Desgroseillier) – Technical advice on using data for establishing fish-habitat relationships related to over-winter survival and distribution in the Entiat River.

Climate Impacts Group (Amy Snover) – Technical assistance

South Fork Research (Carol Volk) – Will create specific outputs of the MODIS model to support thermal refuge data collection.

16. Stakeholder outreach. CCNRD has worked extensively with community members in the Upper Wenatchee Basin including conducting public meetings on a bi-annual basis to update citizens on Salmon Recovery Planning, Watershed Planning, and Community Lands Planning and on specific habitat improvement projects. CCNRD will include a stakeholder outreach component in the project to inform the community on the assessment and the strategy for addressing climate impacts within the Wenatchee Basin.

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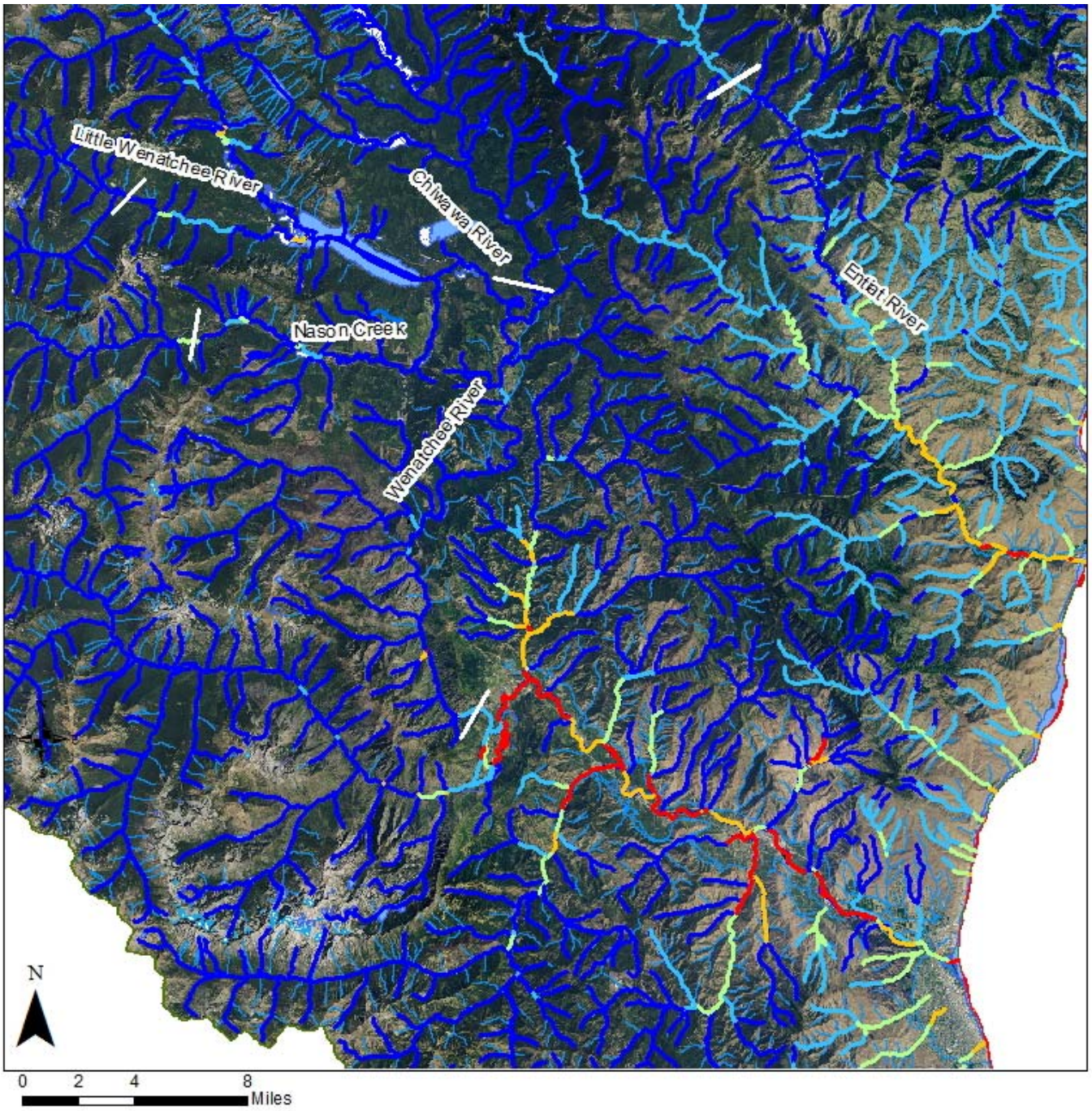
Figure 1. Project Area (White bars denote reach breaks) with MODIS layer depicting the 8-day weekly mean of January 1, 2013.



Legend – Temp in °C
0 – 0.3
0.3 – 0.45
0.45 – 0.6
0.6 – 0.8
0.8 – 1.0

UPDATE FROM PRE-PROPOSAL: Due to high root mean square error for this time period (Wenatchee 1.04°C and Entiat 1.4°) this particular 8-day block will not be used in this assessment (See "response to comments" question 4).

Table 1. Available temperature data and proposed data collection per reach

	Temperature data available to review				Proposed supplemental temperature data collection				
	MODIS MODELING	NORWEST MODELING	FLIR	temp logger network	TRIB SPOT CHECKING	FLIR COLD SPOT CHECKING	TEMP PROFILE FLOAT	TIR DRONE FLIGHT	TEMP LOGGER NETWORK
Nason	X	X	X	/	X	X	X		X
Upper/Middle Wenatchee	X	X	X	/	X	X	X	X	X
Lower Chiwawa	X	X	X	/	X	X	X		X
Little Wenatchee	X	X	X	/	X				X
Entiat	/	X		X	X	X		X	/

X = complete, / = partial

This data will be collected in reaches that are temp limiting to rearing Steelhead/Spring Chinook according to review of available temp data

Figure 2. NORWEST model Upper Wenatchee Basin – Average August mean temperature 2002- 2011. Numbers correspond to hypothetical habitat projects listed in Table 2

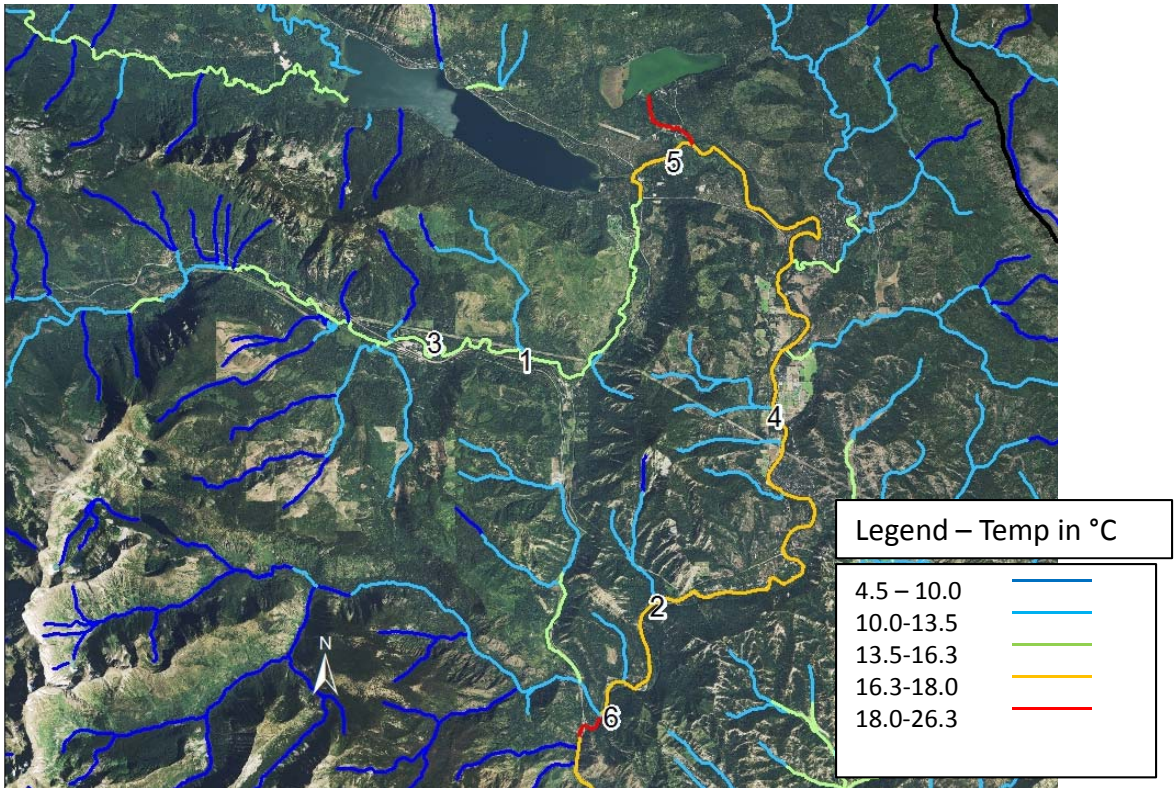


Figure 3. NORWEST model Upper Wenatchee Basin – Average August mean temperature based on A1B climate warming trajectory in the 2040s

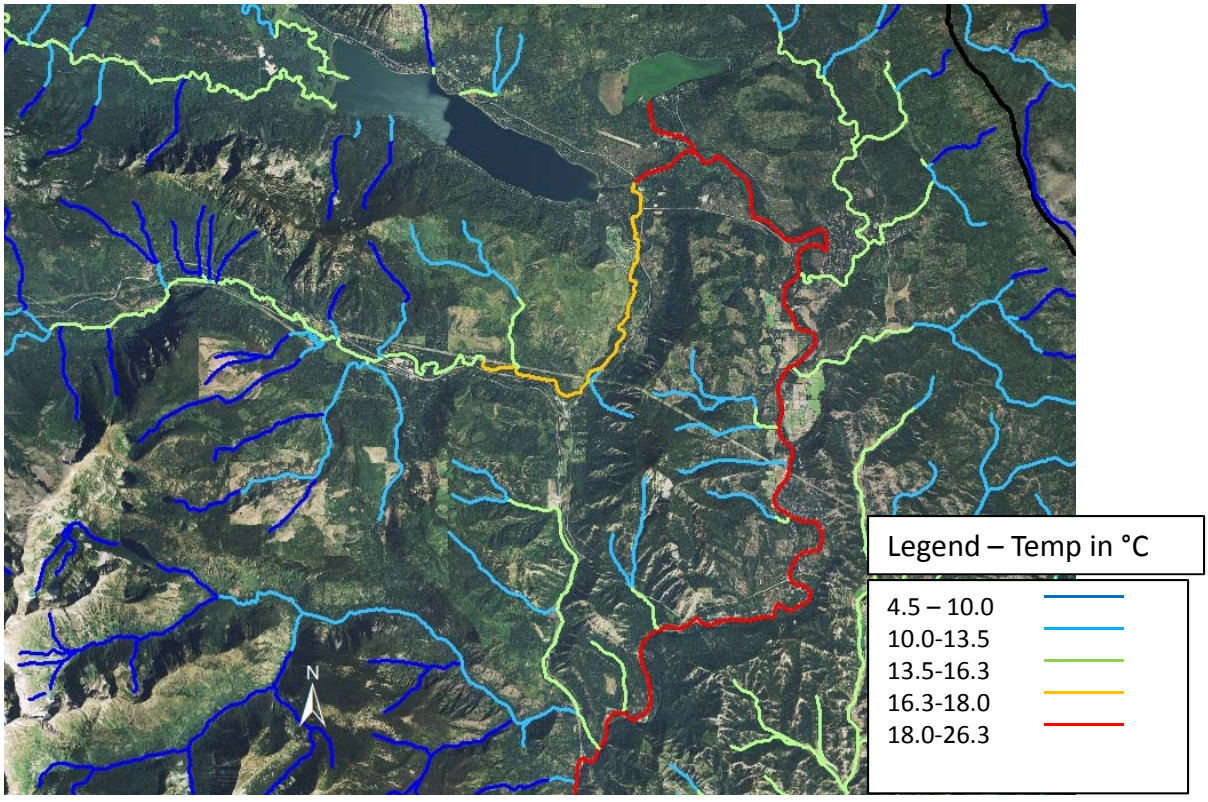


Table 2. List of *hypothetical* projects, Map ID numbers correspond to those on Figure 1. Format is a short subset of the types of projects and presentation format that would be included in the completed Thermal Refuge Assessment.

MAP ID	Name	Description	Habitat Action	Goal	Priority	Feasability	Other notes
1	Kahler Creek	Cold trib plume, 6 ft²	Deflector structure	Reduce thermal mixing, increase plume size	H	H	Conceptual design completed
2	Dead horse Creek	Cold trib plume, 5 ft²	Deflector structure	Reduce thermal mixing, increase plume size	H	M	High concentration steelhead redds
3	Nason Creek Rest Area	Cold ground and hyporheic input	LWD structures	Increase pool area and provide fish cover	M	M	High concentration Chinnok redds
4	Upper Wenatchee RM 45	Cold trib plume, 4 ft²	Deflector structure	Reduce thermal mixing, increase plume size	M	M	Climate change pred. temp limiting
5	Upper Wenatchee RM 49 - 53	Area of rapid warming	Structure and gravel augmentation	Increase porosity and hydrolic forcing to increase hyporheic flow	H	M	Spring Chinook redds decreased in recent years
6	Chiwakum Creek	Cold trib plume 20 ft²	Deflector structure	Increase plume size, encourage pool formation and provide cover	M	M	Functioning thermal refuge although pool depth and cover are low.

Figure 4. A cold-water plume at the mouth of a tributary before (a) and after (b) installation of a channel deflector to limit advective thermal mixing (Kurylyk et al 2014). Creating a larger cold plume with a wood structure increases habitat capacity of the thermal refuge as well as reach-scale thermal diversity. Tributaries will be surveyed and habitat projects will be identified as part of this Assessment.

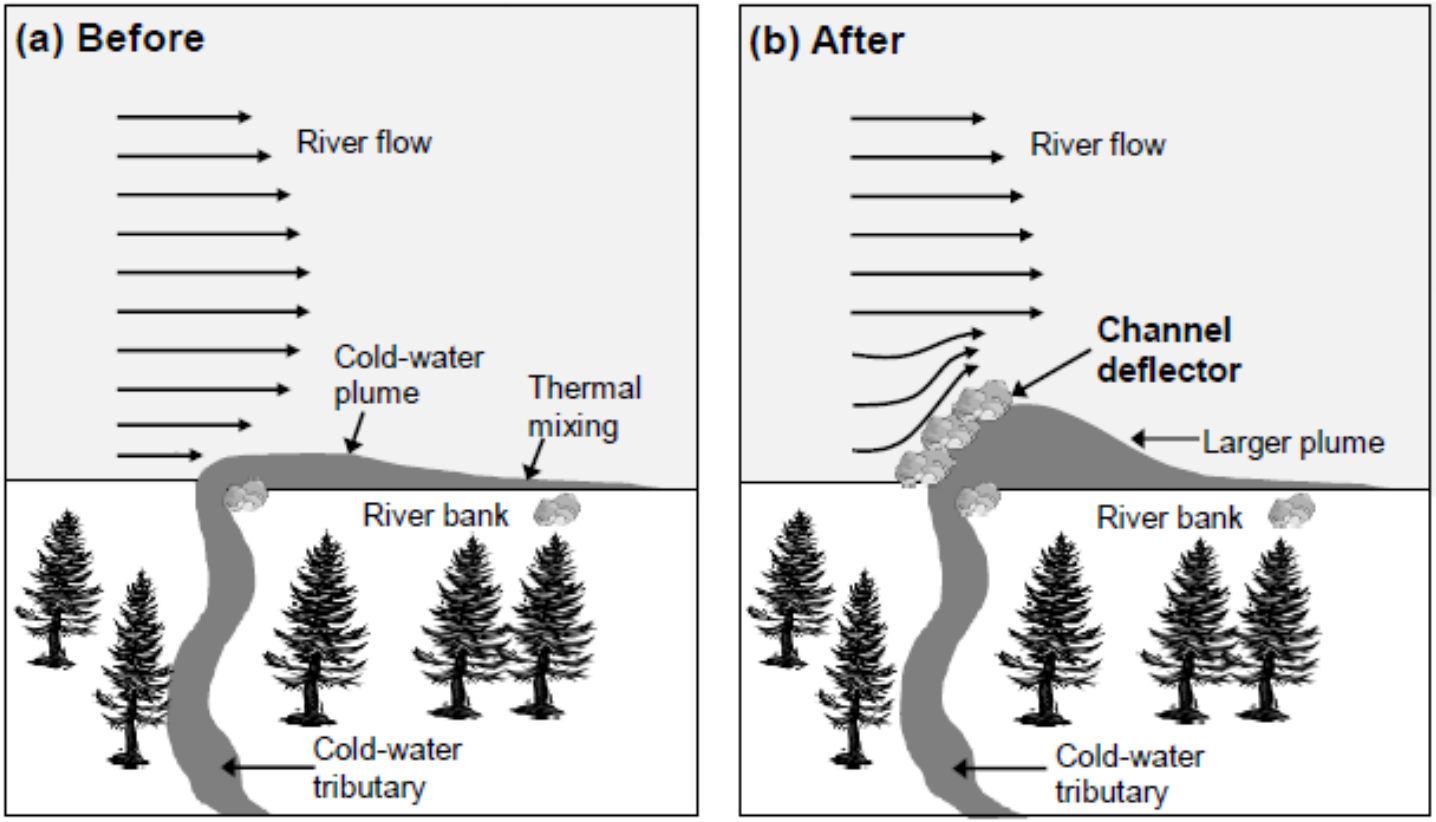


Figure 5. ICF created this online viewer for a dataset in the Chehalis. A similar interactive online GIS portal will be on the UCSRB website and will allow users to zoom in and out and view multi-scalar thermal heterogeneity, small reaches with cold plume sizes, recommended habitat projects and other fish and land use layers.

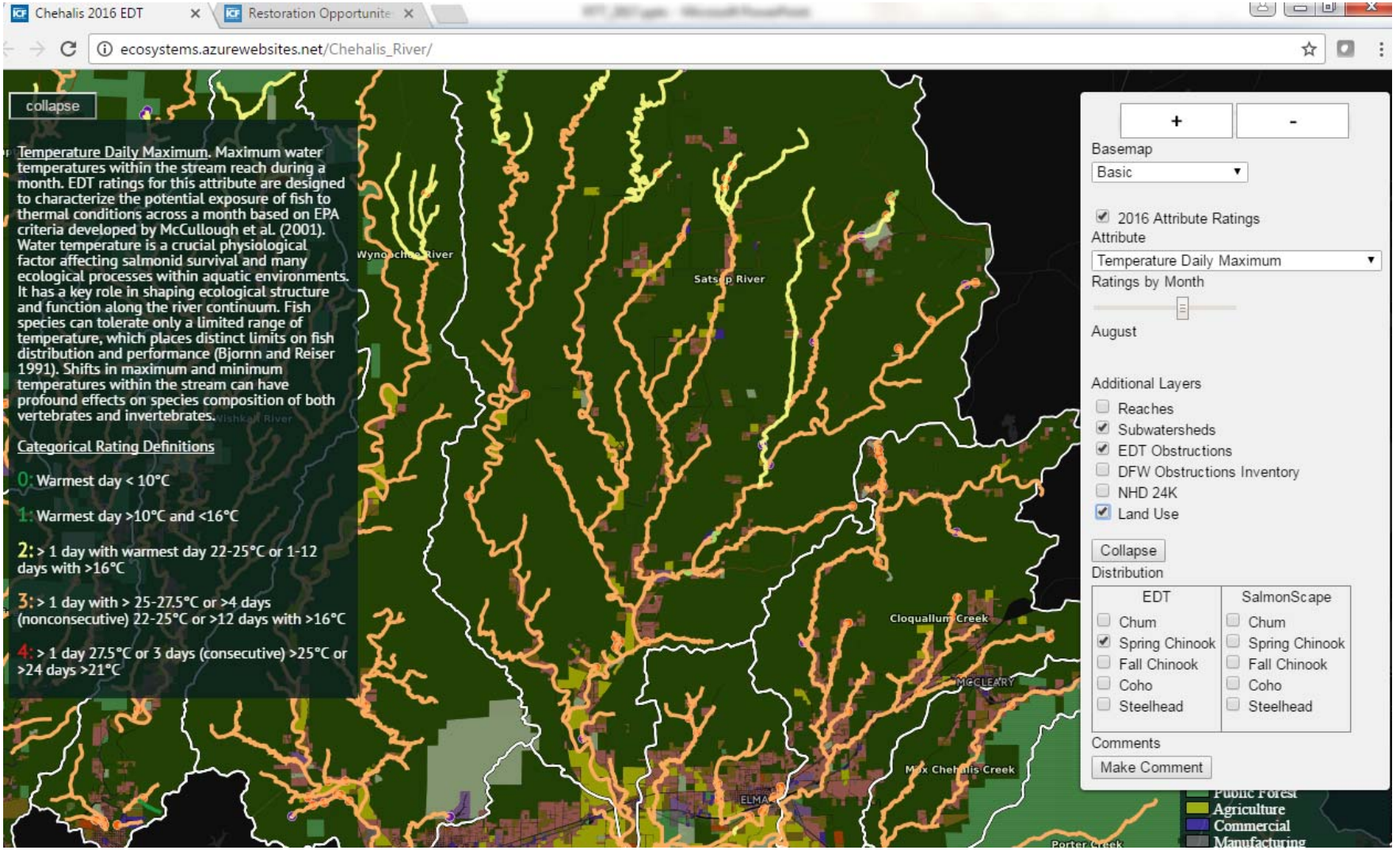


Figure 6. Schematic included in Kahler Conceptual Design. Elements highlighted in yellow were based partially on thermal profiling and spot checking work that this Assessment proposes to expand. Kahler Creek is a cold tributary with a small plume that will be enhanced as part of Kahler Reach restoration. Current habitat quality of cold seeps in the side channel is low and will be enhanced with ELJs that provide fish cover.