Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators: Annual Report 2013

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Annual Report 2013

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Introduction

The Columbia River Inter-Tribal Fish Commission is conducting a fish habitat monitoring program in the Upper Grande Ronde River and Catherine Creek basins designed to evaluate the effectiveness of aggregate restoration actions in improving freshwater habitat conditions and viability of ESA-listed salmon populations (McCullough and Sharma 2009). A critical uncertainty for fisheries managers in the Columbia Basin involves determining whether habitat restoration actions will yield a net improvement in basin-wide habitat quality. Bonneville Power Administration funds our project and has an interest in determining whether expected improvements in fish production can be brought about by improvements in the quality and quantity of salmon habitat. Beyond this, BPA is concerned with whether the monitoring of fish/habitat relationships in the study basins can be extrapolated to basins not studied intensively so that recovery at the MPG or ESU levels can be inferred.

Habitat restoration is being conducted by agencies such as the US Forest Service (upper Grande Ronde mine tailings restoration, where channel damage was done by historic dredge mining of the streambed), the Umatilla Tribe (e.g., McCoy Creek Meadows restoration, where natural river meanders are being restored to a channelized stream), the Oregon Department of Fish and Wildlife, and the Grande Ronde Model Watershed (e.g., riparian fencing, riparian planting, improvement of irrigation diversions). The US Bureau of Reclamation is also conducting studies of water use and availability in Catherine Creek watershed and may implement projects based on the findings (BOR 2013).

There have been many studies conducted in recent years examining the current condition of fish habitat in all the subbasins of the Columbia River. Some of the most common impediments to survival of salmon tend to be high water temperatures, increased concentrations of fine sediment in spawning gravel, loss of riparian vegetation, channelization, loss of large woody debris in the channel, loss of large pools for adult fish to hold in prior to spawning, and summertime depletion of streamflows in the channel. Added to these concerns caused by human influence is climate change, which can lead progressively to changes in the timing of runoff from snowmelt, increased summer air temperatures, and change in the seasonal distribution of precipitation.

We are attempting to monitor all habitat factors that have been identified by previous studies as the key limiting factors. Our monitoring plan includes measurement of: water temperature, streambed substrate composition and fine sediment concentrations, streamflow, water chemistry, riparian condition, stream channel morphology (including spawning habitat and large pool distribution), large woody debris, benthic macroinvertebrates (diversity and density, which indicate long-term water quality), drifting macroinvertebrates (indicating fish food availability), and fish snorkeling (indicating relative abundance of salmonids and qualitative indices of abundance of non-salmonids). Habitat surveys are conducted in 25 sites per year distributed throughout the currently used spring Chinook spawning and rearing habitat in the Upper Grande Ronde and Catherine Creek basins following methods developed by the Columbia Habitat Monitoring Program (CHaMP; www.champmonitoring.org).

As a means to integrate habitat monitoring efforts with recovery planning, CRITFC is developing a life cycle model. The current prototype population is Catherine Creek spring/summer Chinook, but the model's utility will extend to other salmonid populations and life history types. The fundamental basis of the model is that habitat conditions are drivers that affect known limiting factors (e.g., flow, temperature, pool area, etc.), and therefore survival via both density dependent and independent

processes. Habitat/survival relationships are built into several freshwater and marine life stages such that both age structure and spatial structure can be predicted in relation to changes in environmental conditions. Thus, the current and future habitat conditions can act as predictors of relative change in survival at different life history stages, and therefore affect recovery potential. Furthermore, the spatial availability and quality of spawning and rearing habitat, and the allocation of resources to improve habitat can have an indirect but quantifiable effect on the potential production of a population. Climate change will be integrated into population predictions as an exogenous factor that affects some of the key limiting factors. The life cycle model is being designed as a tool to simulate population trends in relation to projected habitat conditions, and to examine the relative benefits of habitat improvements on population recovery potential.

The primary objectives of this project are to: 1) Assess current status and trends in fish habitat characteristics considered to be key limiting factors (particularly water temperature, pool habitats, streamflow, and fine sediment) to viability of spring Chinook salmon populations; 2) Evaluate effectiveness of aggregate stream restoration actions aimed at improving key limiting habitat factors; 3) Develop a life cycle model to link biotic responses of spring Chinook populations to projected changes in stream habitat conditions.

Methods: Protocols, Study Designs, and Study Area

Tributary Habitat RM&E

Monitor and evaluate tributary habitat conditions that may be limiting achievement of biological performance objectives.

What are the tributary habitat limiting factors (ecological impairments) or threats preventing the achievement of desired tributary habitat performance objectives?

Study Area

This study is being conducted in the Grande Ronde River and its tributaries, which originates in the Blue Mountains of NE Oregon and flows 334 km to its confluence with Snake River near the town of Rogersburg, Washington (Figure 1). Focal watersheds include the upper Grande Ronde River above the town of La Grande, Catherine Creek, and to a lesser extent, the Minam River, which drain areas of approximately 1,896, 1,051, and 618 km^2 respectively.

The topography of the upper portion of the subbasin (i.e., upstream of the Wallowa River confluence) is characterized by rugged mountains in the headwater areas and a broad, low gradient valley between the Blue and Wallowa Mountains. Peaks in the Wallowa Mountains reach a maximum elevation of 2,999 m (9,838 ft), and provide the source of many of the Grande Ronde's tributaries including Catherine Creek and the Wallowa River. The Blue Mountains reach elevations of 2,347 m (7,700 ft), and are the source of the Grande Ronde River, Wenaha River, and other tributaries. Due to the lower elevation of the Blue Mountains, snow melt generally occurs earlier in these tributaries, often resulting in very low flows during summer.

Surface geology of the Grande Ronde Subbasin is dominated by rocks of the Columbia River Basalt group, with some older granitic intrusives and older volcanics with associated sedimentary deposits present in the headwater areas of the Upper Grande Ronde and Catherine Creek. The climate is characterized by cold, moist winters and warm, dry summers with mean daily air temperatures near La Grande averaging -0.42 °C (31 °F) in January and 21 °C (70 °F) in July. Average annual precipitation

ranges from 36 cm (14 in) in the valleys to 152 cm (60 in) in the mountains, with most of the precipitation in the mountains falling as winter snow.

The vegetation community at lower elevations is dominated by grasslands consisting of Idaho fescue-bluebunch wheatgrass (*Festuca idahoensis-Agropyron spicatum*) and bluebunch wheatgrass-Sandberg's bluegrass (*Agropyron spicatum-Poa sandbergii*) (Nowak 2004). As elevation increases, the grasslands transition to shrub/scrub plants, and eventually to coniferous forests in the mountains. Forest species consist of low elevation Ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) associations grading into Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), subalpine fir (*Abies lasiocarpa*), and mountain hemlock (*Tsuga mertensiana*) associations at higher elevations. Riparian vegetation is dominated by black cottonwood (*Populus trichocarpa*) and willow *(Salix* spp), black hawthorn (*Crataegus douglasii*), mountain alder (*Alnus incana*), and mountain maple (*Acer glabrum*).

Approximately 49% of the land in the Grande Ronde basin is publically owned, of which about 97% is managed by the US Forest Service. The remaining public land is managed by the Bureau of Land Management and the States of Oregon and Washington. With the exception of the Eagle Cap and Wenaha-Tucannon Wilderness Areas, the National Forests are managed for multiple use including timber production, livestock grazing, and recreation. Private property comprises 51% of the land in the basin and is located primarily in lower elevation valleys and along rivers. A large proportion of the private property is used for agriculture including crop production, livestock grazing, and forestry. Only 0.1 % of the land in the Grande Ronde Basin is currently owned by the tribes, although the tribes retain fishing and hunting access rights at all usual and accustomed locations as afforded under the treaties of 1855 and 1863.

Spring Chinook populations in these basins were listed as threatened under the Endangered Species Act in 1992. Population declines over the past century were due in part to severely degraded habitat conditions resulting from intensive anthropogenic disturbances including timber harvest, cattle grazing, levee and road construction, and stream diversions for irrigation. Specifically, stream temperature, streamflow, fine sediment, habitat diversity, and quantity of key habitats such as large pools, have been identified as key limiting factors for recovery of Chinook populations in these basins (Nowak 2004).

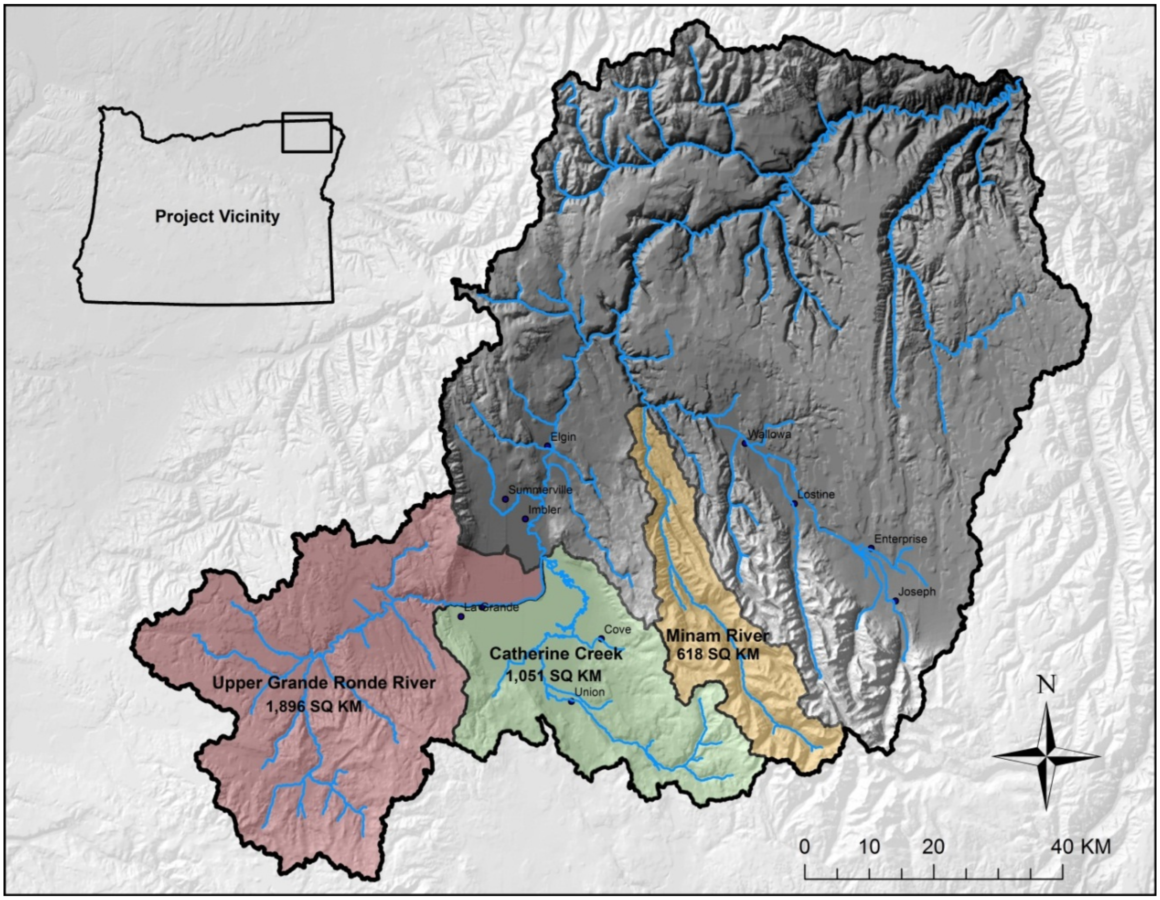

Figure 1. Study area in the Grande Ronde River basin, NE Oregon. Focal watersheds include the Upper Grande Ronde River, Catherine Creek, and Minam River. The Upper Grande Ronde and Catherine Creek are the basins with significantly damaged habitat that is undergoing restoration in various locations. The Minam River basin is the local reference basin that has far less current evidence of human impact.

Work Element C 157: Collect all CHaMP habitat data, such as water temperature, sediment, streamflow and habitat condition data.

Summarizing selected CHaMP metrics using GRTS

In 2013 we finalized CHaMP sampling at all spatially-unique sites for the anticipated duration of the project. Selected habitat metrics important for Chinook salmon at various life history stages (percent pools, total fish cover, large woody debris per 100 m, and fine particles <6 mm) were summarized for the entire the upper Grande Ronde and Catherine Creek watersheds in spawning & rearing vs. rearing only habitat, as well as by assessment unit. Assessment unit boundaries correspond approximately to the HUC6 watershed boundaries, but were aggregated or modified to better represent significant breaks in physical channel morphology (e.g., tributary junctions or major changes in valley confinement), land ownership, or fish use. Assessment units were developed by local experts associated with the Federal Columbia River Power System (FCRPS) Biological Opinion expert panel and restoration implementation group (i.e., Atlas Group) for use in planning and implementing stream restoration actions. Habitat metrics were summarized by watershed and assessment unit using a generalized random-tessellation stratified (GRTS) design, which allows for a spatially-balanced random sample and incorporates inclusion probabilities for each sample (Stevens 2002; Stevens & Olson 2004). Estimates were computed using the spsurvey package in R (Kincaid & Olsen 2013).

We used methods described in the Columbia Habitat Monitoring Program (CHaMP) protocol to collect stream habitat data at 25 sites within the Upper Grande Ronde and Catherine Creek basins during the summer of 2013 (CHaMP 2013; https://www.monitoringmethods.org/Protocol/Details/1966). CHaMP is designed as a Columbia River basin-wide habitat status and trends monitoring program built around a single protocol with a programmatic approach to data collection and management (RM&E Workgroup 2010). CHaMP will result in the collection and analysis of systematic habitat status and trends information that will be used to assess basin-wide habitat conditions. When coupled with biological response indicators, this status and trends information will be used to evaluate habitat management strategies.

The CHaMP program will be integrated with ongoing Pacific Northwest Aquatic Monitoring Program (PNAMP) recovery planning efforts and will be part of the collaborative process across Columbia Basin fish management agencies and tribes and other state and federal agencies that are monitoring anadromous salmonids and/or their habitat. The implementation of CHaMP will characterize stream responses to watershed restoration and/or management actions in at least one population within each steelhead and spring Chinook Major Population Group (MPG) which have, or will have, “fish-in” and “fish-out” monitoring. CHaMP was designed to deliver trends in habitat indicators and requires that monitoring occur for three cycles of a sampling panel, at least 9 years.

Survey sites were randomly selected using the Generalized Random Tessellation Stratified (GRTS) survey design (Stevens and Olsen 2004), and were distributed with equal probability across all wadable portions of the stream network that were classified as current spawning and rearing areas for spring Chinook salmon (Figure 2). The fish use classification was modified from fish distribution maps produced by ODFW StreamNet (StreamNet 2009), the Grande Ronde Subbasin plan (Nowak 2004), and the NOAA’s Interior Columbia Basin Technical Recovery Team (ICTRT), and is described in more detail in McCullough et al. (2012).

We used a 3-year rotating panel design (Table 1) with the intention of achieving a good balance between power to describe current status (i.e., accurate description of spatial variation across the entire sampling extent) and power to detect trends over time. This temporal design includes 5 annual sites and 10 rotating panel sites in each basin. Annual sites are surveyed every year and rotating panel sites are

surveyed every 3 years. A total of 30 sites are surveyed each year, with a total sample size of 70 unique sites after 3 years. Note that 5 of the 30 sites within our target sample frame are surveyed by ODFW each year.

A large suite of stream habitat variables is measured at each site, generating over 100 metrics describing the condition of the stream. Most of the variables measured were chosen because they are directly related to salmonid fish growth and/or survival or because they provide critical information used to describe ecological processes in the stream or broader landscape that may be indirectly related to fish productivity. Some of the key habitat variables that we measure include general channel topography (gradient, bankfull width, sinuosity), channel unit type and dimensions (i.e., pools, riffles, cascades), large woody debris frequency and volume, fish cover (overhanging and aquatic vegetation, woody debris, undercut banks), stream temperature, discharge, substrate size composition and fine sediment, riparian structure and cover, and solar input.

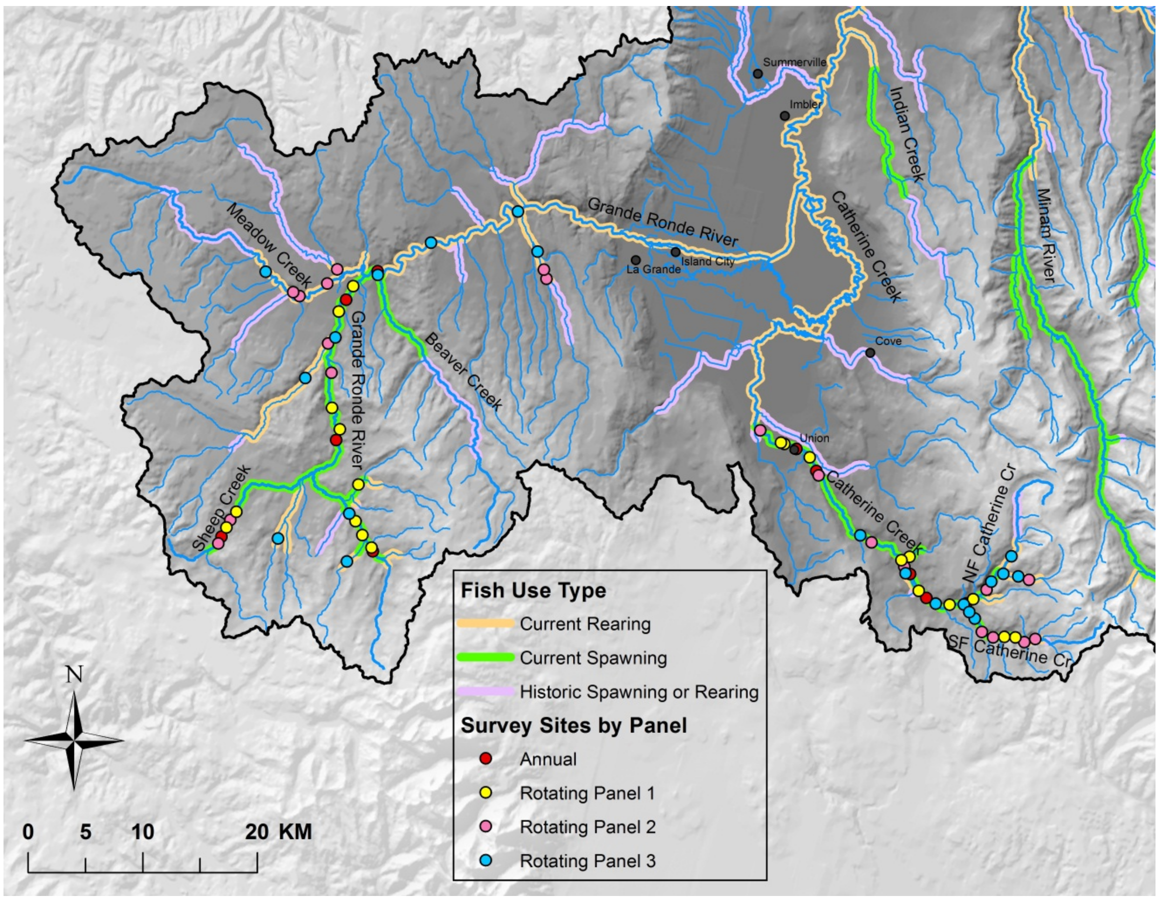

Figure 2. Sampling design showing the distribution of habitat survey sites in the Upper Grande Ronde River and Catherine Creek basins.

Table 1. Rotating panel design for CHaMP survey sites in the upper Grande Ronde River and Catherine Creek basins. Note that 5 of the 30 sites in our survey design are surveyed by ODFW each year.

	Year								
Panel	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Grande Ronde Chinook									
Annual Panel	5	5	5	5	5	5	5	5	5
Rotating Panel 1	10			10			10		
Rotating Panel 2		10			10			10	
Rotating Panel 3			10			10			10
Catherine Creek Chinook									
Annual Panel	5	5	5	5	5	5	5	5	5
Rotating Panel 1	10			10			10		
Rotating Panel 2		10			10			10	
Rotating Panel 3			10			10			10
Total Annual Samples	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
Total Unique Samples	**70**								

Work Element J 157: Collect stream gauging data within overall data collection

In the summer of 2013 CRITFC project PIs decided to discontinue collection of the stream gauging data at the two temporary gauging stations that were set up two years earlier. We discovered that flows from the upper end of the South Fork Catherine Creek were being diverted into an adjoining watershed, thereby altering the summer low flows on which we wished to collect data to represent natural low flows. This left just the site on Sheep Creek that represented summer low flows that were not affected by diversions. It also appeared that more frequent visits during the summer, as well as winter visits were needed to measure stream discharge to correlate with stage height. Because it appeared that we would need to spend much more effort in collecting streamflow measurements to make the stage height data useful, and we had lost one of our two key sites due to diversion, we decided to discontinue these measurements. Sheep Creek is far up the upper Grande Ronde drainage and requires considerable time to reach the gauge site. When field crews are surveying sites lower in the UGR or Catherine Creek, it is a logistical problem to fit a trip to the upper basin into a day's work to take a streamflow measurement.

Our best remaining alternative to estimating low flow characteristics of ungauged streams is found in the CRITFC/USGS contract. This study made use of many regionally available sites that have greater than 10 years of data. With these data, our USGS contractor was able to create a model relating summer low flows to intrinsic basin characteristics.

Work Element E 157: Collect benthic macroinvertebrate samples and process

We collected benthic macroinvertebrate samples at all 25 CHaMP sites using the sampling protocol developed by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP 2007; https://www.monitoringmethods.org/Protocol/Details/44). The sampling protocol was designed to generate data sufficient to characterize the benthic macroinvertebrate assemblage and evaluate impacts from human caused disturbances.

In short, we used a Hess sampler (500 um) to collect 8 square foot subsamples of the benthos at randomly selected locations within riffle habitats at each site. The subsamples were combined to produce a single composite sample for each site. Benthic macroinvertebrate samples were preserved in 95% ethanol, and shipped to ABR, Inc. (now referred to as Cole Ecological, Inc.) for processing and analysis. Invertebrate taxa were identified using the standard levels of taxonomic resolution (level 2) for Northwest benthic macroinvertebrate samples, as established by the Northwest Biological Assessment Workgroup. These standards generally include identification of all major taxonomic groups to genus/species. Benthic collections were subsampled using a gridded Caton tray (GT) and a minimum of 500 organisms was measured for length class and identified.

ABR calculated a suite of metrics for each sample including: standard biotic condition indices (BCI), functional feeding group composition, Hilsenhoff metrics, tolerant/intolerant species based on fine sediment and temperature conditions, PREDATOR model indices, DEQ temperature and fine sediment stressor model indices, total taxa densities, and biomass per m^2. A summary of selected metrics from the 2013 sample year is provided in Appendix A.

Although the information content in the macroinvertebrate data from collections made in 2011-2013 is extensive, Cole Ecological made various computations of community metrics that they provided in summary tables. These data were associated with 181 samples taken by CRITFC and ODFW in this three-year period throughout the combined spring Chinook and summer steelhead spawning and rearing areas. The figures provided in Appendix A show only the average summary metric distribution from this three-year period for the 20 sites present on the mainstem UGR, starting from the headwaters in the mine-tailings area to the mainstem at Hilgaard State Park. The mine tailings area is known to provide the highest quality spawning habitat in terms of optimum water temperatures. However, the McNeil sample data reported in the last annual report (McCullough et al. 2013) indicate that the mine tailings area in the upstream extent of spawning in the mainstem UGR had higher than average subsurface fines. Because surface fines tend to be related to subsurface fines (McCullough et al. 2013), one would expect that sediment sensitive species would be depressed in the mine tailings area.

Work Element F 157: Collect McNeil sediment core samples and process

We collected sediment core samples using a modified McNeil sampler at 6 Minam sites in addition to sites in the Grande Ronde and Catherine Creek in 2013 to quantify the amount of fine sediment present in Chinook salmon spawning gravels. Core sampling was conducted only at sites with suitable spawning habitat for Chinook salmon. In addition, some sites were not sampled due to the presence of spawning salmon and/or freshly-built redds. All sediment samples were returned to the lab where they were dried, sieved, and weighed to determine particle size distribution and fine sediment composition. Detailed sampling and processing methods are described in Justice et al. (2012(a)) (https://www.monitoringmethods.org/Protocol/Details/723).

For each site, we quantified the proportion of sediment particles in the streambed subsurface that was smaller than 2 mm and 6.3 mm in accordance with commonly cited studies examining the effects of fine sediment on egg-to-fry survival of salmonid fishes (Tappel and Bjornn 1983, Chapman and McLeod

1987). Prior to calculating the fraction of fine sediment in each sample, we truncated the data by removing all sediment particles greater than 63mm from the sample to ensure that estimates of percent fines were not disproportionately affected by the presence of a few anomalously large cobbles as recommended by Church et al. (1987).

We compiled all McNeil samples collected between 2010 through 2013 to assess average fine sediment levels for the Upper Grande Ronde and Catherine Creek basins and potential implications for survival of Chinook salmon eggs.

We computed standard Pearson correlation coefficients to evaluate pairwise relationships among a set of 6 different fine sediment metrics including: 1) McNeil fines < 2 mm (*mnfines2*), 2) McNeil fines < 6.35 mm (*mnfines6*), 3) pool tail fines < 2 mm (*ptfines2*), 4) pool tail fines < 6 mm (ptfines6), 5) ocular fines < 2 mm in all habitat types (*ocfinesall2*), and 6) ocular fines < 2 mm in scour pools (*ocfinespools2).*

Work Element H 157: Current and potential riparian vegetation mapping of Upper Grande Ronde and Catherine Creek

PNV mapping project

We are working with riparian plant ecologists to classify and map the potential natural riparian vegetation throughout the streamside zone in Catherine Creek and the Upper Grande Ronde River basins. Detailed methods for this work are described in http://www.monitoringmethods.org/Protocol/Details/805. This project includes four objectives including: 1) Classify and map existing and potential natural vegetation (PNV) upstream of Ladd Creek on Catherine Creek and La Grande on the Upper Grande Ronde River; 2) Attribute PNV polygons based on vegetation height and density with estimates of canopy height and density to use in computing the solar radiation input parameter in the water temperature model; 3) Classify and attribute PNV polygons based on estimates of natural levels of streambank stabilization of dominant plant species; and 4) In the area downstream of La Grande and Ladd Creek, map existing vegetation and identify broad groups of native plant species that may have typified these areas before human settlement.

In the area upstream of La Grande and Ladd Creek, the mapping will follow an Integrated Terrain Unit (ITU) approach (Jorgenson et al 2003) modified for northeastern Oregon. Integrated Terrain Unit Mapping is the process of adjusting terrain unit boundaries so that there is increased coincidence between the boundaries and occurrences of interdependent terrain variables such as hydrography, geology, physiography, soils and vegetation units. The riparian plant ecologists will use currently available classification systems and other pertinent literature to tailor the ITU classification system to northeastern Oregon.

In the area downstream of La Grande and Ladd Creek, we will map existing vegetation and geomorphic surfaces at a scale of 1:24,000 – 1:48,000. Field surveys of current native vegetation as well as historic photos or historic accounts of the riparian vegetation will be used to draw inferences regarding broad groups of native species that may have typified this area before human settlement

The ITU components will be displayed on maps individually to produce distinct geomorphology, surface form, and existing vegetation maps, as well as aggregated to display PNV, physiography, existing and PNV vegetation height and density, canopy structure and complexity, streambank stability, canopy type (broadleaf vs. needleleaf), ecotype (local-scale ecosystem), and Plant Association Groups (Powell et al. 2007). This multi- parameter, aggregative technique makes the ITU approach a powerful mapping tool for completing the study objectives.

Current progress in mapping potential natural vegetation can be summarized in the statements of work for this project for Phase 2 (April 1, 2013-March 31, 2014) and Phase 3 (April 1, 2014-March 31, 2014). Division of labor was specified by the contractors, Aaron Wells of ABR, Inc. and Elizabeth Crowe (independent contractor).

PHASE 2

April 1 – May 31, 2013—Continue ITU mapping [EC].

June 1 – September 30, 2013—ABR and EC in field on other projects, no work to be completed [ABR, EC]

August 26-September 30, 2013 – Continue draft ITU mapping and classification [EC]

October 1, 2013 – March 1, 2014— Complete draft ITU mapping and classification [ABR, EC]

March 15, 2014 — Draft Phase 2 progress report (1 PDF Version), preliminary classification, and existing and PNV riparian maps to date [ABR, EC].

March 31, 2014—Final Phase 2 progress report (1 PDF version) [ABR, EC].

PHASE 3

April 1 – June 9, 2014—Develop sampling plan for July field work based on draft existing and PNV riparian maps; prepare for field surveys [ABR, EC]

June 10 – 20, 2014 (dates approximate)—Field surveys (including 2-travel days and 9-field days) to verify preliminary map and model inputs [ABR, EC].

June 21 – September 30, 2014— Field data analysis [EC]; ABR in field on other projects, no work to be completed [ABR]

October 1 – December 1, 2014—Finalize data analysis and ITU mapping and classification based on field data [ABR, EC].

December 15, 2014 —Draft report and mapping [ABR, EC].

January 31, 2015—Final report (1 PDF version, 3 hard copies), field survey data (MS Access), and GIS deliverables (ArcView Geodatabase) [ABR, EC].

An extensive search for environmental data in tabular and GIS map formats was conducted for the study area that would be useful in mapping potential riparian vegetation according to the protocol adopted. A summary of the data sets compiled and evaluated is provided in Appendix B.

Historic vegetation from government land office survey

Government land office (GLO) surveys for the project area were extracted to describe historic vegetation and other watershed characteristics in the basin. The GLO surveys conducted in the mid to late 19th century were originally intended to provide information to prospective settlers regarding timber harvest, agriculture and animal grazing. During the GLO survey, a surveyor walked each 1 mile section line in which the township was broken up into 36 sections of 1 square mile. Surveyors also walked to boundaries of all townships. Distance was measured in chains and chain links, where 80 chains equals one mile. Surveyors recorded where vegetation, streams/rivers/wetlands, human structures, trails/roads, or other noteworthy features were located on the section line. Upon completing a township, the surveyor usually noted a general description of the township.

Methodologies for extracting information from GLO surveys were adapted and revised from McAllister (2008). GLO survey notebooks were viewed online at the Bureau of Land Management website (http://www.blm.gov/or/landrecords/survey/) and used as a primary data source to spatially locate on a map the vegetation types, landscape characteristics, and human features described in the handwritten notes. ESRIs geographic information system (GIS) ArcMap 10 was used to map the data extracted from surveys.

A point was plotted in GIS for each feature at the location along the township section line (Figure 3) and recorded in a GIS attribute table. A general description was written about each section line's vegetation and soil quality. Data recorded in the GIS attribute table which originated from the surveys consist of date surveyed, surveyor, stream crossing names, width and depth, soil type, human structures, and a number of vegetative species. Data created from the surveys include an accuracy rating of exact feature location versus point placement, animals, and Native American uses. Township summaries were recorded in a separate document along with an image of the original data and hand drawn maps.

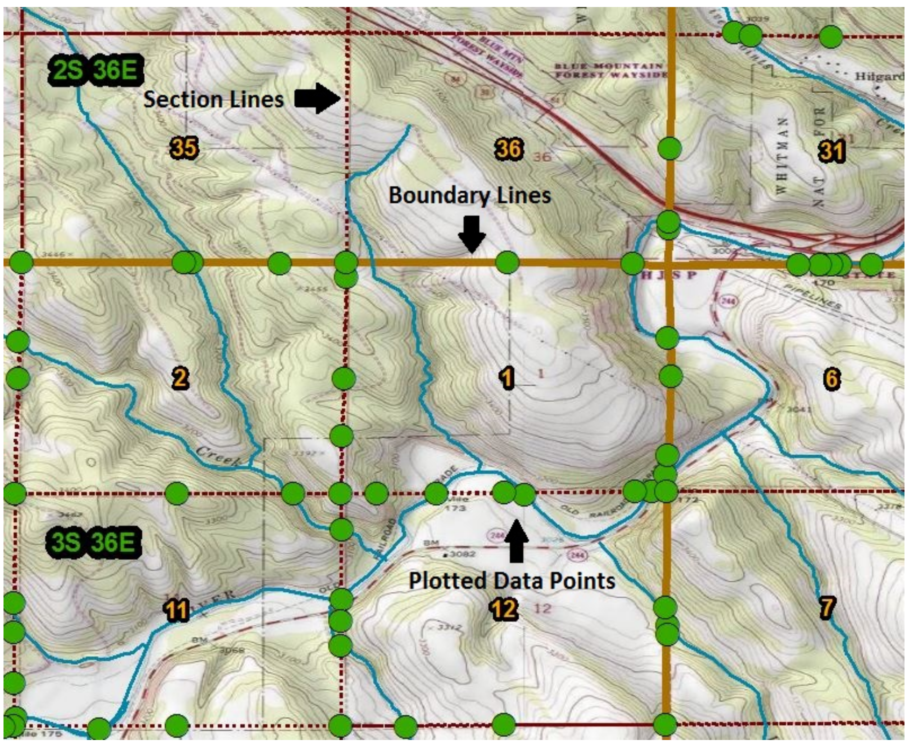

Figure 3. Use of Geographic Information System to plot data points (circles) retrieved from Government Land Office Township surveys in the Grande Ronde Basin.

Work Element 160: Develop and manage fish habitat condition database

Watershed condition

An element of watershed condition that is of key importance in relating to the in-channel condition is the extent and spatial location of the road system. This watershed characteristic is a landuse factor related to in-channel fine sediment, which in turn, is related to biotic response. One of the key limiting factors in the Upper Grande Ronde and Catherine Creek is elevated levels of fine sediment concentrations in spawning gravel. Fine sediment is being measured in various ways. CHaMP protocol calls for measuring fines by means of: (1) ocular estimates of substrate composition in all channel units,

(2) Wolman pebble counts made in fast water channel units (preferably riffles) by randomly selecting 110 particles from the streambed (reduced from 210 particles in the summer of 2012), (3) pool tail fines, which is estimated from placement of grids in pool tailouts and counting the number of grid intersections with particles <2 mm and <6 mm. In addition, CRITFC has been measuring subsurface fine sediment concentrations by taking McNeil core samples randomly within pool tailouts and, alternatively, spawning patches not associated with pools.

Sources of fines in the streambed can be traced to the watershed, riparian zone, or streambanks. These sources specifically include (1) streamside roads, (2) upstream watershed roads, (3) unstable hillsides yielding naturally high levels of sediment yield from slope failures and debris torrents, (4) streambank instability, and (5) transport from instream sediment storage areas upstream. Increased instability of hillslopes is often linked to presence of roads on the hillslopes or logging activity. Increases in the natural instability of streambanks are typically caused by disturbance by either riparian timber harvest (often thinning or salvage) or livestock graving, which both result in loss of riparian vegetation, loss of root strength, and loss of resistance to scouring effects of streamflow.

Roads on the watershed have a significant effect on streams. Roads can lead to increased erosion and sediment yields to the stream network. A road system is accompanied by drainage ditches that route hillslope (cutslope and fill slope) sediments to streams. Roads intercept shallow groundwater flowing downslope. This water is then routed to the roadside ditch, and because the flow is converted to surface flow, it begins to rapidly equilibrate to air temperature. When this water is delivered to the nearest stream, the natural longitudinal temperature pattern is disrupted and abruptly increased. Roads in riparian zones lead to reduced canopy cover, and thereby, often result in increased direct beam solar radiation inputs. Roads also facilitate access to streamside zones by livestock.

The road network is an important land use feature that must be accounted for so that stream habitat conditions can be understood. When a watershed goes from a pristine state to a highly roaded state, the relationship between sediment transport and streamflow changes. That is, for every increment of streamflow, the sediment transport level is greater at every step increase in basin development. In the highly roaded state, a watershed has a sediment rating curve that reflects the high levels of sediment yield. Recovery trends can be followed in annual monitoring by detecting a long-term shift in the slope and intercept of this regression toward a level more similar to a watershed of similar size having a reference salmonid population and with a low level of development (National Research Council 2001).

CRITFC has assembled, as part of its GIS geodatabase, road layers for the study watersheds. The USFS office in Baker City sent us their forest roads GIS layer. This file shows the location of forest roads, including many main transport roads as well as secondary roads. This file has extensive data by road segment on road characteristics, such as road surface type. We also obtained the TIGER road layer (US Census Bureau), which is a nationwide road mapping system that focuses on main transportation routes, including roads through national forest land and private land. We included the two road layers in our geodatabase. We then superimposed these two road layers on the NAIP imagery at 1:6000 scale and digitized roads that were visible on the imagery but were not mapped with either the USFS or TIGER roads maps.

Watershed characteristics have also been collected by using the StreamStats program available from USGS online (http://water.usgs.gov/osw/streamstats/). The basin characteristics are able to be calculated from an extensive set of high quality map databases above any point in the stream network. A list of basin characteristics available from StreamStats is given in Appendix C. In addition, basin characteristics were developed using BasinTools software. See Appendix C. A combination of these data on inherent basin characteristics were used by our USGS contractor (Val Kelly) developing a low flow hydrology model.

Roads

Starting in 2012, we began to assemble map data on roads within the study watersheds. It is known that roads are a significant source of sediment delivery to stream channels. Roads within riparian zones are a more direct influence on streambed fine sediment levels than roads on hillslopes. Typically, sediment delivery models (e.g., those available through NetMap), represent the magnitude of sediment delivery as a function of distance from the stream channel. Road systems essentially create an extensive network of roadside ditches that route water and suspended sediment to the stream network. Consequently, interception of road-related runoff anywhere within the extended stream network has the potential to deliver sediments to downstream spawning and rearing habitats used by spring Chinook.

Mapping of the road network was undertaken as a means to assemble all available data that would permit evaluation of the influence of human and natural disturbance on the landscape in leading to elevated levels of fine sediment in stream channels. In addition to roads, other sediment sources include hillslopes that have been subjected to vegetation cover removal, agricultural fields that have been tilled, livestock disturbance of the land surface and removal of vegetative cover by grazing, waste from mining, streambank erosion that may be exacerbated by riparian vegetation removal, grazing, channel straightening, or increased intensity of runoff with rapid snowmelt (potential climate change impact) and urban development. Road-related sediment delivery magnitude impacts are affected by road surface materials, age of the road, traffic type and intensity on the road, road width, and slope gradient of the land surface that the road lays on.

In 2013 habitat monitoring staff and related GIS staff initiated a joint effort to create a comprehensive, high quality map of the road layer. The road map available from the USFS was lacking sufficient detail on private lands. In addition, many of the roads mapped by the USFS were not accurately placed on the landscape. This inaccuracy in spatial data makes it difficult to accurately estimate the road density in riparian buffers when roads can be 30 to 100 m off of their true locations as determined by the latest, geographically projected, high resolution aerial photos. In addition, roads on upper hillslopes that have known instability factors or are associated with patches of timber harvest where root strength stabilizing the slopes is in decline can lead to significant increases in sediment delivery downslope to streams or to roadside ditches that drain to streams.

In addition to the USFS road layer, the TIGER road layer was available from the US Census Bureau. The TIGER roads layer had much better coverage on private lands but also provided coverage on USFS lands. Both the USFS and TIGER road layers were highly variable in their spatial accuracy. Only the USFS roads layer had important road attribute data associated with each road segment. These data included road material and road width (single lane, double lane). Consequently, the USFS road segment was retained when it was duplicated by a TIGER road. The USFS or TIGER roads, however, were adjusted in their spatial positions when they were inaccurately located. To combine these layers to form an updated roads layer required saving those TIGER road segments that were not also represented by a USFS segment. In addition, there was an extensive system of new roads that were not mapped at all by either USFS or TIGER. These roads were digitized manually.

The protocol for creating a composite road map with increased spatial accuracy is provided in Appendix D.

Extent of forest loss

Recently, Hansen et al. (2013) at the University of Maryland published a paper in Science on their efforts to make available the worldwide loss in forest cover from 2001-2012. See http://earthenginepartners.appspot.com/science-2013-global-forest for entry to this data set. For

visualization of the kind of data available, see Appendix E. These data will be useful in estimating the spatial location of recent logging operations of forest fire locations that have reduced forest canopy cover. This change on the landscape can be estimated on a comprehensive spatial basis. We expect that in many cases there will be a direct relationship between areas of high road density and areas that have had significant forest cover loss. However, the forest land on USFS property to the northwest of Vey Ranch illustrates that significant cover loss is not always associated with high road density or road density. Lack of canopy cover is likely associated with increased soil erosion and sediment delivery to stream channels. Lack of vegetative recovery in arid areas can prolong the period in which erosion is a contributor to stream habitat degradation.

Proportion of spring Chinook salmon redds in assessment units

The CRITFC life cycle modeling effort depends on knowing the spatial and temporal distribution of spawning fish in the project area, as indicated by the distribution of redds. Prior to 2009, ODFW spawning surveys involved documenting the number of redds and spawning adults within previously-designated survey reaches. These survey reaches were typically delineated by changes in landownership or visible landmarks (such as bridges) and did not represent reaches with homogenous geomorphic characteristics. This arbitrary designation of survey reaches rendered it problematic to estimate the distribution of redds in unsurveyed reaches and conduct other analyses depending on spatially-referenced redds.

Beginning 2009, ODFW initiated efforts to GPS each redd encountered during the survey, and this continues to the present time (2013). CRITFC staff worked with ODFW to compile a database of spatially-referenced redd locations in Catherine Creek, upper Grande Ronde River, and Minam River from 2009-2013, in addition to mapping accurate start and stop points and gaps in the survey (e.g., private land with no access). Using this information in combination with a revised map of current spawning distribution and a stream network with a geomorphic classification, we described the distribution of redds with spatial units relevant to restoration planning in the project areas—"assessment units" designated by FCRPS Expert Panel and Grande Ronde Atlas restoration planning workgroups. However, this analysis can be conducted for any spatial strata deemed appropriate for the life cycle model or for restoration planning (e.g., HUC6 or combination of HUC6 and assessment unit).

Describing the proportion of redds to assessment units involved the following steps:

Update spatial information on current spring Chinook salmon: Based on ground-truthing the StreamNet maps of current Chinook spawning distribution (http://www.streamnet.org/mapping_apps.cfm), CRITFC and ODFW staff truncated the spawning distribution to represent the currently observed spawning distribution. Notably, in past years' surveys of the Meadow and McCoy Creek tributaries, no spawning had ever been observed. The current spawning distribution was trimmed down in other small tributaries such as the upper South Fork Catherine, Beaver Creek, and Meadowbrook Creek based on field observations and GIS data on geomorphic conditions (reach gradient and valley confinement).

Create a spatial datasets of spawning survey extent and GPS'd redds: CRITFC and ODFW worked together to compile a database of survey start and end points (including any gaps in the survey) and spatially-referenced redd locations.

Use a geomorphic classification to extrapolate redds to unsurveyed areas: Using a GIS, redd locations, survey extent, and spawning extent were transferred to a stream network spatial layer created by CRITFC that contains several environmental attributes that could be used to extrapolate redd densities to unsurveyed areas (White et al. 2011). We averaged redd densities by stream classification category based on watershed area, elevation, stream order, accumulated mean annual precipitation, reach

gradient, and valley confinement; then extrapolated those values to unsurveyed reaches based on classification type.

Calculate the number of redds and proportion of redds in assessment units: For each year and watershed, we calculate the proportion of redds to spatial strata (i.e., assessment units) accounting for unsurveyed reaches and mapped the average proportion of redds in the upper Grande Ronde and Catherine Creek assessment units from 2010-2013 (the 2009 database was incomplete and therefore insufficient for analysis).

Work Element J 162 C: Hydrological analysis

A primary objective of this work is to develop the capacity for CRITFC personnel to conduct characterizations of low-flow regime as needed for specific ungaged stream reaches of interest. With that in mind, the USGS is developing detailed analytical protocols for each step of the analysis, and plans to demonstrate their application for selected streams and reaches to be determined in collaboration with CRITFC. Work began on this project in April 2012. Analytical methods follow previously-published methods for calculating flow metrics (Grehys 1996a, Grehys 1996b, Smakhtin 2001), incorporating climate and landscape-scale characteristics into streamflow predictions (Mayer & Naman 2011), and using the hydrological neighborhood approach (Ribeiro-Correa et al. 1995, Kelly & Jett 2011).

Overview of Analysis

1. Identify appropriate gage stations and acquire streamflow data.
2. Calculate baseflow index (BFI) and derive low-metrics from theoretical frequency distribution for annual 7-day low flow.
3. Identify significant watershed attributes that are associated with low-flow metrics.
4. Conduct canonical correlation analysis (CCA) to quantify multivariate relationship between flow and watershed features.
5. Utilize CCA results to score target ungaged sites along watershed dimension to identify gaged streams that comprise suitable hydrologic neighborhood for target sites.
6. Utilize data from neighborhood sites to generate theoretical regional frequency curves for target sites and derive low-flow metrics.

Characterizing late-season low-flow regime in the upper Grande Ronde River basin

Analysis of streamflow patterns is frequently based on annual streamflow frequency information from the U.S. Geological Survey (USGS) streamflow database. The necessary data are available only for sites where long-term gaging stations are located, however, and many streams are ungaged. Regional frequency analysis provides a way to estimate the frequency distribution for a variety of low-flow metrics at ungaged sites, based on pooled data from gaged sites within a homogeneous region. In this study, an index procedure was used, whereby the regional frequency curve is scaled by a site-specific scaling factor.

Previous work by Risley and others (2008), estimating low-flow frequency statistics for unregulated streams in Oregon, provided the first estimation of a set of streamflow gages suitable for this analysis. Data for daily mean streamflow were obtained from the online USGS National Water Information System (NWISWeb; http://waterdata.usgs.gov/nwis) and from the online data service provided by the Oregon Water Resources Department (OWRD) (http://www.oregon.gov/owrd/Pages/sw/index.aspx) for

those gages (N=61) identified in Risley and others (2008) as Region 6, which was assumed to represent a homogeneous hydrologic region containing the Grande Ronde River. These gages were further augmented by additional OWRD gages on streams that were not included in Region 6 for the Risley analysis. Gages were excluded from further consideration if their upstream watershed area exceeded 500 square miles, the largest watershed included as a target CRITFC ungaged site. Additionally, if two gages were located along the same stream, the ratio of their watershed areas was evaluated, and the gage with the shorter period of record was excluded from further analysis if the ratio was greater than 0.25.

The daily data were first subset to include data only for the late-season summer time period (Julian days 200-300, mid-July through most of October), prior to determining the annual 7-day minimum flow for each year of record. For gages where no long-term temporal trend was observed, the entire dataset was included in the regional analysis. For gages where a significant trend was observed, a subset of the data was evaluated again to determine if a shorter period of record would be suitable for the regional analysis. The period of record was first limited to the record beginning in 1960 and subsequently for the record beginning in 1980. All gages that exhibited a significant trend over the entire period of record continued to show trends over these shorter periods. Sites were further limited so that each had a minimum of 10 years of record. Based on this screening, the total number of suitable gages for analysis was 39.

A large number of basin characteristics were obtained for each gaging station and CRITFC site, including drainage area, topography, precipitation, soil characteristics, metrics of basin shape, and underlying geology. Hydrologic metrics were determined for each site, either directly from the frequency curve or calculated from the time-series data. These metrics describing basin characteristics and low-flow regime were later related to each other using multivariate techniques in order to characterize low-flow regime at ungaged CRITFC sites.

Work Element J 162: Apply Heat Source Model

As part of a previous contract with The Columbia River Inter-Tribal Fish Commission (CRITFC), Watershed Sciences (WSI) completed stream temperature modeling of 17 streams in the Upper Grande Ronde River basin. Heat Source models were set up and calibrated for a 3-week time period spanning August 6–27, 2010 in order to assess critical summertime conditions. CRITFC subsequently contracted with WSI in 2012 to expand these 3-week models to cover the months of July, August, and September of 2010. A detailed summary of the remote sensing and ground level data and a description of the expanded stream temperature modeling results are provided in Watershed Sciences (2012).

The goal of the project was to use previously collected high-resolution LiDAR, streamflow, and FLIR data to develop the Heat Source stream temperature model (Boyd and Kasper 2003). Stream temperature was simulated for the Grande Ronde River, Catherine Creek, and several of their tributaries for a period between July 10 and September 20, 2010. The simulation period is representative of low-flow and high stream temperature conditions, when salmonid habitat is at its most critical condition. Approximately 398 stream kilometers were simulated above the confluence of Catherine Creek and the Grande Ronde River combined. The streams of interest are either historic or current salmonid habitat.

Significant exploratory work was completed in 2013 using the extended Heat Source temperature model to assess the impact of a systematic sequence of riparian restoration scenarios on the thermal recovery of the Upper Grande Ronde River system.

Work Element I 162 F: Develop draft life cycle model

As part of recovery planning, CRITFC is developing a life cycle model that not only reconstructs population trends consistent with changes in freshwater habitat conditions, but also serves as a tool for policy gaming. The model consists of three modeling components: 1. a population model, 2. a habitat model, and 3. a policy optimization model. The approach also embeds functional relationships at an additional level of complexity, i.e., the prediction of changes in habitat conditions as a direct result of management actions. For example, if the population model predicts productivity at the fry-to-parr stage to be sensitive to water temperature change, and if water temperature is affected by shade from tree canopy closure, then changes to riparian forest cover would indirectly predict productivity. Therefore, changes to riparian forest cover would impact population recovery. The model seeks to quantify the relative recovery potential from measurable management actions. One example would be riparian planting. Other examples of recovery actions include changes to streamflow conditions, which could be achieved by purchasing water removal rights and decommissioning barriers. The key element of the CRITFC model is the ability to quantify the degree to which population recovery improves with investment in critical habitat improvements. The model will be used to quantify the relative benefit of alternative management actions, both in magnitude and spatial distribution.

Life-cycle modeling efforts in 2013 added statistical validity to a large portion of the Catherine Creek life-cycle model, i.e., the main stem and ocean stages. A broader scale model was constructed to use empirical abundance data from multiple populations in the Grande Ronde / Imnaha MPG (the upper Grande Ronde, Catherine Creek, Lostine, Minam, Wenaha, and Imnaha). The model makes the assumption that all populations are subject to the same main stem and ocean conditions, and as such, estimating the parameters that predict how downstream conditions affect survival using all six populations provides a better estimate than only using one population. The results of statistically fitting the multiple population model to abundance data using main stem and ocean effects provides the basis for supplying the Catherine Creek life-cycle model with parameters for those stages. Mainstem and early ocean survival appear to be driven in a large part by hydro system activities (indices of proportion spill at hydro dams during migration), an ocean upwelling index, and the PDO. By statistically parameterizing more than half the life cycle, this represents a significant step in adding empirical weight to the life cycle model.

The Catherine Creek life cycle modeling effort is currently at a phase of being populated with habitat metrics and abundance index summaries. The downstream components of the model, i.e., the mainstem and ocean components, have been cross-developed with an independent life cycle and survival estimation model that operates on a broader scale, at the Grande Ronde / Imnaha MPG level. Following a third year of CHaMP data collection, habitat variables are nearing the stage where data can be summarized at the scale at which the life cycle model operates. Similarly, the Heat Source model validation has reached a stage where data can be aggregated at a spatial and temporal resolution consistent with the life cycle model.

The habitat group is currently in the process of working on a synthesis of environmental and habitat variables that will be used to predict spatial and temporal variability in productivity and capacity. The data synthesis involves aggregation of CHaMP data and Heat Source model output to the same distinct spatial areas at which the life cycle model operates, which is a more coarse scale than most data collection.

The finest resolution of the Catherine Creek life-cycle model corresponds to the coarsest resolution of habitat metric summarization, which is currently the scale of an Assessment Unit (AU). Assessment Units correspond roughly to HUC6 boundaries, and are the result of careful consideration of

geomorphology and fish distribution. The AUs were developed by a Federal Columbia River Power System (FCRPS) Biological Opinion expert panel.

The model CRITFC is developing currently focuses on the Catherine Creek population of the Grande Ronde River basin. It predicts abundances of spawners, eggs, emerging fry, juveniles rearing in different reaches of the river, parr that migrate downstream in fall to overwinter, later migrating parr, smolts, fish in the ocean, and returning adults. Fish return to spawn after a number of years rearing in the ocean, which is determined probabilistically such that the age distribution of returning adults is consistent with the observed age distribution. Throughout the life history, survival from one stage to the next is predicted with a Beverton-Holt (BH) survival function. A more detailed description of the model is provided in Appendix F.

The Habitat Team made progress in compiling a table of potential environmental and habitat variables linked with spring Chinook productivity and capacity terms in the life cycle model. These variables are highly linked to the key identified limiting factors and are informed by data collection in the CHaMP program. Improvements to modeling expected are anticipated to come from developing assessment unit-specific estimates of habitat condition that would provide spatial resolution to the projected effect of restoration actions on the population. In addition, the temporal resolution to the habitat data was also outlined that would correspond to the specific periods in the life cycle.

Monitor and evaluate the status and trends of juvenile fish productivity in tributaries relative to habitat quality improvement targets.

Are tributary actions achieving the expected biological and environmental improvements in habitat?

Work Element D 157: Collect fish density data by channel unit and site using snorkel surveys

We conducted snorkel surveys at all 25 sites where CHaMP habitat data were collected in 2013 to quantify juvenile Chinook salmon and steelhead abundance and size as well as fish assemblage structure and to assess potential fish/habitat relationships. The Columbia River Inter-Tribal Fish Commission (CRITFC), Oregon Department of Fish & Wildlife (ODFW), and Confederated Tribes of the Umatilla Indian Reservation (CTUIR) have recognized the need to use a common snorkel survey so that information collected by individual entities can help managers determine whether aggregate habitat restoration actions will yield a net improvement in basin-wide habitat quality for ESA-listed fish species (NOAA 2007). To this end, we developed a snorkeling protocol drawing heavily from the protocols of Thurow (1994) and O'Neal (2007), intended for use among all agencies responsible for data collection in the upper Grande Ronde, Catherine Creek, Minam River, and potentially other nearby basins. Details about the snorkel survey methodology can be found in White et al. (2012); https://www.monitoringmethods.org/Protocol/Details/499).

We continue to examine relationships between fish snorkeling data and habitat metrics as CHaMP metrics become available and validated in the database. In order to discover novel relationships in our data, we compute the maximal information coefficient (MIC) values for best-fit relationships among fish metrics, habitat, and macroinvertebrates. MIC values are similar to Pearson correlation coefficients in that they are method for rapidly finding strong relationships, but have the advantage of incorporating non-linear relationships (Reshef et al. 2011). This method has the advantage of iteratively searching for novel relationships in very large datasets such as ours where many thousands of combinations are possible.

Structural equation modeling (SEM) is a statistical approach to hypothesis testing that accounts for direct and indirect relationships among variables (Grace 2006). SEM evolved from path analysis with several notable improvements including analysis of covariance among variables (versus analysis of

correlations), incorporation of hierarchical modeling approaches, and the use of latent variables. SEM is an appropriate tool for fish-habitat modeling when the interrelationships among factors influencing fish abundance or fish performance (growth, survival, etc.) are of interest. In addition to testing hypotheses about interrelationships between fish and their habitat, SEM can also be used to predict fish habitat conditions in unsampled areas. These predictions based on observed relationships can then be incorporated into simulation analyses such as life cycle modeling.

Work Element K 161: Present findings and procedures in professional meetings

- Implemented multi-stock life cycle model of the Grande Ronde/Imnaha MPG for inclusion in Comparative Survival Studies 2013 annual report. Model was designed to address freshwater environmental effects and hydrosystem operation effects on mainstem and early ocean survival. Upper Grande Ronde, Catherine Creek, Lostine, Minam, and Imnaha populations were individually and simultaneously modeled in life cycle modeling framework that separated individual stock effects in tributaries, and combined stocks dynamics in the mainstem and ocean environment, allowing more robust statistical inference of tributary dynamics. Results indicate relationship between mainstem/ocean survival and hydrosystem operations, as well ocean conditions, indicating possible mitigation potential in hydro operations.
- Participated in workshop in Logan, Utah on River Styles, a method of classification of streams in a watershed context.
- Reviewed solar radiation calculations for Solmetric SunEye vs. Solar Pathfinder to develop a cross-walk for database managers.
- Performed a suite of QAQC procedures for CHaMP habitat data and snorkel survey data including extensive and detailed editing of topographic survey data in GIS and extensive review and editing of auxiliary habitat survey data using CHaMP online tools.
- Integrating prediction of ocean survival with TRT Matrix model.
- White, S.M., A. Puls, and T. Sedell. 2013. Exploring the relationships among macroinvertebrates, habitat, and fish productivity for better monitoring outputs. *Speaker and session convener*, Macroinvertebrates and Fish Habitat session, Oregon Chapter of the American Fisheries Society, Bend, Oregon.

Work Element L 183: Produce draft journal publications on fish/habitat relationships

- Review and editing of final paper submitted by McNair scholar working on Oregon Land Survey records.
- Synthesized the results of an analysis of growth and survival of Chinook salmon in the Upper Grande Ronde River in a draft publication (expected completion date March 2014).
- Two recent presentations to the Grande Ronde Atlas restoration planning and CHaMP collaborators outline progress on a publication relating fish-habitat relationships.

  White, S., Justice, C. and McCullough, D. 2014. Informing recovery options for spring Chinook salmon in the upper Grande Ronde River, CHaMP and ISEMP State of the Science Workshop, February 25th and 26th, Portland, OR.

- This presentation had the following objectives: provide a brief introduction to CRITFC Accords habitat project in the upper Grande Ronde River, recount the history of CRITFC's collaboration with CHaMP-ISEMP groups, and provide examples of summary products for restoration planning. Updates to recent analyses were reported including advances in Heat Source modeling, compilation of a comprehensive multiple-year red database, and new findings from

structural equation modeling linking fish, landscape conditions, and watershed characteristics (all summarized elsewhere in this report). The presentation emphasized the desire of restoration planners to have guidance on life-stage specific and population-level limiting factors; likely outcomes of alternative restoration scenarios (e.g., what happens to water temperature if we restore riparian vegetation on private land vs. public?); and the above information summarized and mapped at a spatial resolution useful for planning (e.g., Assessment Units).

White, S., Justice, C. and McCullough, D. 2014. 2014. Updates to Heat Source model & distribution of Chinook spawning in assessment units, Grande Ronde Atlas Science TAC meeting, March 5th and 6th, La Grande, OR.

This presentation provided restoration planners an overview and update of Heat Source modeling and historic vegetation mapping for restoration scenarios, and the proportion of spawning Chinook to assessment units mentioned above and elsewhere in this report.

Results

Tributary Habitat RM&E

Monitor and evaluate tributary habitat conditions that may be limiting achievement of biological performance objectives.

What are the tributary habitat limiting factors (ecological impairments) or threats preventing the achievement of desired tributary habitat performance objectives?

Work Element C 157: Collect all CHaMP habitat data, such as water temperature, sediment, streamflow and habitat condition data.

Habitat Condition Data—CHaMP program staff spent significant time following the 2013 field season in the process of completing quality control (QC) of all stream habitat data collected in 2013. This year offered new programming algorithms from CHaMP partners that were used in facilitating the QA/QC process. Despite the significant amounts of time devoted to QA/QC, CRITFC staff are award of significant errors in some of the metrics computed by the CHaMP database system. For example, the water temperature metrics had errors that are still not addressed. As additional years of CHaMP data are collected and QC procedures are completed, more thorough analyses of the data will be completed, including, but not limited to, assessment of trends in habitat conditions over time, incorporation of habitat data into a life cycle model, and refinement of fish habitat relationships via structural equation modeling.

One of the most powerful tools implemented by the CHaMP program is the use of surveying equipment (e.g., Total Station) to develop a detailed and spatially-referenced topographic map of the stream channel. These topographic maps can be used to evaluate changes in channel topography over time with a very high degree of accuracy (Figure 4). Raw topographic data consist of points and lines collected at key locations within the stream channel such as the channel thalweg (i.e., channel location with the highest streamflow), edge of water, bankfull elevation, channel unit boundaries (e.g., perimeter of pools or riffles), etc. Raw survey data are edited using Survey Pro software and then converted to a triangular irregular network (TIN) using custom tools in ArcGIS. The TIN, which provides a rough 3-dimensional representation of the stream channel, is edited further in GIS to remove any additional surveying errors, and is then converted to a digital elevation model (DEM). The DEM essentially represents a detailed grid of channel elevations with a 10 X 10-cm grid cell resolution. Information about the water surface elevation and channel unit boundaries can be overlaid with the DEM to evaluate water depth and channel unit boundaries (Figure 4d). Channel topographic data are then analyzed by CHaMP using the River Bathymetric Toolkit (RBT) to produce a suite of habitat metrics of potential importance to fish.

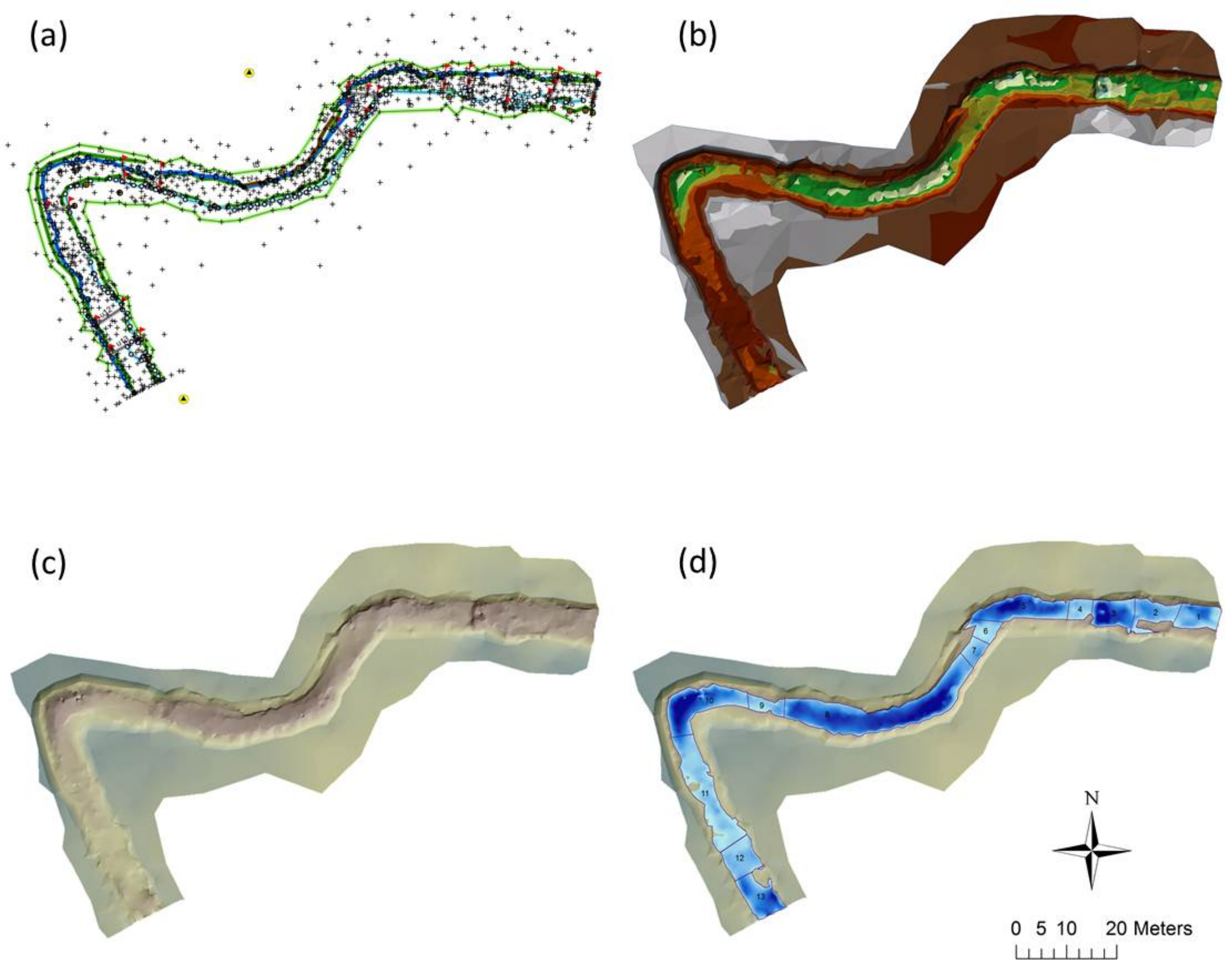

Figure 4. Example of stream channel topographic data collected using the CHaMP protocol at site CBW05583-015162 in McCoy Creek during summer 2012. The figure shows a) raw topographic point and line features, b) the triangular irregular network (TIN) generated from the raw topo data, c) the digital elevation model (DEM) generated from the TIN, and d) the DEM with water depth and channel unit boundaries.

Stream temperature—We summarized stream temperature data collected using Hobo water temperature loggers (U22 and TidBit loggers) at 30 monitoring locations in the Grande Ronde River and Catherine Creek basins in order to understand general temporal and spatial patterns in stream temperatures across the two watersheds and to identify areas exceeding critical thermal requirements for rearing salmonids (Table 2). We calculated six different temperature metrics including average daily temperature during summer (Avg; July 1 – September 15), the lowest daily temperature recorded during summer (Min), the highest daily temperature recorded during summer (Max), the maximum weekly average temperature (MWAT; e.g., maximum 7-day running average of the daily average temperature), the maximum weekly maximum temperature (MWMT; e.g., maximum 7-day running average of the daily max temperature), and the number of days that the daily maximum temperature exceeded thresholds of 16, 18, 20, and 24°C. We also highlighted locations where the MWMT exceeded the

temperature standard of 17.8°C as defined by the Oregon Department of Environmental Quality (ODEQ) in their total maximum daily load (TMDL) evaluation of the Upper Grande Ronde Basin (ODEQ 2000).

Full summer temperature records were available for 30 of sites. Peak stream temperatures were found mainly either on July 2 or August 8-16 in 2013 (Figure 5). Average summer stream temperatures (mean from July 1 – Sept. 15) ranged from 11.78°C to 18.13°C (mean = 14.7°C) in the Catherine Creek basin and from 12.38°C to 21.12°C (mean = 16.5°C) in the Grande Ronde River basin (Table 2).

Catherine Creek sites had cooler temperatures than Grande Ronde River sites on average and reaches closer to the stream source were generally cooler than those further downstream in the basin. Three Catherine Creek sites and two Grande Ronde River sites met the 17.8°C MWMT water temperature standard defined by ODEQ for Chinook salmon rearing habitat in the Upper Grande Ronde sub-basin. MWMT ranged from 15.44°C to 23.09°C (mean = 19.6°C) in the Catherine Creek basin and from 16.21°C to 28.49°C (mean = 23.4°C) in the Grande Ronde River basin.

In order to show daily temperature fluctuations for representative sites within the Upper Grande Ronde and Catherine Creek, we plotted average daily temperatures for the summer period (June 20-Sept 24, 2013) (Figure 5). Sites selected represent optimum thermal sites within the Chinook zone on both study basins (i.e., GR Mine tailings - dsgn4-000009, and NF CC Above MF CC - CBW05583-515498) as well as the typical lower limit to salmonid distribution in the two study basins (i.e., GR Below Beaver Cr. - CBW05583-071770, and CC in Union - dsgn4-000204. The two sites in the headwaters of the UGR and CC were at elevations of 1870 and 1857 m, respectively. The two sites at the lower end of summer distribution were at elevations of 1458 and 1567 m, respectively. The GR mine tailings reach remained approximately 3°C lower than the GR below Beaver Creek throughout the spawning period. The NF CC above the MF CC was approximately 3°C lower than the GR mine tailings area in mid- to late-summer.

Comparing average summer temperatures from 2011-2013 reveals a general increase in temperatures from 2011 to 2013 and number of days exceeding the 17.8°C MWMT water temperature standard defined by ODEQ for Chinook salmon rearing habitat in the Upper Grande Ronde basin and Catherine Creek basin (Table 3). Although this table presents data on only three ChaMP sites, it gives a preliminary view on the annual variations in water temperature that can be expected at a site. The South Fork Catherine Creek mouth and Sheep Creek site on the UGR had nearly the same mean temperatures in 2011, 2012, and 2013, respectively. Temperatures increased from year to year in this time period for reasons that were probably related simply to annual variations in air temperature. Although the SF Catherine Creek means were similar to those in Sheep Creek, the MWMT values in Sheep Creek were generally about 1°C greater in each year. Maximum summertime temperatures were about 2°C greater in Sheep Creek than in SF Catherine Creek, resulting in a greater exposure time to temperatures above the 18°C threshold. In the Grande Ronde River above Beaver Creek, the pattern of annual summertime mean temperatures was the same as for the higher altitude sites. This site also had mean summertime temperatures that increased about 1°C per year from 2011 to 2013. This site above Beaver Creek had annual maximum temperatures that were 9 to 11°C greater than the mean temperatures for 2011-2013, whereas those in Sheep Creek ranged from 6 to 7°C greater. This indicates that it is much more likely that the amplitude of variation in temperatures increases in a downstream direction, resulting in greater times of exposure to temperatures above critical thresholds.

In future work, we will make use of the water temperature model to validate its use in predicting water temperatures measured in subsequent years where we have data on meteorological conditions and streamflows. If we are able to predict temperatures accurately based on these environmental factors, then any unexplained change in this prediction could indicate the influence of riparian loss or gain. It should be feasible to narrow the source of variation in the temperature profile by installing temperature loggers at the mouths of the various Heat Source modeled assessment units.

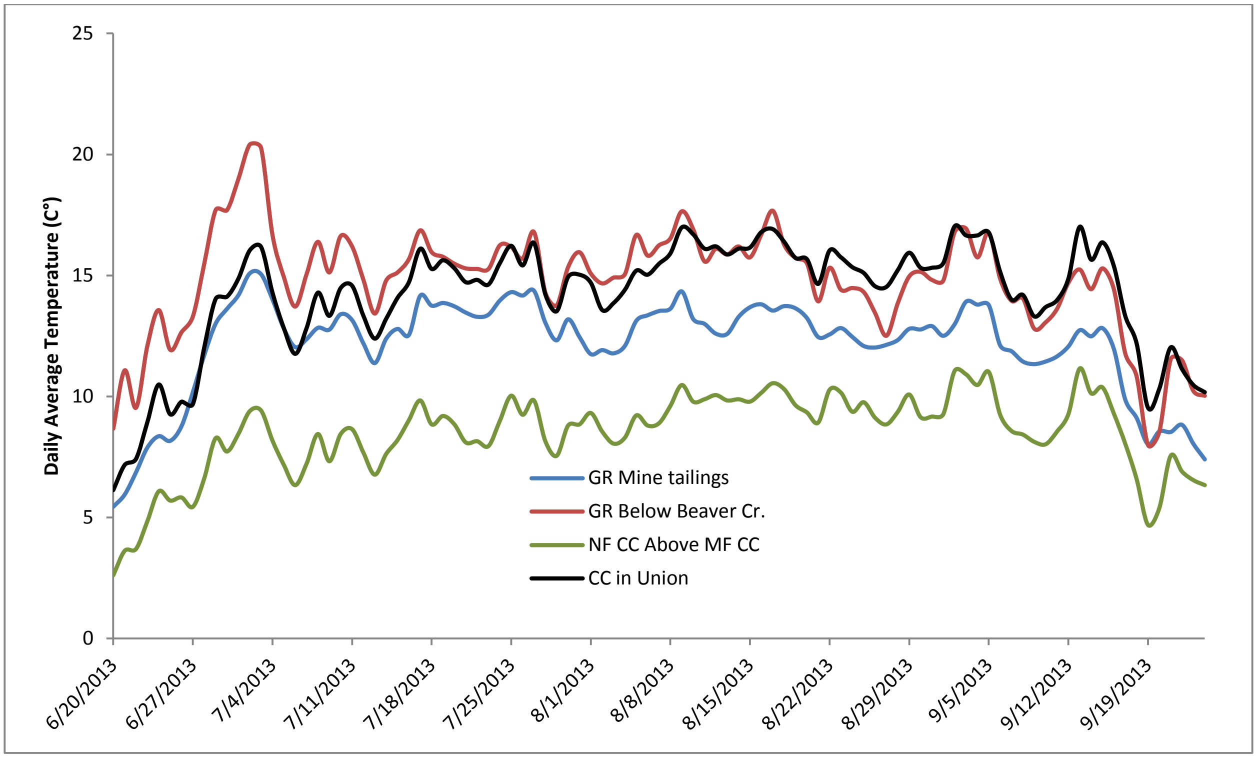

Figure 5.Daily average temperatures (°C) for four sites – two on the Upper Grande Ronde River and two on Catherine Creek from June 20 – Sept 24, 2013. GR Mine tailings was one of our highest elevation Upper Grande Ronde River sites and GR below Beaver Cr. was one of the lowest. North Fork Catherine Creek (NF CC Above MF CC) was one of our highest elevation temperature logger sites on Catherine Creek and CC in Union was one of the lowest elevation sites.

Table 2.Summary of stream temperatures (°C) at 30 sites in Catherine Creek and Grande Ronde River during the summer of 2013 (starting July 1st and extending through September 15th). Temperature metrics include average daily temperature for the summer period (July 1-Sept. 15), the minimum daily temperature recorded during summer (Min), the highest daily temperature recorded during the summer (Max), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the number of days that the daily maximum temperature exceeded thresholds of 16, 18, 20, and 24°C. Values exceeding the ODEQ temperature standard of 17.8°C MWMT are highlighted in gray.

									Sum Days Daily Max Exceeded			
Stream	**Site**	**Start Date**	**End of Date**	**Avg**	**Min**	**Max**	**MWAT**	**MWMT**	**16 °C**	**18 °C**	**20 °C**	**24 °C**
Catherine Creek Basin												
North Fork Catherine Creek	NF CC_above_MF_CC	7/1/2013	9/15/2013	11.78	6.91	15.77	12.87	15.44	0	0	0	0
South Fork Catherine Creek	CBW05583-204202	7/1/2013	9/15/2013	13.11	8.34	17.87	13.97	16.40	11	0	0	0
South Fork Catherine Creek	SF_CC_mouth	7/1/2013	9/15/2013	13.58	8.74	18.32	14.48	17.22	38	1	0	0
North Fork Catherine Creek	NF_CC_mouth	7/1/2013	9/15/2013	13.17	7.90	19.03	14.32	18.43	56	11	0	0
Catherine Creek	CBW05583-036266	7/1/2013	9/15/2013	14.06	8.62	19.29	15.23	18.67	65	24	0	0
North Fork Catherine Creek	CBW05583-515498	7/1/2013	9/15/2013	11.29	6.33	20.34	12.36	18.69	16	6	1	0
Catherine Creek	DSGN4-000010	7/1/2013	9/15/2013	15.15	9.19	20.20	16.43	19.82	77	51	2	0
Milk Creek	ORW03446-071176	7/1/2013	9/15/2013	15.28	9.78	22.03	17.95	20.83	75	38	3	0
Catherine Creek	CBW05583-311466	7/1/2013	9/15/2013	16.30	10.05	22.13	17.63	21.64	77	70	38	0
Catherine Creek	CC_Hwy_203	7/1/2013	9/15/2013	16.39	10.17	22.35	17.71	21.84	77	71	41	0
Catherine Creek	CBW05583-405674	7/1/2013	9/15/2013	17.81	11.30	23.50	19.23	22.85	77	77	59	0
Catherine Creek	DSGN4-000204	7/1/2013	9/15/2013	18.13	11.76	23.76	19.55	23.09	77	77	63	0
Average				14.7	9.1	20.4	16.0	19.6	54	36	17	0
Minimum				11.3	6.3	15.8	12.4	15.4	0	0	0	0
Maximum				18.1	11.8	23.8	19.6	23.1	77	77	63	0

									Sum Days Daily Max Exceeded			
Stream	**Site**	**Start Date**	**End of Date**	**Avg**	**Min**	**Max**	**MWAT**	**MWMT**	**16 °C**	**18 °C**	**20 °C**	**24 °C**
Grande Ronde River Basin												
Grande Ronde River	CBW05583-099818	7/1/2013	9/15/2013	12.38	8.20	17.65	13.70	16.21	13	0	0	0
Clear Creek	Clear_Cr_mouth	7/1/2013	9/15/2013	12.77	8.27	18.27	14.08	16.91	25	1	0	0
Grande Ronde River	DSGN4-000009	7/1/2013	9/15/2013	12.97	8.10	18.58	13.96	18.03	46	9	0	0
Sheep Creek	CBW05583-228666	7/1/2013	9/15/2013	13.33	8.07	20.39	14.85	18.80	55	18	2	0
West Chicken Creek	CBW05583-294202	7/1/2013	9/15/2013	13.55	8.05	20.44	15.07	19.27	50	24	2	0
Grande Ronde River	CBW05583-468458	7/1/2013	9/15/2013	14.22	8.39	20.72	15.36	19.41	59	32	2	0
Fly Creek	Fly_Cr_mouth	7/1/2013	9/15/2013	16.39	11.95	24.48	19.13	22.79	74	49	27	1
Five Points Creek	Five_Points_Cr_mouth	7/1/2013	9/15/2013	16.86	12.20	23.50	18.25	23.19	77	72	52	0
Sheep Creek	Sheep_Cr_below_5160_Rd	7/1/2013	9/15/2013	15.94	8.79	25.45	17.69	23.78	77	71	56	6
Grande Ronde River	DSGN4-000277	7/1/2013	9/15/2013	17.82	9.98	26.70	20.10	25.18	77	76	68	23
Fly Creek	CBW05583-502586	7/1/2013	9/15/2013	16.24	9.95	26.99	20.41	25.27	75	62	41	9
Grande Ronde River	CBW05583-031546	7/1/2013	9/15/2013	17.80	10.81	27.51	20.94	25.41	77	74	69	24
Grande Ronde River	GR_below_Vey	7/1/2013	9/15/2013	18.02	10.00	27.04	20.12	25.83	77	76	71	34
Grande Ronde River	DSGN4-000202	7/1/2013	9/15/2013	18.63	11.32	29.22	21.79	27.10	77	77	73	49
Grande Ronde River	DSGN4-000245	7/1/2013	9/15/2013	19.40	11.44	30.39	22.61	28.03	77	77	73	51
Grande Ronde River	CBW05583-071770	7/1/2013	9/15/2013	20.29	12.51	30.52	23.12	28.30	77	77	74	57
Meadow Creek	Meadow_Cr_mouth	7/1/2013	9/15/2013	19.00	12.12	30.52	23.02	28.49	77	76	73	28
Grande Ronde River	GR_above_Five_Points_Cr	7/1/2013	9/15/2013	21.12	13.02	30.72	24.21	28.96	77	77	77	69
Average				16.5	10.2	24.9	18.8	23.4	65	53	42	20
Minimum				12.4	8.0	17.7	13.7	16.2	13	0	0	0
Maximum				21.1	13.0	30.7	24.2	29.0	77	77	77	69

Table 3. Summary of temperature metrics for 2011-2013. Temperature metrics (°C) include average daily temperature for the summer period (Avg), the minimum daily temperature recorded during summer (Min), the maximum daily temperature recorded during the summer (Max), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the number of days during the summer period in which the daily maximum temperature exceeded various temperature thresholds.

South Fork Catherine Creek Mouth	Avg	Min	Max	MWAT	MWMT	16 °C	18 °C	20 °C	24 °C
2011	11.5	6.5	16.2	13.6	15.5	1	0	0	0
2012	12.5	4.2	18.3	14.8	17.3	37	2	0	0
2013	13.6	8.7	18.3	14.5	17.2	38	1	0	0

Sheep Creek (CBW05583-228666)	Avg	Min	Max	MWAT	MWMT	16 °C	18 °C	20 °C	24 °C
2011	11.5	5.3	17.3	13.2	16.7	5	0	0	0
2012	12.3	3.5	18.9	14.6	18.4	44	15	0	0
2013	13.3	8.1	20.4	14.9	18.8	55	18	2	0

Grande Ronde above Beaver Creek (dsgn4-000245)	Avg	Min	Max	MWAT	MWMT	16 °C	18 °C	20 °C	24 °C
2011	17.4	8.7	26.1	19.7	25.0	65	58	26	5
2012	18.3	6.1	28.1	21.1	26.8	77	73	69	43
2013	19.4	11.4	30.4	22.6	28.0	77	77	73	51

Summarizing selected CHaMP metrics using GRTS

Data summaries of selected CHaMP metrics for combined years 2011-2013 using GRTS revealed a broad range of values depending on spatial resolution (Table 4). At the assessment unit scale, total fish cover was highest in CCC4 (37%, Milk and Little Catherine Creek basins) and lowest in UGC3B (2%, Fly Creek basin). Fines (particles < 6 mm) were most abundant in CCC4 (46%) and lowest in UCG2 (5%, Rock Creek basin). Percent pools was greatest in UGC8 (44%, Sheep Creek basin) and lowest in UGC2 (9%). Volume per stream length of wetted large woody debris was greatest in UGC7 (0.62 m^3/100 m, Grande Ronde mainstem above Fly Creek) and lowest in UGC2 (< 0.01m^3/100 m). Estimates for selected fish habitat metrics varied between watersheds and depended upon fish life use, and sample size were much reduced when rearing areas were excluded from analyses (Table 4). From this exercise we learned the ability to 'downscale' estimates to finer spatial resolution than the watershed is limited by small sample sizes in some spatial strata and depending on fish life use extent. Future estimates at fine spatial grains will likely require the use of a stream classification system as a bridge between sampled and unsampled areas and the use of spatial statistics to capitalize on the spatial structure of the dataset.

Table 4. Sample size, mean values, and standard deviation for selected fish habitat metrics at various spatial resolutions for years 2011-2013 combined using GRTS.

Spatial Resolution	Total fish cover (%)			Particles < 6mm			Percent pool (%)			Wetted wood volume/100m		
	N	Mean	StdDev	N	Mean	StdDev	N	Mean	StdDev	N	Mean	StdDev
Assessment Units												
CCC3B	5	7.35	2.89	9	10.95	13.78	9	23.83	10.72	9	0.05	0.07
CCC3C	5	6.41	4.93	7	9.55	3.60	7	26.23	15.71	7	0.08	0.06
CCC4	2	36.85	7.08	3	46.36	23.33	3	27.33	4.81	3	0.07	0.06
CCC5	14	16.81	7.83	17	18.86	7.71	17	12.90	5.62	17	0.13	0.16
UGC2	8	6.17	1.46	9	5.41	3.24	9	9.29	4.17	9	0.00	0.01
UGC3B	3	2.39	0.01	4	22.41	12.05	4	14.53	1.23	4	0.20	0.11
UGC4	7	20.75	2.51	7	14.87	10.98	7	16.89	9.61	7	0.03	0.01
UGC5	5	10.13	7.93	9	12.64	7.84	9	18.75	10.93	9	0.15	0.09
UGC7	3	12.04	6.15	6	25.43	8.70	6	28.87	14.89	6	0.62	0.71
UGC8	6	25.70	11.13	8	27.22	11.90	8	44.43	16.34	8	0.04	0.07
Spawning												
Catherine Creek	17	7.13	3.63	24	11.37	11.01	24	20.96	12.59	24	0.08	0.08
Upper Grande Ronde	11	12.77	7.07	20	19.18	13.38	20	29.01	19.76	20	0.28	0.45
Spawning & Rearing												
Catherine Creek	26	15.39	9.54	36	17.92	12.59	36	16.99	10.25	36	0.11	0.14
Upper Grande Ronde	32	16.17	11.46	44	19.28	12.61	44	27.74	18.71	44	0.16	0.33

Work Element E 157: Collect benthic macroinvertebrate samples and process

Macroinvertebrate samples were collected in 2011, 2012, and 2013 by CRITFC and ODFW within the Chinook zone of the upper Grande Ronde and Catherine Creek. CRITFC has collected samples at 25 to 28 sites in each of the three years (Table 5). In 2013, a total of 25 sites were sampled. Single samples were collected by CRITFC at 21 sites, while three samples were collected on a monthly basis at three sites, and 4 samples were collected monthly at one site. The monthly samples spanned the months June, July, August, and September. For the three-year period (2011-2013) CRITFC contributed 28 samples in 2011, 28 samples in 2012, and 21+9+4= 34 samples in 2013. ODFW contributed 11 in 2011, 12 in 2012, and 14+6+4=24 samples in the Chinook zone for analysis (Table 6).

Table 5. Number of sites where at least 1 benthic sample was taken in CHaMP Year 2011-2013.

	2011	2012	2013	Total sites
CRITFC	28	28	25	60
ODFW	11	12	17	23

Table 6. Number of stations in the Chinook zone where benthic samples were collected by CRITFC and ODFW from 2011-2013. Rows provide information on the number of sites where between 1 and 6 samples were collected each year. In 2013, a portion of the collections were devoted to assessing monthly variation in macroinvertebrate communities from samples in June, July, August, and September.

	CRITFC			ODFW		
No. of sites w/x samples per year	2011	2012	2013	2011	2012	2013
1	28	28	21	11	12	14
2	0	0	0	0	0	0
3	0	0	3	0	0	2
4	0	0	1	0	0	1
5	0	0	0	0	0	0
6	0	0	0	0	0	0

Benthic insect samples have been processed by ABR, Inc. (Alaska Biological Research, Inc.; now Cole Ecological, Inc.) from collections made in 2011 - 2013. A voucher collection was made by ABR from insects collected in 2011. This collection was validated by ABA (Robert Wisseman).

A voucher list compiled by ABR had 149 unique genera of macroinvertebrates (aquatic and terrestrial) and 176 individual taxa. ABA confirmed the taxonomic identifications made by Cole Ecological and has worked with them to resolve existing discrepancies in taxonomic identification and naming conventions to insure that all taxa have the most appropriate identifiers.

Cole combined the 2011, 2012, and 2013 data into a single spreadsheet. Cole then computed the following macroinvertebrate community indices from our 2011 and 2012 data: Eastern Oregon (Grande Ronde) IBI, Predator (WCCP Model), ODEQ temperature and fine sediment stressor models, functional feeding group composition, Hilsenhoff metrics, tolerant/intolerant species, taxa densities, and biomass per m^2. The IBI metrics include components for mayfly, stonefly, caddisfly richness, sensitive taxa, sediment tolerant taxa, % dominant to develop a score. The functional feeding composition accounts for classification of taxa by function groups, such as collector-filterer, collector-gatherer, macrophyte herbivore, omnivore, parasite, piercing herbivore, predator, scraper, shredder, and unknown. Benthic insect densities are calculated as indiv/m^2, whole sample dry mass. The Predator Model uses a RIVPACS approach to develop observed vs expected taxa relationships for evaluating site macroinvertebrate composition vs a reference condition. Stressor indicator taxa are used to evaluate to what extent the community is adapted to various stressors. For example, if a particular stream site is high in surface fine sediments, it becomes more likely that the community would have a greater density, biomass, or number of taxa adapted to high sediment conditions. Water temperature is another stressor that can favor taxa that are more or less tolerant to warmwater or coldwater conditions.

Summary statistics from three years of macroinvertebrate data were briefly evaluated by plotting data from upstream on the mainstem (mine tailings area) to downstream (Hilgaard State Park) on the mainstem some of the key community statistics in a linear series. Not surprisingly, temperature sensitive taxa were very prominent in the first four sites on the mainstem (6-8 temperature sensitive taxa per sample). This point reaches 3.9 km above the mouth of Limber Jim Creek. From 3.9 km above Limber Jim Cr. to the downstream extent sampled, temperature sensitive taxa declined from 3 to 4 to 0. Temperature tolerant taxa showed a similar pattern with 2-3 temperature tolerant taxa per sample in the first 4 sites (i.e., to 3.9 km above Limber Jim). From that point to the downstream extent, there was a mean of 3-5 tolerant species per sample.

Sediment tolerant taxa followed a similar pattern with 1 to 4 percent sediment tolerant taxa per sample down to 3.9 km above Limber Jim. Below this point to the downstream extent, average percent sediment tolerant taxa varied from about 2 to 14%. In 12 of 16 samples, the mean percentage fine sediment tolerant taxa ranged from 4 to 14%. In terms of number of sediment sensitive taxa, numbers reached a high of 9 sensitive taxa 3.9 km above Limber Jim, but then remained relatively stable downstream to the 13th sample location in the series of 20, or 2.8 stream km above Starkey Station. From that point downstream, there were an average of 2-3 fine sediment sensitive taxa per sample. A plot of mean number of fine sediment tolerant tax was variable, ranging from 2 to 6 taxa per sample. There appeared to be an increasing number of tolerant taxa downstream but there were occasional sites with low numbers.

Considering all tolerant taxa, there was about 10% tolerant taxa from the mine tailings area down to 2.2 km above Limber Jim. From that point downstream, mean percentage tolerant taxa ranged from 10 to 80% and generally followed an increasing trend downstream.

The modified Hilsenhoff biotic index appeared to have a slight increasing trend from upstream to downstream. These scores ranged from 3 in the headwaters to about 5 downstream, with significant variation over the entire series. The average Eastern Oregon IBI score ranged from 40 to 50 from the headwaters down to 3.0 km downstream of Starkey Station. From that point downstream, the total scores declined to about 20.

In terms of mean density (indiv/m^2) per site, the values were very low down to 1.3 km above Limber Jim. From that point downstream, densities generally increased and reached a high of >20,000 indiv/m2 5.5 stream km above Rock Creek mouth on the mainstem UGR.

Dry mass of macroinvertebrates per sample revealed a similar pattern, with very low values 100-750 mg/m^2 downstream to 1.3 km above Limber Jim. Downstream of that point, dry biomass varied from 500 to about 4000 mg/m^2.

There are some technical issues to consider in further data analysis that could have a significant bearing on results. For example, the annual sites had at least three samples (2011-2013) that were averaged. Some of the annual sites had samples taken in 3 or 4 consecutive months to follow trends at a site for 2013. Rotating panel sites tended to be represented by only one sample. The means were computed from all samples available. It is probable that in terms of number of sensitive or tolerant taxa per sample, there will be variation among samples. It will be informative to examine the rate of increase in numbers of sensitive or tolerant taxa observed as more samples are taken at a site.

Work Element F 157: Collect McNeil sediment core samples and process

Subsurface fine sediment levels measured at all 42 sites surveyed with McNeil cores from 2011-2013 were generally low to moderate with the Upper Grande Ronde River basin having the highest proportion of fines among the 3 basins surveyed. The proportion of fine sediment < 2 mm ranged from 0.06 to 0.30 (mean = 0.16) across all sites (**Table 7**). The proportion of fines < 6.35 mm ranged from 0.07 to 0.44 (mean = 0.28). The proportion of fines < 6.35 mm averaged 0.27, 0.29, and 0.30 in Catherine Creek, the Minam River, and the Upper Grande Ronde River, respectively.

Variability in average fine sediment levels across all sites was moderate with a CV of 33% for fines < 2 mm and 26% for fines < 6.35 mm (**Table 7**). Spatial variability in fine sediment levels did not appear to be related to landscape characteristics such as gradient, forest cover, and road density according to a preliminary analysis conducted in 2012 (Justice et al. 2012(b); unpublished technical report). However, efforts to refine our calculations of landscape characteristics are ongoing, and updated analyses may shed new light on the relationship between landscape characteristics and fine sediment.

Most survey sites in the Upper Grande Ronde and Catherine Creek had fine sediment concentrations below what might be considered a critical threshold level for survival of incubating eggs. In a laboratory study of Chinook egg survival relative to fine sediment conducted by Tappel and Bjornn (1983), egg survival remained very high (i.e., 96%) until the fraction of fine sediment < 6.35 mm exceeded approximately 30%, after which, survival declined rapidly, approaching 0 at about 60% fines. Median values for fine sediment < 6.35 mm were below the 30% level in both Catherine Creek and the Upper Grande Ronde River basins.

Correlations among 6 different fine sediment metrics were generally weak to moderate, with the exception of McNeil fines < 2 mm versus McNeil fines < 6 mm (r = 0.73), ocular fines in pools versus ocular fines in all habitat types (r = 0.91); and pool tail fines < 2 mm versus pool tail fines < 6 mm (r = 0.96) (Table 8). It is not surprising that these metrics were strongly correlated as they utilized the same methodology and differed only in terms of the size criteria used to define fines or in the location where fines were measured (e.g., pools versus all channel unit types).

Fine sediment at depth (i.e., McNeil fines) was moderately correlated to overall ocular estimates of surface fines as well as pool tail fines < 6 mm, but was not correlated to ocular estimates of pools or pool tail fines < 2 mm (Table 8). According to a linear regression model, there was a statistically

significant positive relationship between McNeil fines < 2 mm and ocular fines in all habitat types, although this model explained only approximately 27% of the variation in McNeil fines (Figure 6). Similarly, McNeil fines < 6.35 mm were positively related to pool tail fines < 6 mm (Figure 7), with pool tail fines < 6 mm explaining approximately 27% of the variation in McNeil fines < 6.35 mm.

Table 7. Summary statistics for McNeil fine sediment samples collected in Catherine Creek, Minam River, and Upper Grande Ronde River basins between 2010 and 2013.

	Basin			
	Catherine Creek	Minam River	Upper Grande Ronde River	Total
Fines < 2 mm				
Min	0.06	0.10	0.06	0.06
Max	0.19	0.30	0.23	0.30
Mean	0.13	0.20	0.14	0.16
Count	14	8	20	42
StdDev	0.04	0.07	0.05	0.05
Coefficient of Variation	0.29	0.34	0.35	0.33
Standard Error	0.01	0.02	0.01	0.02
95% CI Lower Bound	0.11	0.14	0.12	0.12
95% CI Upper Bound	0.16	0.26	0.16	0.19
Fines < 6.35 mm				
Min	0.07	0.22	0.17	0.07
Max	0.40	0.42	0.44	0.44
Mean	0.27	0.29	0.30	0.28
Count	14	8	20	42
StdDev	0.09	0.06	0.07	0.07
Coefficient of Variation	0.32	0.22	0.23	0.26
Standard Error	0.02	0.02	0.02	0.02
95% CI Lower Bound	0.22	0.23	0.27	0.24
95% CI Upper Bound	0.32	0.34	0.33	0.33

Table 8. Pearson correlation coefficients (*r*) for comparisons among 6 different fine sediment metrics calculated from sediment samples collected in the Upper Grande Ronde River and Catherine Creek basins during summer 2010-2013. Pairwise comparisons with correlation coefficients exceeding 0.5 are highlighted.

	mnfines2	*ptfines2*	*mnfines6*	*ocfinesall*	*ocfinespools*	*ptfines6*
mnfines2	1					
ptfines2	0.347744516	1				
mnfines6	0.729550026	0.470016372	1			
ocfinesall	0.519074179	0.29906528	0.353727209	1		
ocfinespools	0.477235911	0.31426289	0.396784432	0.912929619	1	
ptfines6	0.438668217	0.961001961	0.517386679	0.443626548	0.441334461	1

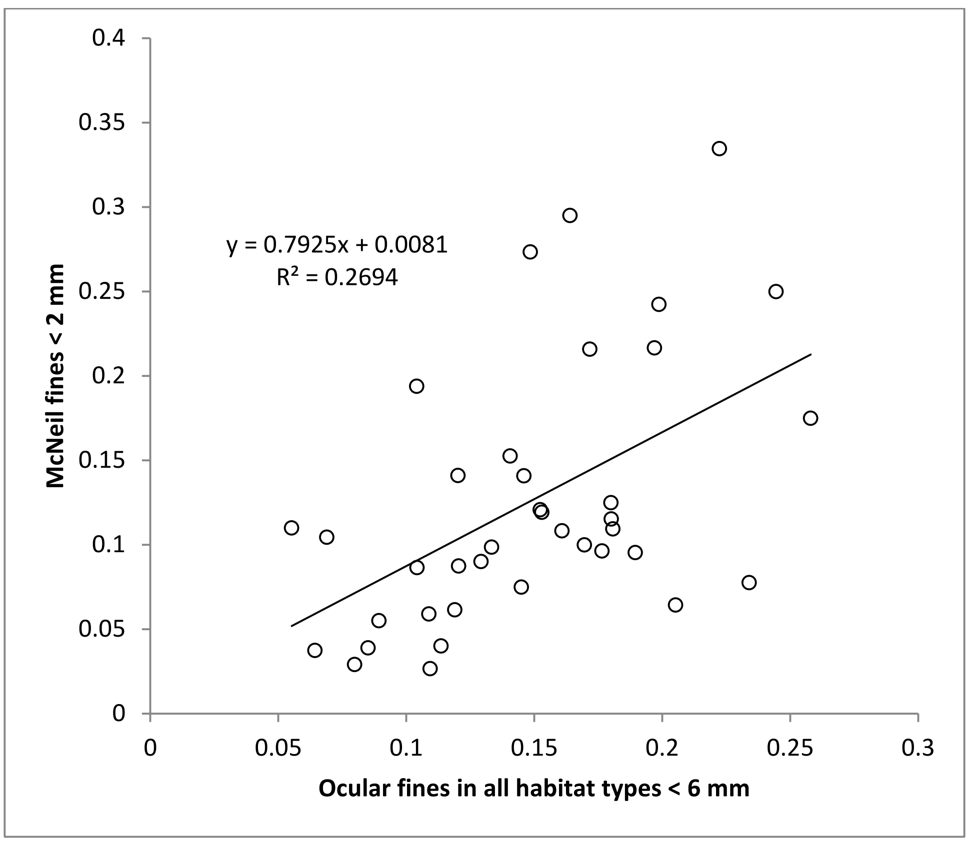

Figure 6. Relationship between ocular fines < 2 mm in pools and McNeil fines < 2 mm from 38 sites surveyed in the Upper Grande Ronde River and Catherine Creek basins from 2010 to 2013.

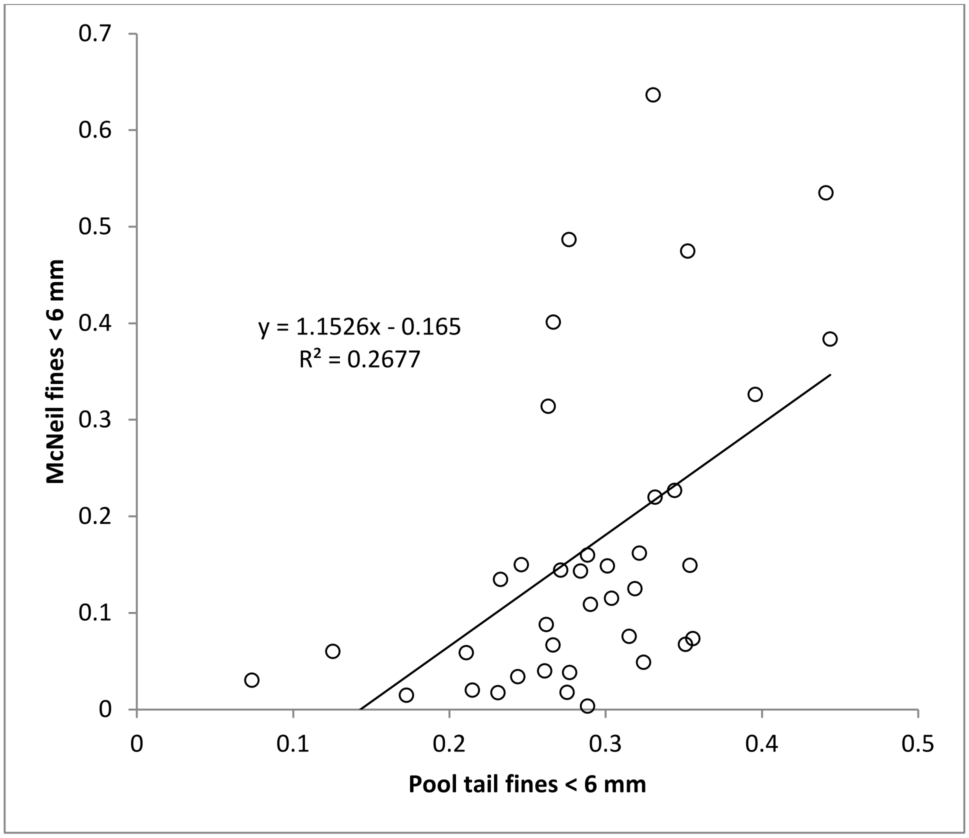

Figure 7.Relationship between pool tail fines < 6 mm and McNeil fines < 6.35 mm from 38 sites surveyed in the Upper Grande Ronde River and Catherine Creek basins from 2010 to 2013.

Work Element H 157: Current and potential riparian vegetation mapping of Upper Grande Ronde and Catherine Creek

PNV mapping project

CRITFC staff have been compiling and updating a geodatabase with natural resources data layers over the course of our Accords work (see CRITFC 2010, 2011, 2012). These data are being made available to the riparian subcontractors mapping potential natural vegetation (PNV) in Catherine Creek and the Upper Grande Ronde. In addition, the subcontractors have been assembling data for their uses in mapping and agreeing upon a list of needed map layers that will be their standards for mapping. CRITFC is also supplying the riparian subcontractors with LiDAR data and high resolution aerial imagery collected during the forward looking infrared (FLIR) flight in 2010 to aid in their analysis of potential natural vegetation.

Final map products from the riparian vegetation mapping project will be not be available until project completion in 2014. However, draft map products and detailed description of methodology is provided in Appendix N. In addition, Appendix B provides a comprehensive tabulation of all the data sources available and considered in the mapping of PNV and current vegetation.

Historic vegetation from government land office survey

In section lines intersecting the current spawning and rearing distribution of spring Chinook salmon, upland versus riparian plants displayed a difference in key taxa describing the community composition, with riparian plants having higher and upland plants having lower non-metric multidimensional (NMS) scores. Ecoregion, basin, life history and surveyor all were significantly representative of historical plant taxa distribution (Figure 8). Of the environmental factors, ecoregion revealed the strongest relationship to historic plant spatial distribution, followed by basin and Chinook salmon use (spawning vs. rearing). Surveyor was also strongly correlated with the highest NMS score representing the vegetative distribution. The Wallowas/Seven Devils Mts and Mesic Forest ecoregions had similar species composition, while the Maritime Influenced Zone represented more upland plants and the Blue Mt Basin was more reflective of riparian plant species Figure 8).

The raw data from this analysis (see Appendix G) for full description of this project) will also be used as ground-truthing of historic vegetation conditions for the potential natural vegetation (PNV) map which is currently in progress.

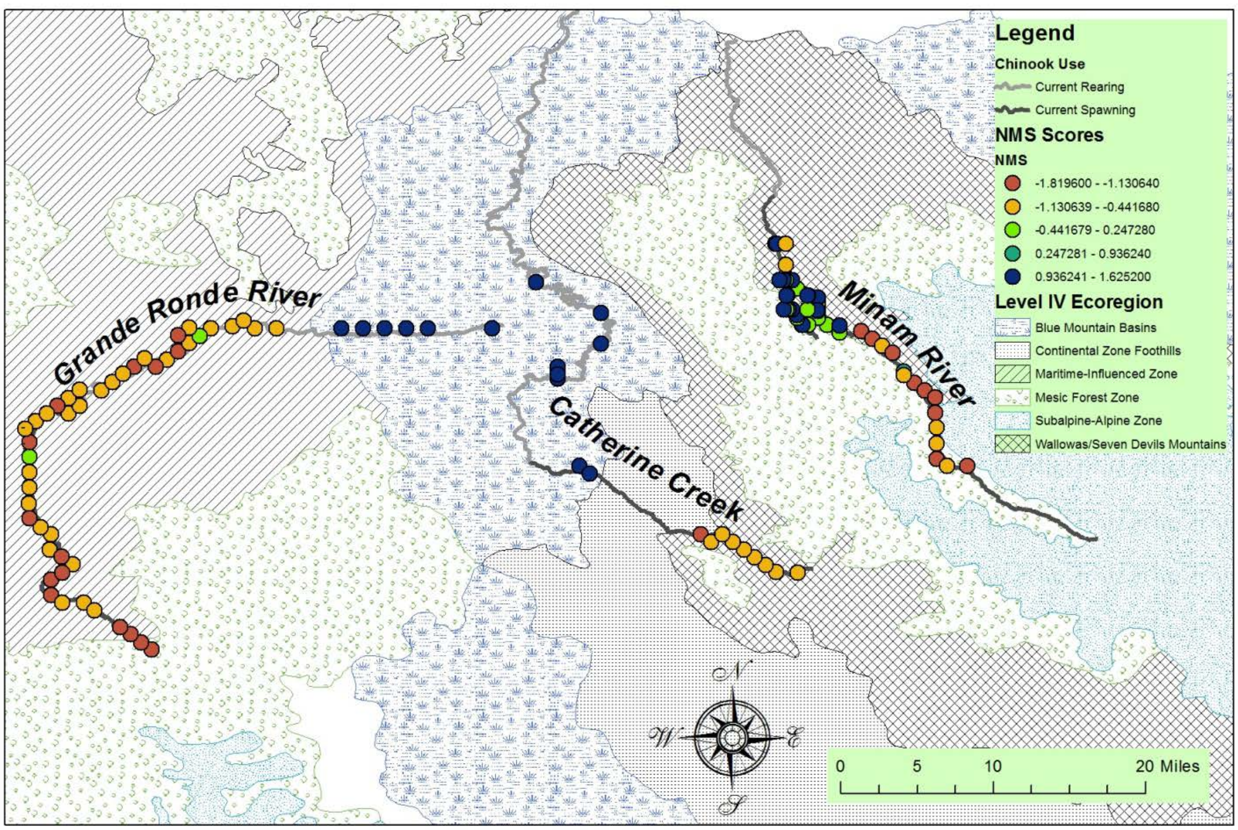

Figure 8. Upland versus riparian vegetation in the Grande Ronde River basin with riparian plants consisting of the higher positive NMS scores and upland plants having a lower negative NMS score.

Work element 160: Develop and manage fish habitat condition database

List of all sites

A list of all CRITFC and ODFW sites within the spring Chinook sample frame is provided in Appendix H. This table reports all unique sample sites. However, there are two anomalies, in that sites dsgn4-000006 (West Chicken Cr.) and dsgn4-000094 (Fly Cr.) are annual sites in which CRITFC conducted the annual survey in 2011, but ODFW continued the surveys in 2012 and 2013. Further, site dsgn4-000092 (Spring Creek) was an annual site where CRITFC did the survey in 2011. After that point, CRITFC determined that this site was not in the spring Chinook rearing zone, so it was deleted from the sample frame. It was, however, a valid summer steelhead site, so it became an annual site for ODFW in its sampling program.

Appendix H also indicates the number of benchmarks currently known to be available at each site. Benchmarks that were retired were deleted from the database. Retired benchmarks were those that were either lost due to natural events or vandalism, or were compromised to the extent that their x, y, z coordinates became suspect. Because annual sites are visited each year, the count of active benchmarks made on the last survey is more likely to represent the number of extant benchmarks. For rotating panel sites, those installed in 2013 would be as likely to reflect extant benchmarks as those counted in the 2013 annual survey. For the 2013 annual survey, if benchmarks were retired for any reason, additional benchmarks were installed to ensure having at least three intervisible benchmarks. Rotating panels 2 and 1 have increasingly greater probability of loss with time.

Tables of key watershed conditions for all sites in the Chinook zone.

There were 59 unique CHaMP sites in the CRITFC monitoring program for the spring Chinook zone and 23 unique sites monitored by ODFW in this zone. Figure 9 and Figure 10 indicate the distribution of all Chinook study sites with elevation and considering the drainage area contributing to the study areas. These two basin characteristics were computed for all study watersheds using StreamStats from USGS.

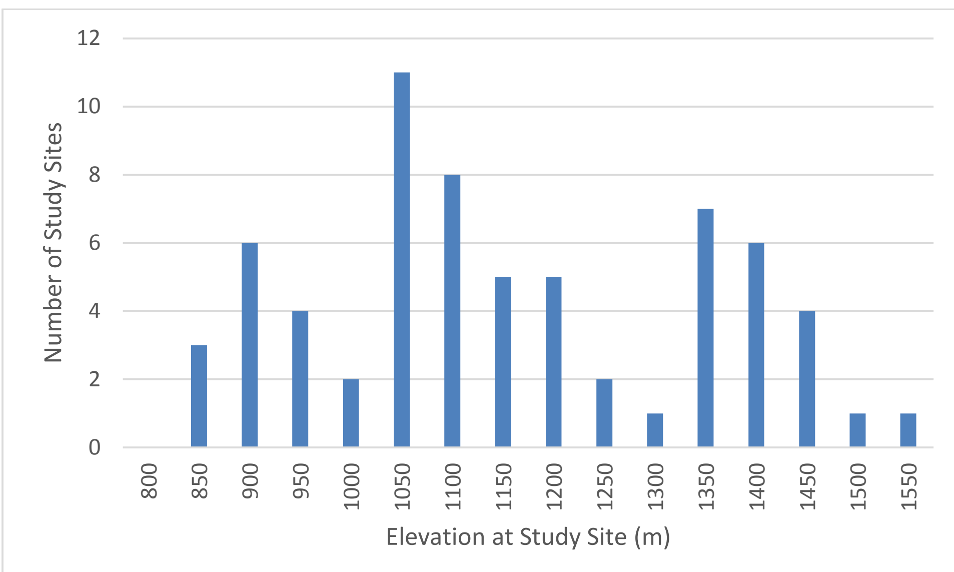

Figure 9. Frequency distribution of CHaMP study sites (CRITFC plus ODFW) within the spring Chinook sample frame in the Upper Grande Ronde basin and Catherine Creek basin having elevations at the bottom of site corresponding to the bins indicated.

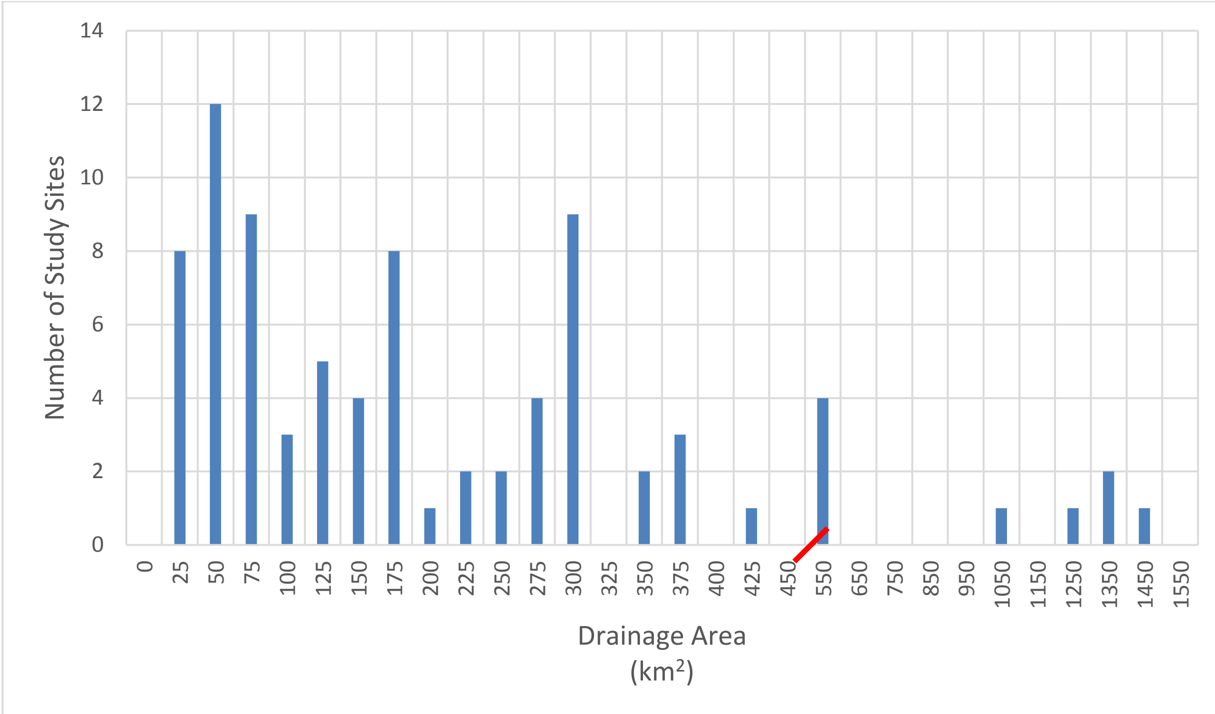

Figure 10. Frequency distribution of CHaMP study sites (CRITFC plus ODFW) within the spring Chinook sample frame in the Upper Grande Ronde basin and Catherine Creek basin having upstream contributing drainage area (km^2) within bins.

Status of GeoDatabase and other map data and documents stored

The CRITFC GIS group continues to coordinate and manage the GIS map files and associated documents. The spatial data are typically compiled in a geodatabase. Other map data such as LiDAR, FLIR, special purpose aerial photos, and other massive data sets are also kept independently. Geodatabase map files have metadata produced for them, which gives information on source and type of modification that the data may have been subject to. Screen images of all the map files available on the Grande Ronde basin are shown in Appendix I. See file: List of map files in geodatabase and in ArcCatalog database-2014-b.pdf.

Road mapping project

We have done considerable work in compiling a roads database in GIS. The USFS and TIGER roads constitute the most complete coverage for roads information in the Upper Grande Ronde basin. Unfortunately, the TIGER roads layer does not include information on road type. It would be helpful to have information on road surface type in the context of a sediment delivery model because it is known that native surface, gravel, and paved surface roads all have different erosion coefficients. Also, road width plays a significant role in magnitude of surface erosion. Road age is a third factor in controlling the amount of sediment delivered from a road surface. After construction of a new road, there is a steady decline in sediment delivery as the road stabilizes, but the new background level of sediment delivery is always greater than was the same land surface before the road. The amount of traffic on the road is also significant in controlling yield. Higher levels of traffic and traffic by log trucks vs cars/trucks are also

controlling factors. If a road is decommissioned, it may be either disconnected from the transportation system by barriers, or it could be put to bed. Putting a road to bed normally involves scarifying the surface to loosen it, followed by planting with trees. Initially, sediment delivery levels are high, but they exponentially decline with time as the slope recovers vegetation cover. Another factor that controls the extent of road-related erosion and sediment delivery is the maintenance level. If a road and its culverts are well maintained and the road is originally built with best practices, one would expect that (1) culverts are kept clear so that road crossings are not vulnerable to failure, (2) culverts are properly sized to permit the largest flows anticipated, (3) roadside ditches are rocked to reduce erosion in the ditch, (4) cut and fill slopes are not extensive, (5) road materials are not cast downhill over the roadside. With the roads spatial GIS coverage and its metadata, we anticipate being able to drape this layer on a DEM for the study basin to allow us to run a sediment delivery model (GRAIP-lite) available from NetMap.

The USFS road metadata can be useful in a road sediment delivery model because of the classification of roads by width and use type (e.g., active, decommissioned). Other road characteristics potentially useful in modeling are not available. TIGER and newly mapped roads that were added to the combined road database were judged to be single lane, natural surface unless good information was available to make other inferences.

It is also obvious on further inspection of the NAIP imagery that serves as the orthorectified background to the road layers that there are many secondary roads that are not mapped in either system. Roads that are not mapped have a great significance when they are within a riparian corridor due to the direct impact on fine sediment in the adjacent reach. This places a high importance on having a comprehensive map available so that road density values by basin are meaningfully linked to existing conditions in stream channels. It will be interesting to analyze the effect of keeping the road layers up to date in estimating sediment delivery. One consideration in this, however, is that the metadata on USFS roads that are eliminated, overgrown, decommissioned, or have become more highly used or rebuilt may not be current, thereby affecting the accuracy of sediment modeling.

Extensive, localized timber harvest in the upper basin very likely contributes significant sediment to tributaries to the mainstem, and thereby to the mainstem from an extensive road system. Forest roads used to harvest timber may be considered to be temporary, but if they produce a ground disturbance footprint equal to a conventional road, it was mapped. Such a road may not have the continuing traffic in coming years that exacerbates sediment delivery, but as long as the scar is visible as a road, it is likely that its sediment delivery needs to be accounted for.

If all road characteristics could be fully known, such as road surface material, age of the road, traffic type and volume, surface steepness, maintenance level, etc., it would be feasible to develop an accurate sediment delivery model. Without having comprehensive information on these road characteristics, the next best thing is to know the complete road density. This means not simply relying on only the USFS road layer or the TIGER road layer, but to combine and condense both layers and to supplement this with all unmapped roads, whether they may be in localized logging areas, or as extensions to other forest and rangeland road systems.

The intensity of effects of roads on a stream's sediment condition can be monitored in terms of changes in the macroinvertebrate community, the stream channel, sediment transport, and in the riparian zone, and watershed in general. Changes in the macroinvertebrate community are expected to reflect shifts to taxa that are more sediment tolerant as levels of fines increase. This shift is likely to be most easily detected in benthic community trends, but may also be obvious in shifts in the drifting organisms. Changes in stream channel levels of fines are reflected in (1) accumulations in surface sediments, (2) accumulation in the deeper subsurface sediments, (3) storage deposits behind LWD or in mid-channel or point bars, (4) primary pool volume and frequency. All of these factors are being measured in either

CHaMP or the full CRITFC monitoring program. Changes in sediment in transport can be detected in changes in (1) turbidity, (2) suspended loads, and (3) bedload transport. These factors are not being measured in CHaMP but the status and trend of the previously mentioned in-channel factors would reflect these sediment transport factors and the watershed development conditions that lead to increased sediment delivery to the streams.

The road network is the source of much of the fine sediment delivery to the stream. This can be measured in terms of road density in (1) the riparian zone for the entire stream network upstream of a study site, (2) the riparian zone upstream of the study site by a fixed distance (e.g., 1 km, as an immediately effective environment), (3) the lateral watershed contributing to the upstream portion of the river segment in which the study site is found, (4) the entire upstream watershed, including its embedded riparian zone. Road density (km/km^2) can be computed as density comprised by roads of different type, where type is a function of (1) road surface material, (2) road width, (3) slope gradient that the road traverses, and (4) hillslope vegetative cover above and below the road. In the event that the quantitative modeling approach does not yield results that are judged to be accurate, it may be feasible to develop an erosion rating system based on the extent, type, and spatial location of the road.

Extent of forest loss

Although we have yet to compute the area of forest loss quantitatively, we presented in Appendix E some example images showing the location of extensive cover loss. The forest cover loss that is shown to the northwest of Vey Ranch appears to be associated with a very small road network. It also does not appear that this was an area denuded from fire. The forest cover loss was detected from a series of annual Landsat images for the area, so cover is compared against prior images showing cover present. It is possible that this area was helicopter logged to reduce erosion.

Future work in developing the database on forest cover loss would include:

1. Create a database year by year of the forest cover loss to establish the time since cover removal for the period 2000-2012. Age since cover loss could be compared with updated NAIP imagery to evaluate time of canopy recovery.
2. Evaluate the relationship between locations of vegetation removal and road density.
3. Evaluate the relationship between mapped locations of vegetation removal, slope characteristics where canopy has been removed or that are lacking in cover for unknown reasons, road density, and in-channel fine sediment concentrations in surface or subsurface sediments.
4. Calculate the total area affected for forest loss in the period from 2000 to 2012.
5. Develop an index of potential slope erosion, using methodology similar to the MUSLE, that evaluates hillslope polygons for slope gradient category and cover category.

Proportion of spring Chinook salmon redds in assessment units

The proportion of redds was relatively consistent among assessment units from 2010-2013 (Table 9), with the largest average proportion of redds occurring in CCC3C in Catherine Creek and UGC7 in the upper Grande Ronde River. In the upper Grande Ronde (Figure 11), redds were concentrated mainly in the upper tributaries Sheep Creek and upper Grande Ronde mainstem above Vey Meadows. Estimates for proportion of redds in Vey Meadows—an area where landowners have denied access—are likely to be conservative because this area represents a reach type that is rare in the basin where no basis of reference exists. In Catherine Creek (Figure 12, redd distributions were relatively uniform from the mainstem extent of spawning and up through the North Fork and South Fork, while spawning appeared to be limited in smaller tributaries.

These results form the basis of preliminary distribution of spawning adults and redds to spatial units of the life cycle model (see Appendix F), and were also used to inform life use areas in the Grande Ronde Atlas process (see Appendix L).

Table 9. Annual proportion of redds in assessment units of the upper Grande Ronde and Catherine Creek basins, 2010-2013 (accounting for unsurveyed areas).

			Annual redd count (expanded to unsurveyed areas)				Annual proportion of redds (%)				
Basin	Assessment Unit	Length of spawning distribution (km)	2010	2011	2012	2013	2010	2011	2012	2013	Average
Catherine Creek	CCC3B	22.17	125.17	117.66	77.96	33.98	32.23	25.35	31.52	29.68	29.70
	CCC3C	7.99	151.00	191.00	95.00	62.00	38.88	41.15	38.41	54.16	43.15
	CCC4	0.99	11.72	14.47	6.41	2.36	3.02	3.12	2.59	2.06	2.70
	CCC5	10.12	100.53	141.04	67.94	16.13	25.88	30.39	27.47	14.09	24.46
	TOTAL	**41.27**	**388**	**464**	**247**	**114**	**100**	**100**	**100**	**100**	**100**
Upper Grande Ronde	UGC3A	3.22	37.31	35.60	13.62	10.24	6.21	7.92	8.05	8.92	7.78
	UGC5	23.85	195.50	59.69	32.02	1.12	32.55	13.29	18.93	0.98	16.44
	UGC6	6.27	71.59	67.78	22.49	20.59	11.92	15.09	13.30	17.94	14.56
	UGC7	7.71	164.65	176.51	65.25	41.13	27.41	39.29	38.58	35.83	35.28
	UGC8	15.97	115.93	103.25	33.60	39.75	19.30	22.98	19.87	34.63	24.20
	UGC9	1.14	15.68	6.43	2.14	1.95	2.61	1.43	1.26	1.70	1.75
	TOTAL	**58.16**	**601**	**449**	**169**	**115**	**100**	**100**	**100**	**100**	**100**

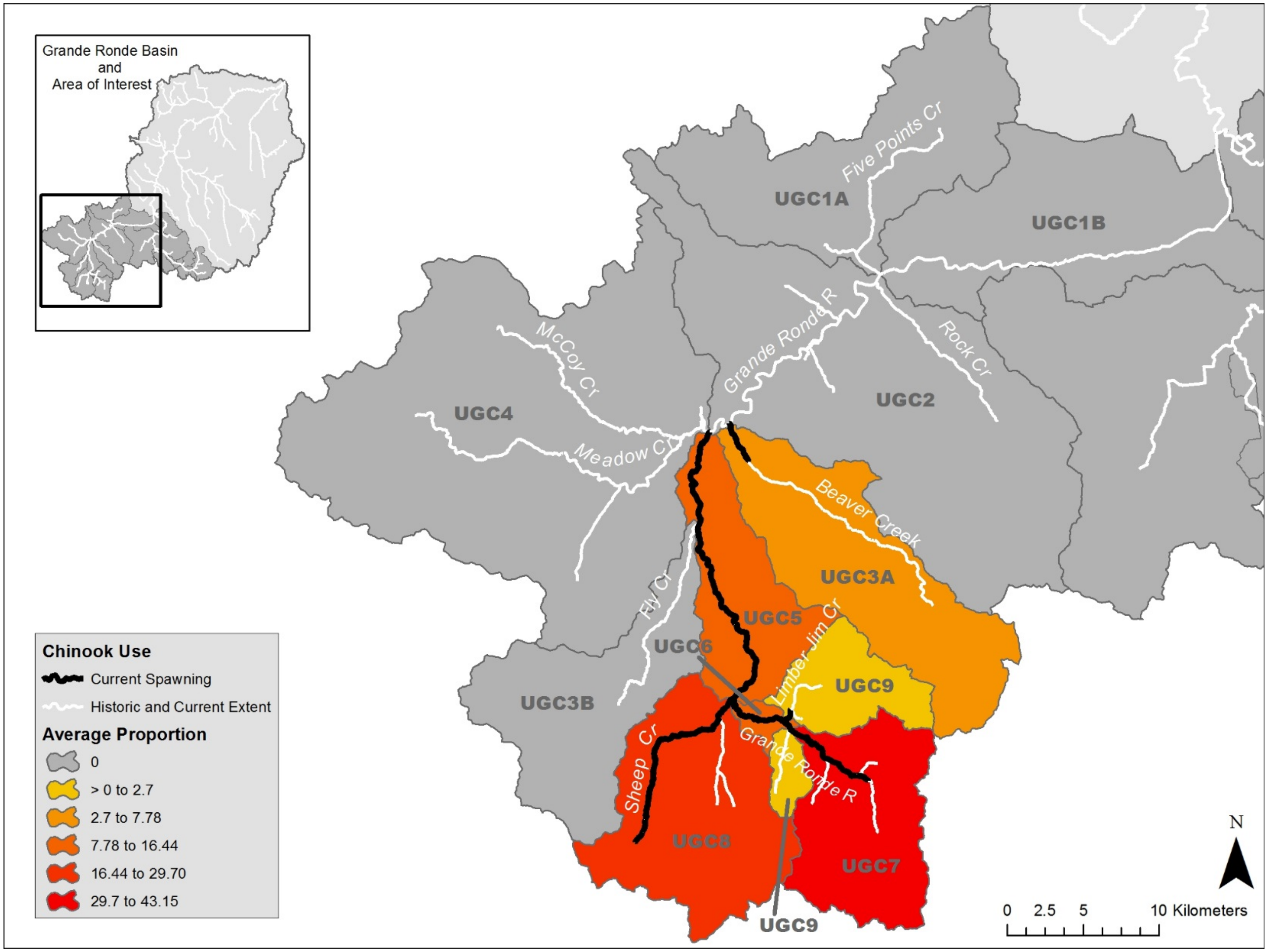

Figure 11. Average proportion of spring Chinook salmon redds in upper Grande Ronde River 2010-2013, accounting for unsurveyed areas.

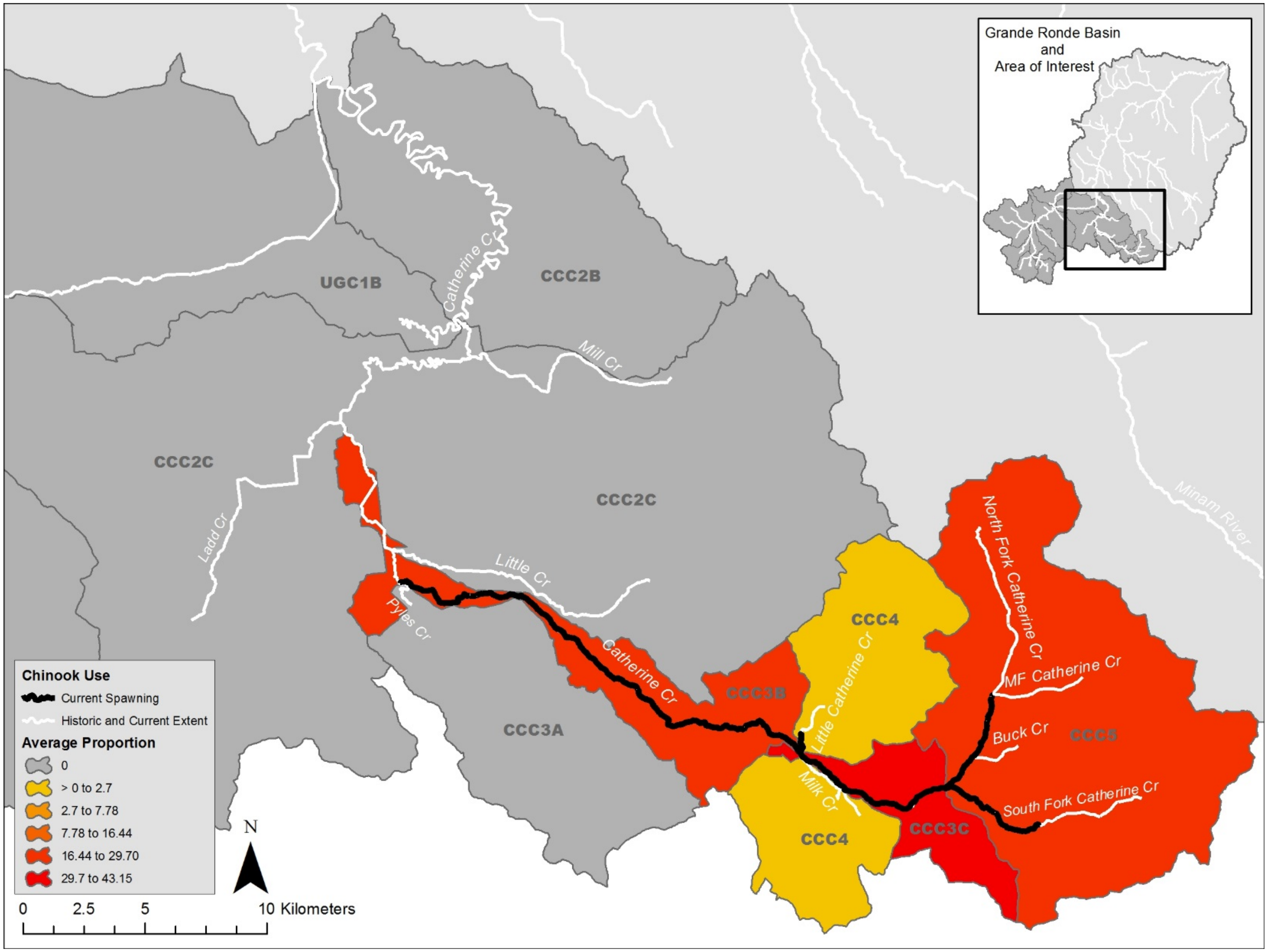

Figure 12. Average proportion of spring Chinook salmon redds in Catherine Creek 2010-2013, accounting for unsurveyed areas.

Work Element J 162 C: Hydrological analysis

Characterizing late-season low-flow regime in the upper Grande Ronde River basin

To relate basin characteristics to low-flow regime, canonical correlation analysis was performed between selected sets of watershed variables and sets of hydrologic metrics. Variables for each set were selected on the basis of principle component analysis (PCA) ordination of hydrologic metrics. Examination of correlations of the metrics with the ordination provided the justification for identification of three relatively independent dimensions of low-flow regime—one identified with a measure of low-flow variability (Q98), one identified with a measure of low-flow timing (jday), and one identified with a measure of baseflow index or influence of groundwater (BFI). The selection of watershed variables was based on examination of a joint plot, which portrayed the direction and strength of the correlation between the two sets of variables. The variables selected were those that showed the strongest linear relationship with the ordination structure of the hydrologic regime: stream density (total stream length/drainage area), maximum January temperature, and mean annual precipitation (Figure 13).

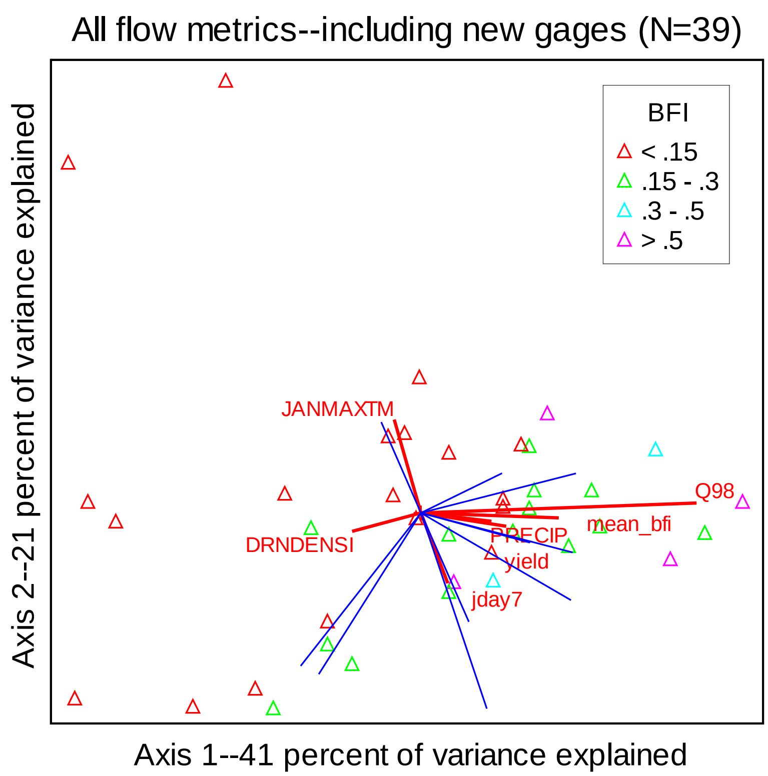

Figure 13. Biplot of PCA relating late-season low-flow metrics with basin characteristics.

There remains considerable uncertainty for some streams that may be associated with their lack of correspondence with other gaged streams, thereby constraining the regionalization component of the analysis. This uncertainty may be somewhat alleviated for the target streams, depending on how similar they are to the gaged streams. We will have a limited ability to assess this uncertainty, although we can do the following—

- Evaluate the probabilities associated with the regionalization groups

- Evaluate the variability associated with the flow and watershed metrics for each group

Next steps:

- Acquire watershed characterizations from StreamStats for selected metrics for target ungaged streams (Done)
- Acquire drainage areas for special flow sites sampled in September, for evaluation of yields in context of geologic structure
- Complete documentation of method in report

Work Element J 162: Apply Heat Source Model

Model output includes stream temperature at points spaced every 100 meters along the stream network for every minute of the day during the simulation period (Jul 10 - Sep 20). From these data, we calculated the maximum weekly maximum temperature (MWMT or the maximum of the 7-day running average of the daily maximum temperature), and produced a map showing the distribution of MWMT throughout the Chinook distribution area (Figure 14 and Figure 15). In addition, we examined model output for various restoration scenarios representing projected changes in riparian vegetation cover, streamflow, or climatic conditions.

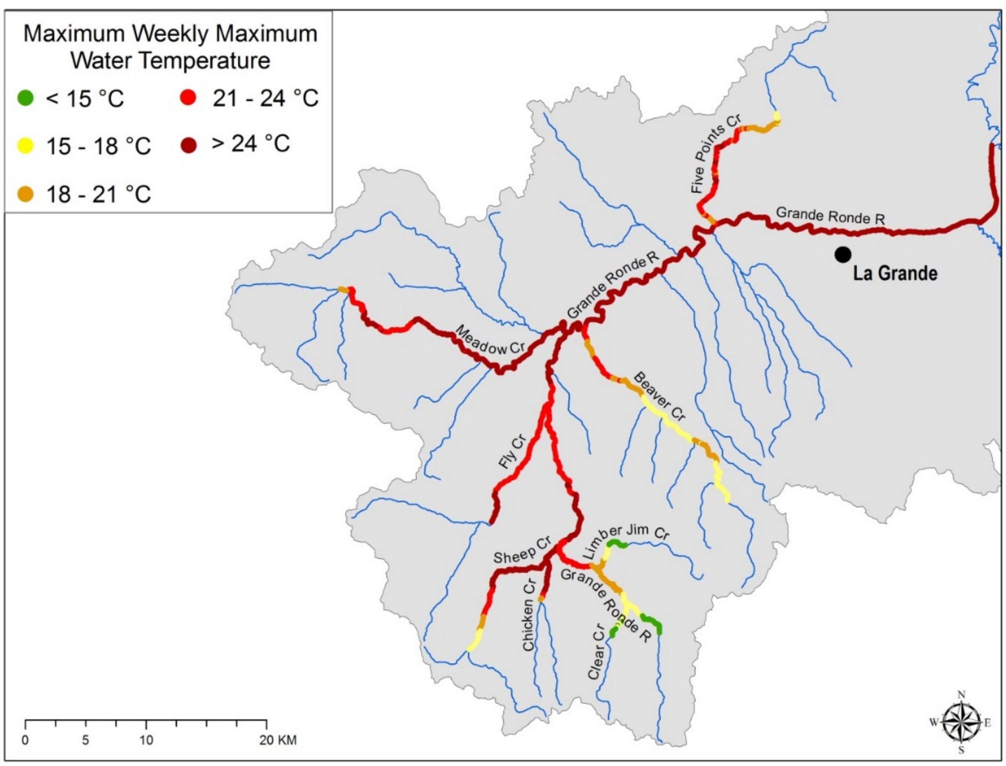

Figure 14. Maximum weekly maximum water temperature (maximum 7-day running average of the daily maximum temperature; °C) in the Upper Grande Ronde River basin during summer 2010. These data were simulated using the Heat Source water temperature model for the period July 10 – September 20.

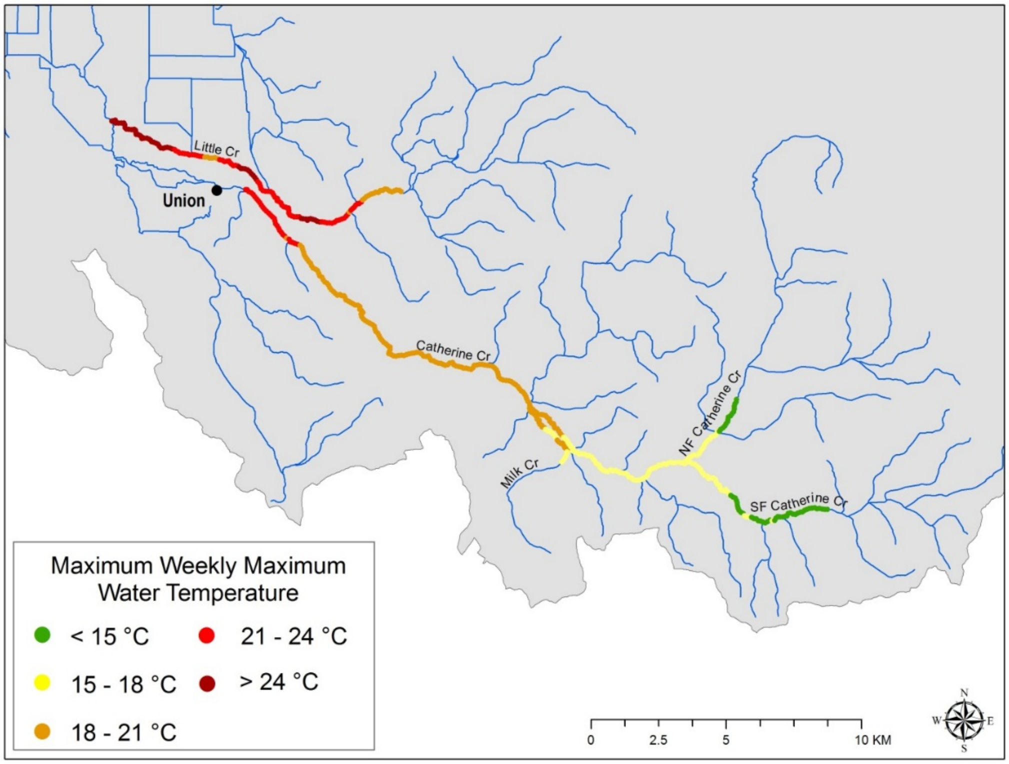

Figure 15. Maximum weekly maximum water temperature (maximum 7-day running average of the daily maximum temperature; °C) in the Upper Grande Ronde River basin during summer 2010. These data were simulated using the Heat Source water temperature model for the period July 10 – September 20.

Work Element I 162 F: Develop draft life cycle model

The life cycle aspect of Catherine Creek spring Chinook modeling is operational. Spatial calibration and resource allocation components are currently under development. The resource allocation component has been prototyped for sensitivity to riparian planting efforts. A range of planting scenarios were examined such that the rate of growth of trees and the current state of riparian areas could be tested for recovery potential under different scenarios of planting intensity. Under assumed growth and shade accumulation, simulation results indicate that depending on the initial average age of riparian growth, benefits to production from the intensity of planting efforts are not commensurately larger with larger intensity of planting. Results indicate that the timing and intensity should be carefully considered in recovery planning. More details about the life cycle model are provided in Appendix F.

The life cycle model will be able to make significant use of the spatial resolution now available from Heat Source modeling of potential natural vegetation restoration scenarios. In addition, it will be able to make use of (1) zonation of water temperature thresholds linked to productivity and capacity (See Figure 14 and Figure 15), (2) a table of habitat metrics tailored to life cycle-specific temporal and spatial scales (See Appendix J), (3) the annual proportion of redds by assessment unit in the two study areas (See Table 9), and (4) future assessments from snorkel data of the relative use of channel units and assessment units.

Catherine Creek model subcomponent

We analyzed passive integrated transponder (PIT) tag data collected by the Oregon Department of Fish and Wildlife from migration years 1994 to 2012 to evaluate factors influencing growth and survival of juvenile Chinook salmon captured in rotary screw traps in the Upper Grande Ronde River and Catherine Creek, eastern Oregon. We developed a set of linear models to test a series of a priori hypotheses about the factors influencing both fish length and survival.

The best fitting model for mean fish length included migration group (i.e., early or late migrants), spawner abundance and average summer water temperature (July-August) as independent variables. The top model explained approximately 82 percent of the variation in average fish length for Catherine Creek migrants and 72 percent for Upper Grande Ronde migrants. Migration group explained the largest proportion of the variation in average fish length among the variables examined, accounting for approximately 46 and 37 percent of the total variation in fish length in Catherine Creek and the Upper Grande Ronde respectively. Late migrants were approximately 7.4 mm larger on average than early migrants in Catherine Creek, and 6.3 mm larger in the Upper Grande Ronde.

Fish length was negatively correlated with both spawner abundance and average summer temperature in both populations. Spawner abundance accounted for approximately 25 and 20 percent of the variation in mean fish length in Catherine Creek and the Upper Grande Ronde populations respectively. The slope of the relationship between length and spawner abundance was very similar between the two populations, with average fish length declining by approximately 1.3 and 1.2 mm for every increase of 100 spawners in Catherine Creek and the Upper Grande Ronde respectively.

Because body size has such a direct bearing on juvenile survival during seaward migration, factors that control body size (length), such as water temperature and rearing density (e.g., spawner abundance), are important inputs to our life cycle model. Work done to elucidate these relationships to density dependent and density independent factors is reported in greater detail in Appendix K.

Application of Heat Source Model

The extended Heat Source Model was applied in a pilot project to explore the ability to improve the thermal regime for the 17 model tributary/mainstem subcomponents in a systematic simulated restoration program from the headwaters to downstream. The results of this modeling effort are presented in detail in Appendix L. This work involved developing a preliminary model of potential natural riparian vegetation in a GIS format where vegetation polygons were assigned potential height and canopy density values. These model inputs were then used to generate predicted changes to stream shading that were translated mathematically to changes in the thermal regime on an hourly basis for every 100 m of the stream network modeled. This pilot analysis will be revised upon completion of the major riparian potential vegetation mapping project. These model results will then become key inputs to the life cycle model described above. The linkages between water temperature and fish length, considering the influence of spawner abundance, will help generate meaningful LCM outputs that will be a key to assigning benefits to stream restoration, especially riparian vegetation recovery. These benefits must also be weighed against concurrent losses in riparian forest cover from logging (see Appendix E), as well as delayed recovery in stream reaches that receive continuing impacts from riparian livestock grazing.

Monitor and evaluate the status and trends of juvenile fish productivity in tributaries relative to habitat quality improvement targets.

Are tributary actions achieving the expected biological and environmental improvements in habitat?

Work Element D 157: Collect fish density data by channel unit and site using snorkel surveys

We conducted snorkel surveys at all 25 sites where CHaMP habitat data were collected in 2013 to quantify juvenile Chinook salmon and steelhead abundance and size as well as fish assemblage structure and to assess potential fish/habitat relationships. The Columbia River Inter-Tribal Fish Commission (CRITFC), Oregon Department of Fish & Wildlife (ODFW), and Confederated Tribes of the Umatilla Indian Reservation (CTUIR) have recognized the need to use a common snorkel survey so that information collected by individual entities can help managers determine whether aggregate habitat restoration actions will yield a net improvement in basin-wide habitat quality for ESA-listed fish species. To this end, we developed a snorkeling protocol drawing heavily from the protocols of Thurow (1994) and O'Neal (2007), intended for use among all agencies responsible for data collection in the Upper Grande Ronde, Catherine Creek, Minam River, and potentially other nearby basins. Details about the snorkel survey methodology can be found in White et al. (2012); https://www.monitoringmethods.org/Protocol/Details/499).

Collecting fish density data using snorkel surveys

The 2013 field season marks the completion of three rotating panels and three consecutive visits to annual panels for CHaMP sampling, coupled with associated fish snorkeling and macroinvertebrate collections. While several analyses of fish distribution and its linkages to local and landscape conditions are underway, a cursory look at juvenile Chinook salmon rearing densities at primary visits in three watersheds (upper Grande Ronde, Catherine Creek, and Minam River) and by life use (spawning and rearing vs. rearing only) was instructive (Table 10). Over the three-year period, there were a total number of 120 snorkel visits to sites within the spring Chinook salmon domain, excluding any within-season revisits. Overall, fish densities were higher in Catherine Creek (2.31 fish/m) than the other basins across years combined. However the Minam River was only sampled in 2013 and in that year fish densities were higher than all other watersheds (0.82 fish/m). The annual trend for watersheds in upper Grande Ronde and Catherine Creek—where multiple-year sampling was carried out—was one of decreasing juvenile Chinook salmon densities. Calculating separate estimates for life history type revealed that the current spawning domain yield much higher fish densities (e.g., Catherine Creek with 2011 with 0.02 fish/m in rearing only areas and 6.60 fish/m in spawning areas). Higher densities of juveniles in spawning areas can be explained by closer proximity to redds, located in areas with more favorable valley setting, or more likely a combination of the both.

We attributed 2011-2013 data with selected attributes from StreamStats. Sites in the upper Grande Ronde had on average the largest cumulative watershed area (132 km^2), lowest elevation (5070 m), and smallest percentage of area in forest (77%). Sites in the Minam River had on average the highest elevation (6401 m) whereas sites in Catherine Creek had the largest percentage in forest (84%).

Table 10. Mean values and standard deviation for juvenile Chinook rearing densities in three watersheds and two life use areas in the Grande Ronde River basin, along with selected attributes from StreamStats. Within-year, repeat site visits are excluded from this summary.

	Mean fish/m	Mean fish/m^2	Mean elevation (m)	Mean drainage area (km^2)	Mean forested area (%)
Catherine Creek	**2.31**	**0.26**	**5556**	**59**	**84**
2011	**4.66**	**0.52**	**5621**	**62**	**84**
current rearing	0.02	0.00	5960	15	84
current spawning	6.60	0.73	5480	81	84
2012	**1.90**	**0.22**	**5379**	**53**	**83**
current rearing	0.03	0.00	5649	11	79
current spawning	2.68	0.32	5266	70	84
2013	**0.67**	**0.08**	**5652**	**61**	**85**
current rearing	0.01	0.00	5634	24	87
current spawning	0.96	0.12	5660	77	84
Minam River 2013	**0.82**	**0.07**	**6401**	**62**	**68**
Upper Grande Ronde	**1.84**	**0.23**	**5070**	**132**	**77**
2011	**3.17**	**0.34**	**5230**	**131**	**78**
current rearing	0.92	0.08	4817	182	74
current spawning	4.90	0.55	5547	92	82
2012	**0.99**	**0.16**	**4920**	**103**	**76**
current rearing	0.79	0.16	4747	114	72
current spawning	1.43	0.17	5292	79	85
2013	**0.76**	**0.12**	**5037**	**194**	**76**
current rearing	0.00	0.00	4751	252	73
current spawning	2.09	0.34	5537	94	82

Grand Total	**1.97**	**0.23**	**5400**	**93**	**79**

Coordination and Data Management RM&E

Actively support the coordination and standardization of regional and Program monitoring efforts with other federal, state, and tribal monitoring programs including the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, meta-data, and data access.

How has regional coordination supported communication or the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, meta-data, and data access to support Fish and Wildlife Program strategies at http://www.cbfish.org/ProgramStrategy.mvc/ or how regional coordination support prioritization of habitat restoration or operations of hatchery facilities

<u>Work Element B 191: Coordinate with regional agencies, tribes, and landowners</u>

Scientists and other staff on this project have significantly contributed to the coordination and standardization of regional monitoring efforts by actively participating in several working groups beyond the scope of this individual project (described below). CRITFC continues to engage with landowners in the upper Grande Ronde and Catherine Creek basins through direct communication for access to private property and communication of site-specific findings via an annual letter of thanks and reporting to them site-specific data for their property.

Columbia Habitat Monitoring Program (CHaMP) – Project staff continue to actively participate in the development and refinement of the CHaMP protocol. Project scientists have had significant input into which habitat characteristics are quantified, and how those characteristics will be measured by crews in the field. We have also led efforts to conduct quality control checks on how CHaMP metrics are calculated. At the February 25-26, 2014 post-season CHaMP workshop in Portland, project staff gave a presentation on "Informing recovery options for spring Chinook salmon in the upper Grande Ronde River." This presentation reviewed the state of the science in the CHaMP monitoring program and how its results will be useful in advising managers wishing to have rollups of habitat information to the population, MPG, or ESU level. CRITFC field technicians and other staff continue to attend "CHaMP Camp," an 11-day training in habitat protocols conducted annually in June.

FCRPS Adaptive Management Implementation Plan (AMIP) – CRITFC's habitat and population modeling efforts are being coordinated with state and federal agencies. AMIP coordinates life cycle modeling efforts for recovery planning required by the 2008 BiOp for all Columbia River listed stocks. CRITFC is a steering committee member of AMIP, and has been coordinating Catherine Creek life cycle model development with NOAA and ODFW. ChaMP efforts are also an integral part of AMIP, and those protocols are the basis for the habitat component of CRITFC modeling efforts. The current AMIP report, which was reviewed by the ISAB, is posted at: http://www.nwfsc.noaa.gov/trt/lcm/docs/Interior.Columbia.LCM.6.28.13.pdf.

FCRPS BiOp Expert Panel and Implementation Prioritization Strategy – Project scientists remain involved in the Science Advisory Committee (SAC) for the upper Grande Ronde and Catherine Creek basins. With oversight by the BPA, the SAC provides data for decision making and advises the prioritization of restoration projects based on scientific principles. Involvement with this group provides the opportunity to have a direct impact on where, when, how much, and what kind of restoration occurs in the basins. Other organizations represented on the SAC include CTUIR, ODFW, NOAA, USFS, and Grande Ronde Model Watershed.

Pacific Northwest Aquatic Monitoring Partnership (PNAMP) – Project scientists are actively engaged with PNAMP staff in an effort to make use of the past and existing benthic macroinvertebrate (BMI) data collected in the Pacific Northwest, in addition to shaping the way BMIs are collected in the field, how they are processed in the laboratory including standard taxonomic effort, and how data can be shared across organizations.

Integrated Status and Effectiveness Monitoring Program (ISEMP) – Project scientists have engaged in several workshops and conference calls with ISEMP staff to facilitate the sharing of fish-related data across the Columbia basin. Through interaction with ISEMP staff, CRITFC has maintained involvement in developing analytical methods to explore regional fish datasets.

Work Element G 156: Review and refine monitoring protocols and statistical designs

Since the spring of 2011, CRITFC has been an active participant in the CHaMP program, providing detailed reviews and feedback on field collection and analysis methods, coauthoring various sections of the field protocol, assisting with crew training and logistics, and presenting data analyses and findings at CHaMP workshops. We believe these efforts have helped to improve the accuracy, repeatability, and validity of the data collected by other CHaMP participants and have strengthened our ability to assess status and trends in stream habitat conditions over a broad regional scale.

Work Element H 160: Develop and manage fish habitat condition database

Project staff continue to develop a comprehensive database of in-stream and landscape-scale habitat characteristics and biotic conditions that can be used for analyses of fish-habitat relationships. In 2013, we made significant advances in acquiring new datasets and improving existing ones. See Appendix I for a comprehensive list of GIS database elements.

Database and Application Development for Temperature data, flow data, sediment sample data, human disturbance surveys and snorkel surveys for 2013

In 2013 we continued additions to the snorkel survey and human disturbance (SSHD) data collected during the field season by CRITFC and ODFW in the project area. Staff from BPA and the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) expressed a desire to standardize training, data collection, and data storage for fish sampling in the region; and requested the snorkel protocol, datasheets, and data structure developed be based on those developed by CRITFC. We have been involved in several planning meetings and workgroups to standardize these procedures with multiple agencies throughout the Pacific Northwest. Examples of standardization include agreement on size classes for recording fish observed, species codes, and associated site data collected while snorkeling. A local snorkel training involving CRITFC, ODFW, CTUIR, PNAMP, BPA and Shoshone-Bannock tribes is being planned for July 2014 in La Grande, OR.

In 2013, the raw flow and temperature (raFT) database was modified and renamed. The temperature data tables were removed and stored in a new database called Grande Ronde Temperature (GRT), which is modeled after the database structure created by the Yakama Nation Fisheries Program Data manager for the Klickitat Field Office for storing stream temperature data. Figure 16 shows the GRT database structure. This new structure allows the Fisheries Scientists to keep track of temperature data loggers, a feature that was missing in the raFT.

Additionally, an application was created in Microsoft Visual Studio 2010 with C# to automatically upload data exported from the temperature loggers, validate the values and summarize the data by each 24-hour day.

The sharing of stream temperature data collected by CRITFC is on-going. Temperature data was sent in 2013 to Sherry Wollrab from the USFS Boise office. This data was included in the NorWeST Stream Temperature Regional Database (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). The NorWeST database is more of a data reporting tool, and is not capable of tracking our loggers and providing notices for when maintenance is due and provide information on which loggers will be available for use for the next season.

The GRT database stores information about each logger and logger calibration details. Additionally, GRT's automated system is capable of providing email notifications of logger services due, problems with the uploaded data, and instantaneous reports of summarized temperature data over the long term.

The original raFT database now only contains the flow data, acquired by Oregon Water Resources Department (OWRD) as described in the following paragraphs, and sediment data collected by CRITFC and ODFW habitat survey crews. We changed the database name to raw Flow and Sediment database (raFS) and retired the name raFT. The flow and sediment data stored are consistent with what was described in 2011.

Prior to raFS creation, CRITFC conducted an extensive survey of water flow station location sites in the Grande Ronde Basin and found that 85 stations had been, or were still located, in the Grande Ronde Basin (http://www.hydro.washington.edu/SurfaceWaterGroup/Data/ARCINFO.html#usgs_gages, correspondences with Richard Marvin and Ken Stahr, OWRD, 2011 and 2012). However, only 53 flow stations of the 85 were included in the raFS database, since these were the only ones that record the height of the surface water every 15 minutes as the measurement of flow. These recordings were then transformed to mean daily flow (MDF) in cubic feet per second using a stage discharge curve or rating table. The discharge curve or rating table was created by measuring flow at cross sections with known areas according to OWRD website (http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/).

Of these 53 stations, 17 are actively recording MDF data. In 2013, to ensure we were working with a complete record set of flow stations we rectified sites with The Grande Ronde Model Watershed Program (http://www.grmw.org/projects/projectdb/59/). During the rectification process, we noticed that the latitude and longitude location data housed on the Grande Ronde Model Watershed Program website did not always match with the data we obtained from OWRD. It was also determined that our raFS station location table included all new stations.

The MDF data, from all active OWRD station locations, are downloaded from the internet into the raFS database using an automated application. This application was created using Microsoft Visual Studio 2010 and C#. This application updated the raFS for new MDFs acquired at each active site weekly during 2013.

Sediment samples collected during the 2013 field season were processed at CRITFC Fisheries lab and uploaded to the raFS using Adapx digital pen technology (http://www.adapx.com/) connected to CRITFC's cloud based Microsoft SharePoint Server 2010. This technology allows the fishery scientist to record on paper datasheets and afterward upload the digitally stored data from the pen using a USB port and Capturx for SharePoint software. Once the data are uploaded to the SharePoint server, they can be checked for errors, corrected, and approved for transfer to the raFS database. Using reporting functions in the raFS, reports of particle weight by size class are recorded. This pen application was implemented in 2012 and updated in 2013.

Data collected by ODFW and CRITFC for the Snorkel Survey and the Human Disturbance Surveys for 2013 have been entered into the Snorkel Survey and Human Disturbance Database (SSHD). The data entry application, as described in 2012, was slightly modified in 2013 to accommodate electroshocking fish

survey data. Additionally, we made improvements to the reporting application of the population indices from the counts of species collected during the snorkel surveys.

These databases were created using Microsoft SQL Server 2008 R2 and are installed on a virtual machine with Windows Server 2008 R2 Operating System. The backup system is provided using a Drobo backup device and VMWare mirroring, on a daily basis. Additionally, backed up data are stored offsite on a biweekly basis.

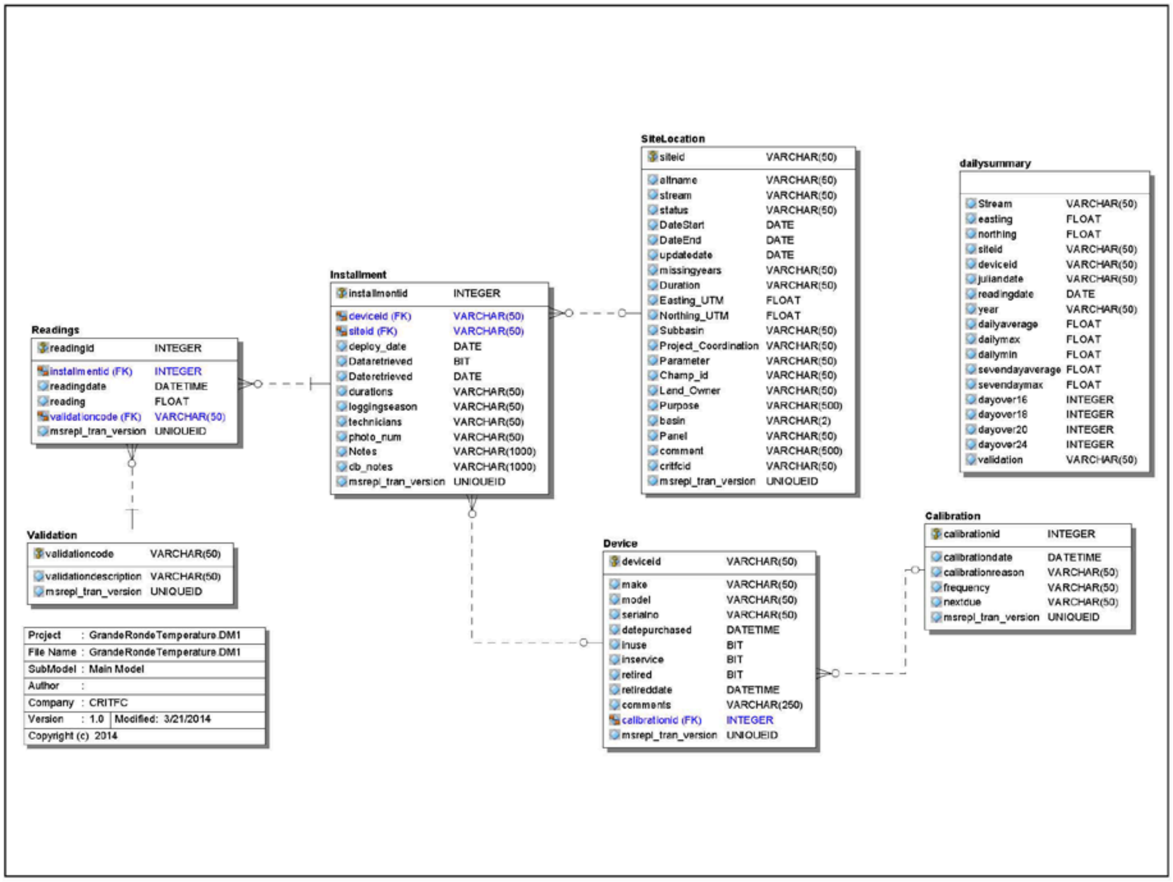

Figure 16. Structure of the newly created GRT database. Each box represents a table within the database. Column names and data types are show within each box/table with table linkages represented with connecting lines.

Synthesis of Findings: Discussion/Conclusions

Tributary Habitat RM&E

Monitor and evaluate tributary habitat conditions that may be limiting achievement of biological performance objectives.

What are the tributary habitat limiting factors (ecological impairments) or threats preventing the achievement of desired tributary habitat performance objectives?

In the Accords (2008) (i.e., a memorandum of agreement between the Columbia River Tribes and three federal Action Agencies that resulted in funding of habitat restoration projects to improve productivity and abundance of ESA-listed Columbia River salmon) it was estimated that the current percentage function (i.e., an average condition of fish habitat, owing to the percentage survival that would be attributable to the individual effect of each of the limiting factors, measured against their optimal condition) of the Upper Grande Ronde River and Catherine Creek, respectively, was 34% and 44%. It was also estimated that the absolute change in percentage function in a 10-year period could be 10% for each watershed. The identified primary limiting factors for the Upper Grande Ronde were in-channel characteristics, riparian/floodplain, sediment, and water temperature. Water temperature was noted as the most important limiting factor. In Catherine Creek the primary limiting factors were identified as in-channel characteristics, riparian/floodplain, and water temperature. For Catherine Creek, in-channel characteristics and water temperature were equally limiting, but were not nearly as limiting as water temperature in the Upper Grande Ronde. It was estimated at the time of publication of the Accords that each limiting factor could improve by an absolute 10% in level of function.

At the conclusion of the 2013 field season, we had three years of data collected using the combination of CHaMP protocol and the additional CRITFC monitoring protocols for monitoring. Logical questions to attempt to answer within our monitoring program include:

1. Are the limiting factors identified in the Accords estimates still the most important limiting factors?
2. Are there any other habitat limiting factors that have been revealed through monitoring that are as important, or more important, than those already noted?
3. Is the percentage habitat function identified through intensive monitoring comparable to the rough estimates made in the Accords?
4. Are there any better means to identify current level of function?
5. What means are there to estimate the likely percentage improvement in habitat function based on current in-stream habitat and environmental condition, planned habitat restoration actions, and what is known about the linkage between land use, environmental condition, and in-stream habitat trends?
6. Is there a way to translate improvements in habitat condition (function) or habitat quantity/quality into potential improvements in the listed species populations?
7. Can monitoring results on the populations that are studied intensively be translated to potential improvements in the MPG or ESU as a whole?
8. What might be some valuable pieces of information that could be collected comprehensively on those watersheds that are not intensively monitored that could allow extrapolation of results from

intensively monitored watersheds to those watersheds supporting other populations in the MPG or ESU?

After the first three years of our full monitoring program, we have gained significant information about the primary habitat limiting factors in the two study basins. We singled out water temperature, fine sediment, and streamflow as three key limiting factors, based on a variety of sources. In addition, we have monitored other important habitat factors that could potentially be limiting. For example, we are monitoring pool volume and frequency, large woody debris, streambank overhang area and other fish cover elements, and food availability. At the present time, we can probably draw a conclusion that water temperature is the key factor limiting total basin capacity for spawning and rearing. However, we cannot make a definitive statement that fine sediment and streamflows are more or less important than the other habitat factors, except in the lower sections of the upper Grande Ronde and Catherine Creek, which are diverted to the extent of totally dewatering the rivers. We have selected all these factors to monitor on the annual and rotating panel design so that we could assess the rate of change in these factors with time. We plan to also assess the changes in relation to known levels of restoration actions. In pursuit of the information needed to make these relationships clear, we are exploring the ability to fund a grad student to assemble a database on the restoration actions taken in our study watersheds as well as the distribution of the major land disturbing actions that have taken place and are ongoing. Gaining a comprehensive database of intensity and timing of restoration actions will be an important piece of information needed to compare against aggregate habitat response rates. This task has been identified as a regional need, but exceeds our current funding.

As described in more detail in our annual report, the full life cycle model for spring Chinook is one of our primary goals. This model will make use of our spatially explicit and spatially balanced representation of the stream system habitat quality supporting each listed spring Chinook population to estimate population trends in relation to habitat trends. We have made significant progress in development of this model in 2013. (See Appendix F). However, at this early stage of our research, we are not able to make population predictions based on specific current instream habitat conditions, watershed conditions, and expected habitat actions.

The life cycle model derives its input data from a number of subcomponent models that are under development. The core submodels (Table 11) include the Heat Source water temperature model, sediment delivery model, fine sediment-fish survival, water temperature-fish survival model, natural potential riparian vegetation, macroinvertebrate drift, and low flow models. We described in some detail, progress on each of these components in Methods and Results for 2013.

The Heat Source water temperature model was calibrated for an extended period (July 10-September 20, 2010). Stream temperature was simulated for the Grande Ronde River, Catherine Creek, and several of their tributaries. The simulation period is representative of low-flow and high stream temperature conditions, when salmonid habitat is at its most critical condition. Approximately 247 stream miles were simulated above the confluence of Catherine Creek and the Grande Ronde River. The streams of interest are either historic or current salmonid habitat. This model will allow prediction of water temperatures for each 100 m linear distance along the mainstem of the Upper Grande Ronde, Catherine Creek, and their major tributaries.

Availability of detailed hourly water temperatures for each of these points in the stream systems providing rearing for spring Chinook allowed prediction of survival (and in future work, may allow us to predict site-specific growth rates) on a continuous basis.

A step we were able to take in 2013 with the Heat Source model was to explore site specific restoration of riparian vegetation on the longitudinal temperature profile of the streams. CRITFC staff coordinated with NOAA staff and other participants in the BPA Atlas process to select restoration scenarios that would be of interest to model so as to effectively see the value of restoration of riparian habitats to PNV (potential natural vegetation) conditions in a systematic restoration program. This work required using available Ecoregion information and published information on potential height and cover of dominant tree species to develop a draft, improved mapping of PNV in advance of the product that will be coming in 2014 from our riparian ecologist consultants. Existing LiDAR data provided the current riparian effective shading values in the model. By using the model experimentally to add shade to vegetation-limited stream reaches, we were able to assess the potential for improvement in water temperature regime. This was compared with the past estimates made by ODEQ (1999) using other PNV assumptions. With the calculations of potential improvement in the water temperature regime, we expect to be able to enter these data to our life cycle model and project potential influence on the listed species.

Table 11. Individual habitat model components whose outputs are used in the overall spring Chinook life cycle model.

Habitat model	Data sources	Model output
Heat Source Temperature Model	LiDAR, FLIR, stream temperature & flow, stream channel morphology, riparian condition	Spatially-explicit predictions of water temperature under various land use & restoration scenarios
Sediment Delivery Model	Hillslope and channel gradient, road density, grazing intensity	Identification of at-risk areas in the watershed where sediment is likely to have detrimental effects on fish
Fine Sediment-Fish Survival	Literature effects of fines, field tests of incubation survival	Functional relationship between fine sediment values measured in the field and theoretical fish survival
Water Temperature-Fish Survival	Literature effects of water temperature on survival and growth	Functional relationship between stream temperature measured in the field and theoretical fish growth and survival
Natural Potential Riparian Vegetation	Historical vegetation maps, geology & soil maps, aerial photos, valley morphology, climate data	Map of current & historical vegetation as a reference condition to compare against alternative riparian management scenarios
Macroinvertebrate Drift	Drift samples, riparian condition, upstream land use, stream substrate, water temperature	Spatially-explicit predictions of energetic resources available to fish
Low Flows	USGS flow data, watershed area, geology, mean annual precipitation, drainage basin morphology	Spatially-explicit predictions of stream reaches vulnerable to detrimental low flows

Progress that we reported on mapping riparian potential natural vegetation (PNV) and the work to be finalized under this mapping effort in the coming year will be used to guide restoration efforts that require riparian planting. Reliable maps of PNV are essentially considered a model of the riparian or streamside zone because they are based on a combination of existing plot data and ecological knowledge relating individual species to key environmental gradients (e.g., climatic region, valley width, soil types, and channel slope). PNV maps will provide key input data to use in modeling (1) potential effective shade in highly disturbed stream reaches, (2) sediment yield to stream channels based on streambank stability and rooting potential of PNV communities, and (3) potential terrestrial macroinvertebrate inputs to drift, measured as biomass and diversity. PNV maps could also be used to make inferences about the food base relative to assumed differences in allochthonous litter input rates and litter diversity (coniferous/deciduous balance).

The biological response to habitat quantity and quality was assessed using juvenile fish abundance and macroinvertebrate data. Fish were monitored using snorkel surveys to count numbers and sizes by species for all salmonids, and presence/absence for all non-salmonids at all CHaMP survey sites. Benthic macroinvertebrate samples were taken at corresponding CHaMP sites and their indicator values will be compared with fish and habitat metrics. These biological responses reflect the habitat quantity and quality of the channel units from which the samples are taken as well as the conditions of the upstream channel, its riparian or streamside zone, and the upstream watershed. For fish response in pool channel units, the fish species, sizes, and densities observed are related to the quantity and quality of the channel unit. The quantity is a function of the pool area and volume. The quality is a function of the substrate composition, cover (boulders, wetted LWD, overhanging vegetation or wood, overhanging banks, and artificial

structures), water temperature, water chemistry, streamflow regime (peak flow and low flow characteristics) and riparian cover (related to litter input composition and quantity, and terrestrial macroinvertebrate inputs).

We will soon be in a position to explore the correlation between fish densities and water temperatures at all survey sites. Information such as this will likely reveal a combination of sublethal effects of thermal loads and behavioral response.

These longitudinal trends in fish density related to water temperature trends will need to be distinguished from effects of other habitat characteristics, such as LWD and other cover elements. Recent analyses indicate significant relationships between amount of LWD, pools, and Chinook densities. In addition, fish densities appear to be related to mean annual flow, forested area, thalweg depth, and channel unit type (see McCullough et al. 2013). Many previous studies have found that densities of salmonids decline steadily with increasing water temperatures until densities become near zero when maximum temperatures reach approximately 24°C. See Appendix M for representative figures from the literature indicating the influence of water temperature on salmonid juvenile density.

An important aspect of our monitoring program is biological sampling, which provides information on the distribution and abundance of fish and macroinvertebrates, food sources for fish, and biotic indices that relate to watershed health. Food availability will be related to macroinvertebrate drift transport rates. Currently, benthic macroinvertebrate data are not available through the CHaMP program. In the CRITFC program we have collected benthic macroinvertebrate samples and reported basic indices.

CRITFC also has participated in recent discussions with regional experts about the linkages between drift and benthic macroinvertebrate samples. We plan to integrate the temperature logger data and site- specific Heat Source hourly temperature data with food availability and fish density data to estimate fish growth rates through the use of bioenergetic modeling.

In 2012, we reported continuing progress in assessing the status of subsurface fine sediment concentrations in spawning gravels in study areas. We demonstrated significant correlations between surface fine sediments (measured by the CHaMP protocol) and subsurface fine sediments (measured with the CRITFC protocol). These results lend support to the ability to conduct rapid analyses of surface fine sediment conditions as a means of identifying important trends in subsurface fines. Subsurface fine sediment concentrations provide a known connection to salmonid incubation survival rates. Because subsurface fines are more difficult and time-consuming to monitor, a good relationship to subsurface fines would help establish threshold values that could serve as uniform restoration targets for various stream sites. It would likewise provide an essential linkage that would allow CHaMP surface fines data to be used to infer incubation survival rates. We need to extend the exploration of the relationship between surface and subsurface fines to include the influence of channel gradient. If channel gradient affects the relationship between surface and subsurface fines, restoration thresholds may need to vary by gradient class.

For 2013 we reported progress in mapping riparian and overall watershed road densities. The current GIS road layers are derived from the USFS and TIGER roads data. Neither of these layers is sufficiently comprehensive to be used alone to provide a reliable estimate of road density. Merging these layers is more than a matter of simply combining the line work of each because lines representing identical road segments vary greatly between map sources in accuracy of placement on the ground, necessitating that duplicate road segments be deleted and some segments repositioned to more accurately represent true location. Most striking was the magnitude of roads present on the landscape and not mapped by either mapping system.

The road density relative to every stream study reach will be analyzed by proximity to the reach. We hypothesize that levels of surface and subsurface fines in the study sites will be related to magnitude of sediment sources. The sediment yield model that we will construct will be either a correlative or predictive model that is a function of road density, proximity of the roads to the study site, and condition of the streamside zones (vegetation coverage or bare ground in streamside zones).

Our CRITFC/USGS cooperative agreement has made significant progress in developing a model of low flows in the Upper Grande Ronde and Catherine Creek basins. This model is nearing completion in 2014 and is based on available long-term stream gauge data from around the region in similar climates and watershed characteristics. The model developed by USGS can be used predictively for summer low flows. Watershed conditions were developed from a combination of

USGS StreamStats, NVision's BasinTools, and numerous GIS data layers present in the CRITFC geodatabase that have been documented extensively in our two previous annual reports (McCullough et al. 2011, 2012). The low flow model will presumably help predict the frequency of critically low flows during the spawning season, predict the annual likelihood of restricted spawning areas, and allow estimation of the additional impact of further changes in mean annual precipitation or onset of snowmelt to the low flow condition.

This model will link watershed intrinsic characteristics to low flow potential. In addition, the long-term trends in low flows linked to climate change will become critical to long-term viability of spring Chinook populations. Change in air temperature spatial distribution and depth of snowpack will lead to changing patterns of stream runoff and summertime low flow conditions. Some streams will be more or less naturally resistant to these climatic trends due to the stability of their summer low flows. This inherent potential for resistance to low flow variation can be observed in differences in recession rates during rain-free periods and in ratios in low flow statistics, such as Q7L2 and Q7L20 (7-day low flows with 2- and 20-year recurrence intervals) (Orsborn 1990). Due to geologic or alluvial valley fill characteristics, some small streams are more resistant to annual variations in meteorological conditions in their influence on low flows, consequent water temperature extremes, and shrinkage in useable rearing or spawning area in August-September.

Are tributary actions achieving the expected biological and environmental improvements in habitat?

Our project is not primarily an action effectiveness monitoring project. Unless by chance we have our GRTS-selected monitoring sites established in locations where future restoration actions take place so that we have a pre-restoration baseline established and future monitoring can follow trends at a site, it may not be possible to assign improvements in habitat conditions to any specific action. However, our project does monitor trends in a wide array of habitat conditions. This can be related to the aggregate restoration actions from past and ongoing actions throughout a watershed upstream of monitoring sites. It may be that the strength of many actions will be related to proximity to sites where monitoring takes place, as well as the cumulative impact of all upstream actions. It is also likely that by classifying restoration actions by the type of limiting factor that they address we will be able to detect changes in specific habitat conditions most related to the action. For example, because fine sediment in spawning gravel or filling pools is taken as one of our most limiting factors, those actions that limit sediment yield to stream channels will be most effective in restoring spawning gravel quality/quantity as well as pool depth, volume, and frequency. The actions that have the greatest likelihood of improving fine sediment and pool-related conditions will be those cumulative actions that address the combination of (1) road density, (2) livestock access to stream channels, (3) riparian vegetation density and maturity, or similarity to PNV conditions, (4) and general level of land disturbance that creates bare ground.

Although our project has potential to contribute to answering questions about (1) whether cumulative actions are resulting in an overall improvement in habitat conditions, (2) the rate of improvement in habitat conditions, and (3) the likely impact of habitat improvement trends to the life stages of spring Chinook and future population trends, it is still premature to draw definitive conclusions. It is well known that the effects of restoration actions can take years to manifest in streams such as the Grande Ronde. Even if the percentage improvement in habitat productivity occurs that is described in the Accords document (an absolute 10% improvement within 10 years), it is doubtful that the level of monitoring currently funded will be sufficient to show this small an improvement in a 3-year period (i.e., the number of years of CHaMP monitoring so far). Also, because the level of effort applied to habitat restoration basin-wide may be less than needed to achieve the desired productivity targets, it would be even more difficult to detect smaller percentages of improvement. It may be easier to show significant changes in shorter timeframes for site-specific restoration directed to certain proximal limiting factors, but the more important factors controlling overall production are the basin-wide habitat conditions. For example, water temperature may change slightly from a site-specific action, but in most respects, the actions directed to the entire basin upstream of the monitoring site are more important. Water temperature trends on an entire stream network level will have the greatest potential to reveal improvements due to the precision of temperature loggers. The Heat Source water temperature model will be vital as a tool for comparing future water temperature trends under different scenarios such as climate change, restored riparian vegetation, or changes in streamflow that may occur over a longer timeframe than is afforded under this Accords project. It also provides a

necessary tool to allow us to assess CHaMP water temperature daily data to ascertain whether apparent trends are caused by improvements in riparian condition or merely by annual variation in meteorological conditions. This implies that in order to determine whether an apparent trend in water temperatures has occurred, there are two key options: (1) plot annual temperature statistics for individual sites for the July-August time period, and couple this with a prediction of the temperatures that should have been produced given the known meteorological conditions, or (2) conduct a repeat LiDAR aerial survey to assess whether there has been an improvement in riparian canopy. In the first case, if warmer temperatures would be predicted than observed, the difference would be attributed to riparian canopy improvement. In the second case, an improvement in riparian canopy would be directly observed and could act as input to the temperature model to predict resulting temperatures.

What are the benefits of collecting CHaMP data to the region?

Rosy Mazaika of BPA recently asked us: Specifically, I want to understand what you have utilized to date from the CHAMP project as data, outputs, or summary products and your reaction to what is delivered and how? What is valued added and of use to you? We are really trying to understand the full utility of the CHAMP products for the users perspective. We decided that it would be of use to try to answer some of these issues.

1) CHaMP monitoring, data generation, analysis, and application addressed three significant areas for us.
    a. It provides a regionally consistent habitat monitoring protocol that guides the collection of raw habitat data.
    b. It is a community of scientists developing aspects of habitat monitoring methodologies, application of additional technologies to assist in analysis, sharing expertise in data analysis, getting assistance in analysis when the methods are highly specialized and developed by certain members of the CHaMP team.
    c. It provides a management application. Products from monitoring help provide a more quantitative, meaningful alternative to use of expert panels charged with assessing progress in improving Chinook habitat. The expected changes in habitat condition projected in the Accords due to habitat restoration must be assessed at a basin scale because the restoration actions are scattered throughout the basin and comprise a wide variety of actions, with different lag times and effectiveness. The population response as a whole is sought rather than a mere change in fish density in relation to a localized habitat amendment (e.g., LWD addition). Even changes of 23% in 25 years as expected in the Upper Grande Ronde are relatively small and slow. This will require a robust statistical design and a long period of consistently applied monitoring to be able to demonstrate progress.
2) CHaMP provides us the information that we can use to drive a life cycle model (LCM). This model would be the best alternative to an expert panel process to simply reach consensus on the quality of habitat and trends in this habitat quality. A model is a structured way to derive a prediction of the benefits of habitat improvement.
3) The CRITFC approach also generates other models. For example, we developed a Heat Source water temperature model with consultant expertise (Watershed Sciences, Inc.). With this model we can link land use effects or restoration to generate changes in water temperature and relate this to Chinook productivity in the LCM.
4) CHaMP provides value added by:
    a. Maintaining a consistently organized database.
        i. Note: more work needs to be done to make multiple years of data consistent in the columns of data provided in Excel spreadsheets so that multiple-year summaries can be conducted easier.
    b. Providing basic statistical summaries of habitat metrics that can be used in conducting other analyses—e.g., explaining macroinvertebrate distribution.
        i. Note: more needs to be done here to ensure that metrics are calculated correctly. Also, there needs to be a crosswalk among years of data collection when methods change from year to year.
    c. Providing tools to assist in the QA/QC process.

d. Maintaining performance of equipment used in the field by recalling gear for recalibration and repair. Providing updates to internal Total Station firmware.
e. Providing tools such as
    i. GIS macros,
    ii. Total Station software for data collection,
    iii. RBT analytical capabilities so we can use our own field surveys to model water surface area at different flows,
    iv. NREI (Net Rate of Energy Intake) models,
    v. Use of MODIS satellite data to predict distributed temperature metrics on a stream network level.
f. Assistance with creating rollups of habitat quality or quantity data from surveys by use of GRTS-based sample design. This also permits use of site stratification within the GRTS framework. Strata can be AUs adopted by management agencies, tributaries, or reach types (based on features such as gradient, bankfull width, elevation, ecoregion). A reach type would be classified by characteristics such as channel gradient, drainage area, and valley width. Given these intrinsic characteristics, the composition of channel units can be specified. If CHaMP monitoring has multiple study areas in a reach type, the composition by channel unit type can be assessed. In this way, physical features such as number of pools per km or biological features such as numbers of rearing juveniles per km can be assessed. Juvenile rearing densities would be calculated for a reach type by multiplying the mean number of juveniles per channel unit type by the number or area of that type and adding up the numbers for each channel unit type.
g. Providing the data from which rollups at the ESU level can be achieved. It was recognized early by BPA that there would not be sufficient funding to conduct monitoring of every basin supporting a listed population. For this reason, it was deemed necessary to study those basins having very damaged populations and damaged habitat that had a significant potential for recovery. CHaMP data provide a spatially balanced means to assess long-term trends in habitat condition essential for supporting the listed populations involved in the surveys. Rollups at the basin level provide an index to the changes in key limiting factors. In a simply heuristic manner, if significant changes are observed in all factors considered to be controlling productivity and capacity, one can infer population recovery potential. There is always a potential for downstream impacts in the mainstem of the major river system collecting fish from each of the contributing basins or in the Snake or Columbia Rivers or ocean. An evaluation of the status of the MPG or ESU would require evaluation of all the CHaMP basins within the MPG or ESU. For example, with the Grande Ronde/Imnaha MPG consists of populations of the Upper Grande Ronde, Catherine Creek, Wallow/Lostine, Minam, Wenaha, Big Sheep Creek, and Imnaha River. Of this MGP containing 7 populations, there are only three populations with CHaMP surveys. CRITFC and ODFW believed strongly that the Minam was needed as a reference site to add to the two damaged basins already included in CHaMP survey work, so CRITFC decided to fund ODFW to carry on its monitoring in the Minam in 2014. The entire Snake River spring/summer Chinook ESU brings the total populations and number of basins supporting these populations to 32. Obviously, what is learned from the basins studied in CHaMP will have to be extrapolated to unstudied basins. One thing that could permit this extrapolation would be to assess the level spatial extent of restoration actions relative to the current state in non-CHaMP basins. The current extent could be assessed comprehensively using aerial survey techniques to gather select data, such as using LiDAR to collect data on current riparian canopy cover. Repeat LiDAR surveys could be used to track progress to restore water temperatures. Aerial survey techniques could allow collection of data on abundance of LWD and pools, provided that these are tested against ground-based methods for data collection in the CHaMP basins. The relationship between improvement in fish-habitat relationships stemming from known type and spatial distribution of restoration actions in CHaMP basins could be used to infer similar fish response in non-CHaMP basins.

5) Even without a model such as an LCM, CHaMP data can be used to monitor progress in addressing habitat limiting factors. Linking these directly to improved productivity of a population can only be done through a LCM. However, using functional relationships describing the effect of the habitat variable on survival or capacity, it is

possible to make predictions of the level of improvement to survival derived from measured changes in key habitat variables. There is no convenient means to derive these data from expert, ocular based judgments from general familiarity with streams. The percentage changes expected are significant to the populations and their recovery, but they are still small. The magnitude of the change being detected and the large, diverse area over which the change is monitored require the GRTS-based approach plus stratification to adequately summarize to infer effects on the population. Having multiple limiting factors affecting various life stages requires application of a life stage approach to assessing the cumulative impact of changes to two or more limiting factors. These factors can be additive or multiplicative, density dependent or independent. CHaMP protocol for field collection of habitat data generates the information that can address trends in all essential limiting factors. This information can then be assembled and evaluated heuristically or by use of a structured freshwater life cycle approach to project the impacts on the population.

a. Examples of using CHaMP data directly to demonstrate improvements in habitat quality include following annual trends in features such as:
    i. Solar radiation by site as an index to riparian cover improvement. This can also be addressed by application of LiDAR every 10 years. LiDAR is capable of producing a total census at the stream network scale of riparian vegetation cover. One other advantage of LiDAR over the use of the SunEye in measuring changes in shading is that LiDAR can identify shading due to canopy vs. topography. The SunEye does not discriminate canopy from topography in producing shade. However, it can show annual trends with accuracy each year without conducting the extensive analysis required of LiDAR data.
    ii. Measurements of fine sediment (<6 mm and <2 mm) in spawning gravels or changes in substrate composition throughout the reach. This should also be linked to subsurface fine sediments or other interstitial substrate metrics such as intergravel DO. CRITFC has measured subsurface fines using McNeil sampling. This has produced a reasonable correlation of surface with subsurface fines that justifies continued measurement of surface fines using CHaMP methodology.
    iii. Pool surface area or volume. It is known in the UGR and CC that pool loss was substantial (>70%) from the 1930s to early 1990s (McIntosh 19xx). Pools are critical for adult holding, especially when water temperatures are suitable because they provide adequate cover to protect adults from predation. Improvements in pool area and volume are captured in CHaMP data metrics. These are derived by use of RBT with the DEMs generated by Total Station surveys. Changes in pool habitat also affect favored rearing areas where Chinook parr can feed on drifting macroinvertebrates.
        1. Note: Pool area or volume can also be measured at a stream network scale. This analysis is able to indicate the long-term recovery of pool area or volume. The value of a rollup to broader spatial scales from GRTS-based sampling is to estimate network scale availability of pools and trends. The census-based approach to pool metrics involves walking extensive stream length and visually estimating pool length, width and depth. These estimates are far cruder than those based on Total Station measurements. They also require a great effort to derive a re-census, which would tend to be every 10 years for economy. The level of accuracy in estimating pool volume visually (or by ocular methods with a 10% measurement calibration procedure, such as is done with Hankin-Reeves methods) may be large enough that a large change is required to detect the trend.
        2. Pool area can be evaluated as trends at a site. These trends will be a result of a combination of direct improvements in the stream channel, streamside zone (riparian area or hillslope or adjacent floodplain), or upstream watershed. Trends can be influenced by trends in local LWD levels and also by channel sinuosity (flow heterogeneity) or sediment contributing sources. Sediment sources (channel adjacent or upstream) can be a cumulative effect in time or spatial extent of road density, surface area logged, extent of livestock grazing, agricultural impacts, or urban development.

Impact intensity of sediment sources can be modeled as a function of aerial extent of the disturbance, nature of the disturbance, characteristics of the land being disturbed (e.g., slope gradient or vegetation cover and rooting depth of the land surface that the road crosses), and instream distance from the source to the study reach. The ability of the stream to transport the impact to the study site is a function of the intervening channel gradient, streamflow, and depositional nature of the study reach. Study reaches that are low gradient are apt to have a greater response rate to sediment inputs.

iv. Large woody debris. CHaMP measures LWD volume and number of pieces of various length categories by channel unit. This will allow us to attribute area, numbers, or volume of pools with quantity of LWD. LWD is also a key attribute providing fish cover. This is useful as an explanatory variable for fish snorkel counts made by CRITFC and ODFW teams working cooperatively in the three study basins (UGR, CC, and Minam).

v. Overall fish cover. Fish cover is a total surface area occupied by LWD, live terrestrial vegetation and roots within 1 m of the stream surface, aquatic vegetation, and artificial structures. Although % surface area occupied by boulders and % overhanging banks are not included in this CHaMP metric, it is noted in the ocular substrate metric.

Coordination and Data Management RM&E

Actively support the coordination and standardization of regional and Program monitoring efforts with other federal, state, and tribal monitoring programs including the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, meta-data, and data access.

How has regional coordination supported communication or the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, meta- data, and data access to support Fish and Wildlife Program strategies at http://www.cbfish.org/ProgramStrategy.mvc/ or how regional coordination supports prioritization of habitat restoration or operations of hatchery facilities

Regional coordination and inter-agency cooperation and oversight have aided our project in significant ways. In this report we reviewed in detail CRITFC's participation in regional processes and coordination with other agencies and tribes. We refer the reader to those specific details in the Results section. To recap, we are involved in coordination and data management with the following partners and working groups:

- Columbia Habitat Monitoring Program (CHaMP)
- FCRPS Adaptive Management Implementation Plan (AMIP)
- FCRPS BiOp Expert Panel and Implementation Prioritization Strategy for the upper Grande Ronde and Catherine Creek
- Pacific Northwest Aquatic Monitoring Partnership (PNAMP) Benthic macroinvertebrate planning group
- Integrated Status and Effectiveness Monitoring Program (ISEMP)
- CRITFC member tribes, most recently via 2013 January Tribal Habitat Workshop

CRITFC, although funded by the Accords to monitor habitat status and trends in the Upper Grande Ronde River and Catherine Creek basins, is a participant in CHaMP, a regional effort to develop uniformly applied data collection protocols. CRITFC has been an active participant in CHaMP in many ways. CRITFC has (1) contributed to protocol development by recommending new or revised methods, revisions to existing elements of the protocol, new and

improved equipment, (2) made recommendations to data analysis, (3) made recommendations to RBT improvement, (4) pointed out problems with GIS analysis of Total Station survey data, (5) contributed to methods for QA/QC, (6) given presentations on the successes in application of various methods and data analysis procedures, and (7) participated in regional CHaMP and ISEMP meetings that are attended by other regional agencies.

CRITFC has benefited from this regional process (CHaMP) from (1) its assistance in developing GRTS sample site selection and creating a balance of sites between CRITFC and ODFW that meets the needs for spring Chinook and steelhead sampling, (2) assistance with application of GIS analysis and the custom tools developed for the Total Station survey data, (3) CHaMP providing the infrastructure for development of the RBT tool that, eventually, will facilitate computation of many channel metrics that will streamline habitat surveys, (4) the programming of the data logger used to collect field data, (5) the infrastructure provided to upload data to the cloud, store it, and run diagnostics to perform initial QA procedures, (6) the CHaMP website that can be used to access data from various sampling years and data from other sites.

CRITFC benefits from the systems built by PNAMP that house the monitoring metrics and protocols used regionally. This serves as a system for monitoring method cataloguing and metadata that facilitates developing more uniform methods and protocols (i.e., monitoringmethods.org).

CRITFC has been participating in the regional AMIP process by working on a life cycle model with NOAA and ODFW. This provides the tribes a means to become involved in application of habitat and fish population data to monitor potential trends in list salmon populations.

CRITFC has participated regionally by providing advice to expert panels charged with evaluating progress in address limiting factors. Some of our contributions have included 1) providing GIS analysis, maps, and monitoring data useful for prioritizing restoration actions, 2) development of a life-cycle model to assess how measured or potential habitat improvements will impact ESA-listed Chinook populations, and 3) collection and analysis of macroinvertebrate data in support of a food web study for the Upper Grande Ronde River basin, which has been recommended by the ISAB, and 4) development and application of a Heat Source water temperature model to aid in understanding the spatial patterns in water temperature across the Upper Grande Ronde and Catherine Creek basins and assess potential effects of future climate change and riparian restoration actions on stream temperature and stream biota.

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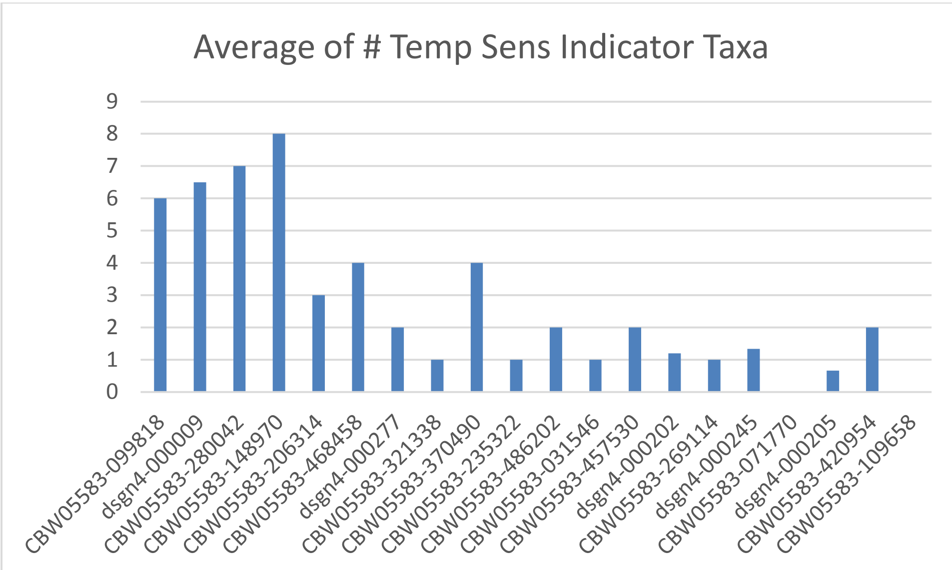
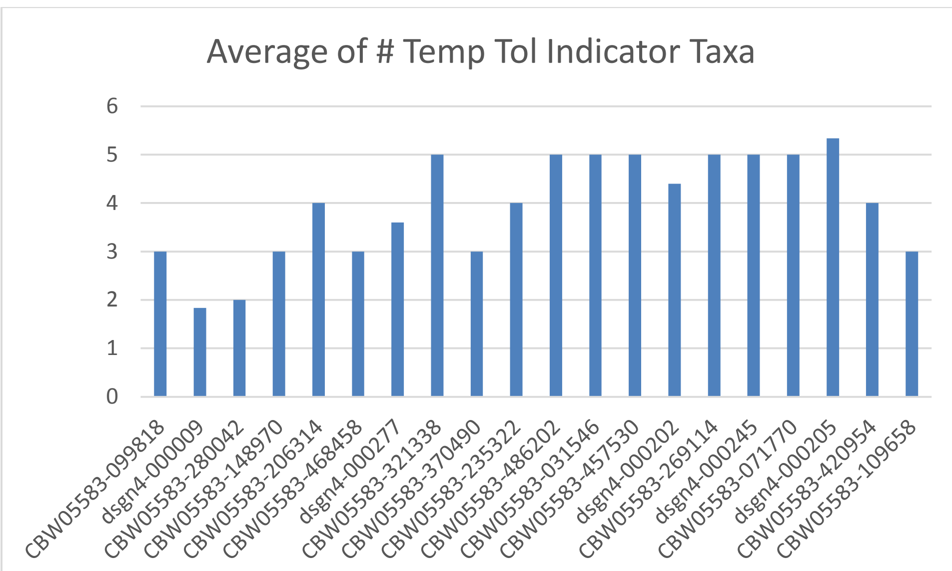
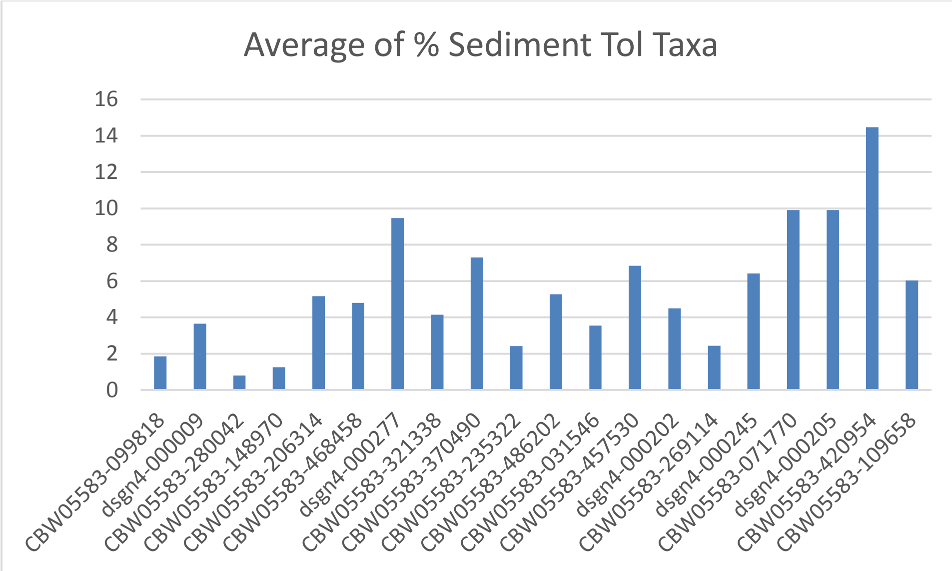
Appendices

Appendix A. A brief view of the longitudinal pattern of macroinvertebrate indices in the Upper Grande Ronde mainstem.






Average of % Sediment Tol Taxa
16
14
12
10
8
6
4
2
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
CBW05583-370490
CBW05583-235322
CBW05583-486202
CBW05583-031546
CBW05583-457530
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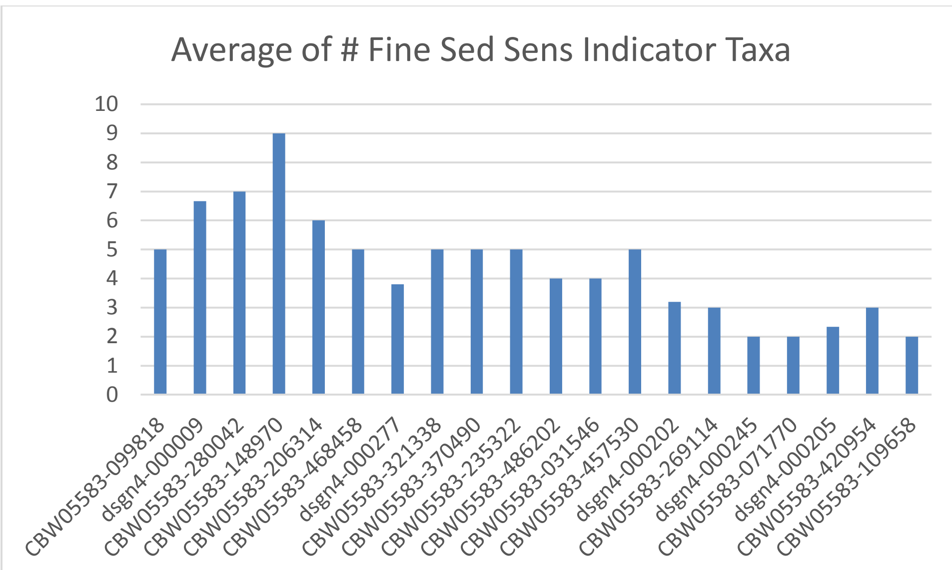
CBW05583-109658


Average of # Fine Sed Sens Indicator Taxa
10
9
8
7
6
5
4
3
2
1
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
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CBW05583-235322
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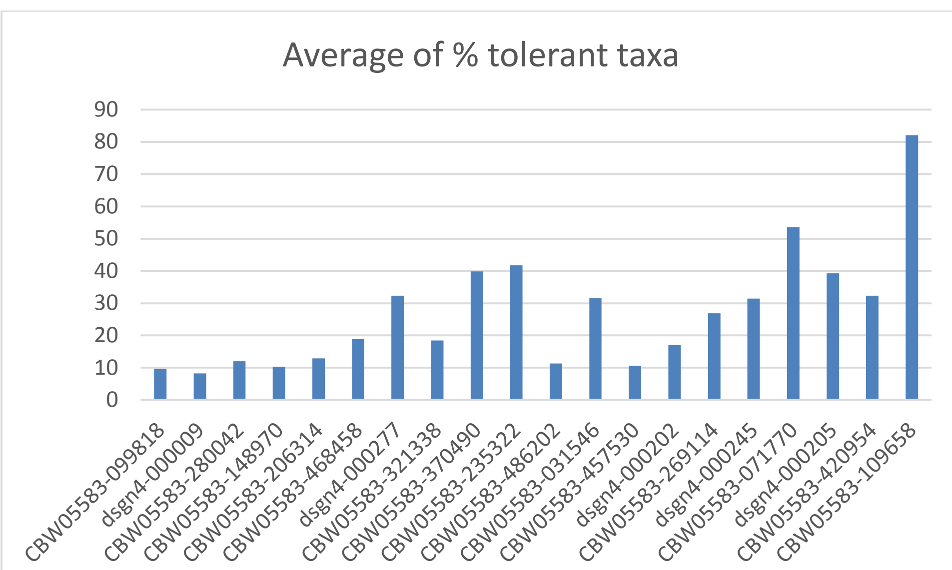
Average of % tolerant taxa
90
80
70
60
50
40
30
20
10
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
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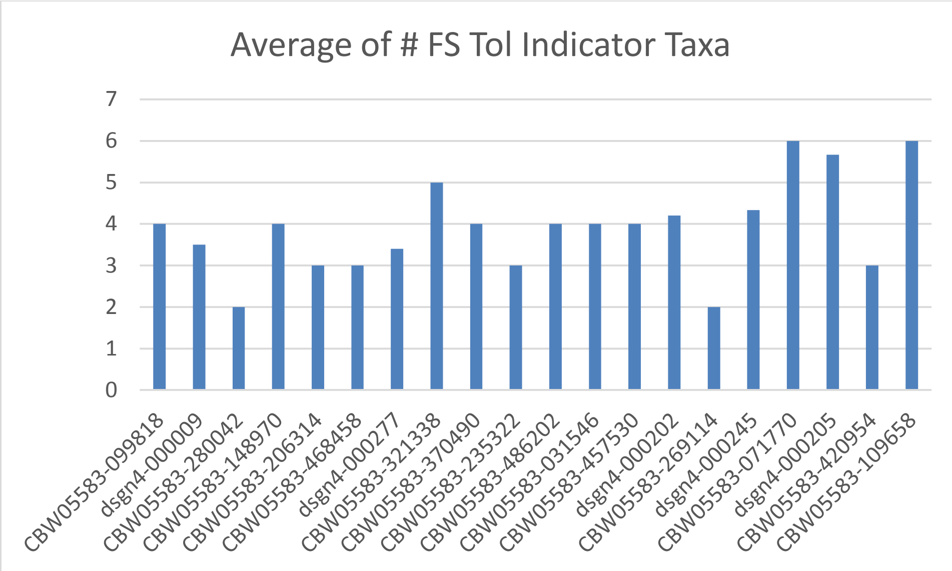
Average of # FS Tol Indicator Taxa
7
6
5
4
3
2
1
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
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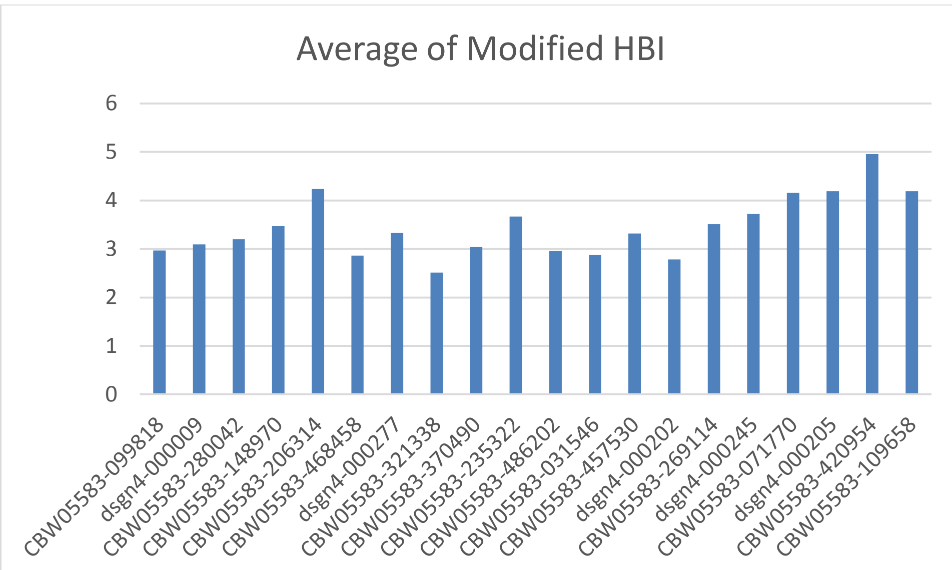
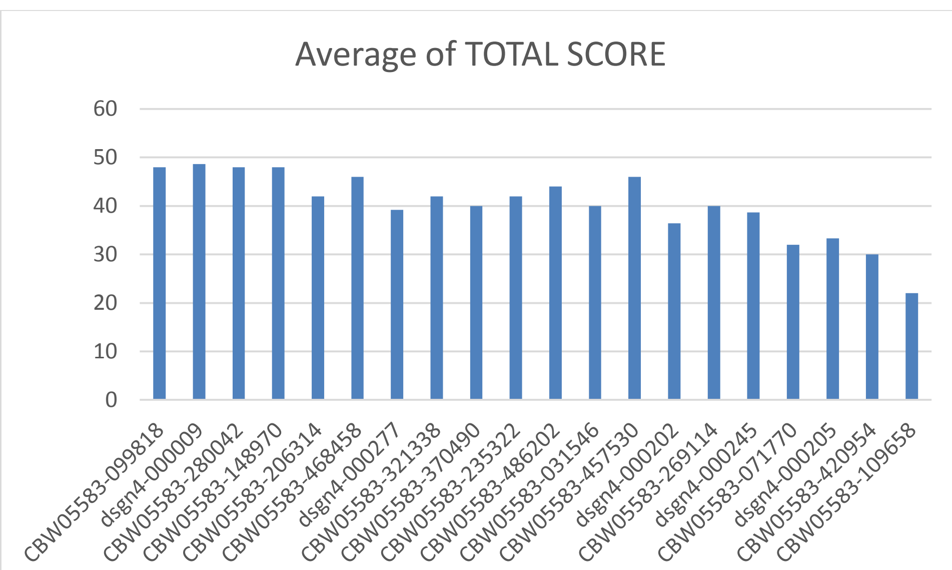
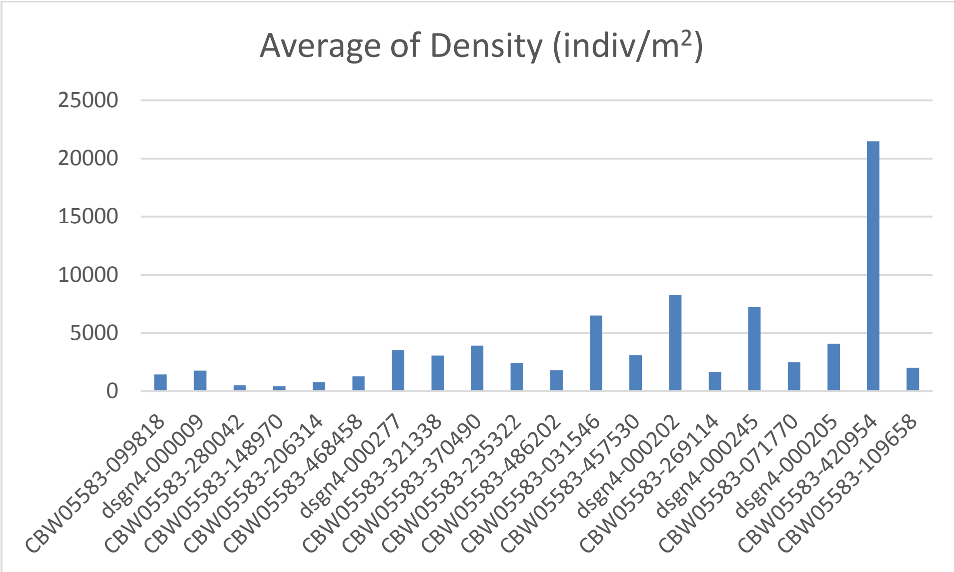
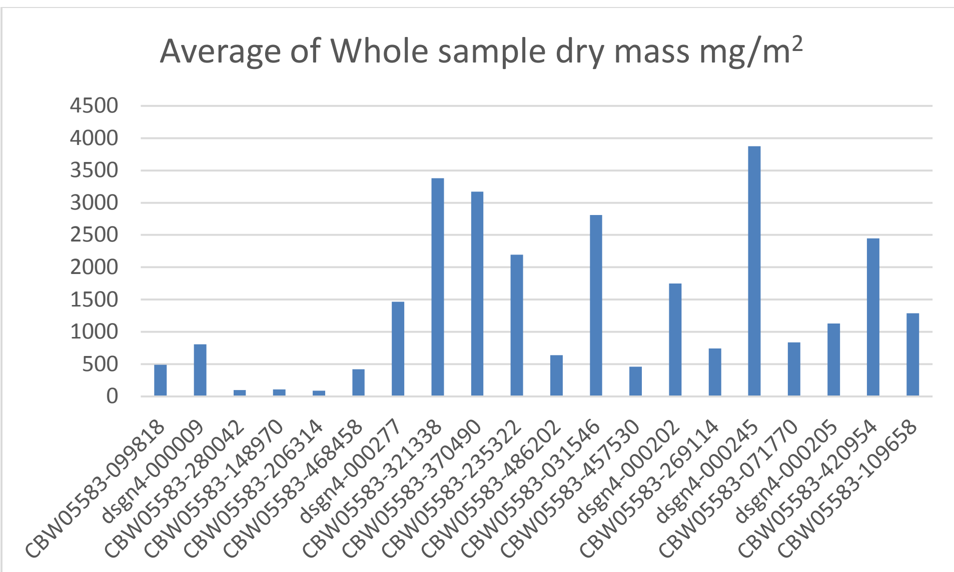
CBW05583-420954
CBW05583-109658


Average of Modified HBI
6
5
4
3
2
1
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
CBW05583-370490
CBW05583-235322
CBW05583-486202
CBW05583-031546
CBW05583-457530
dsgn4-000202
CBW05583-269114
dsgn4-000245
CBW05583-071770
dsgn4-000205
CBW05583-420954
CBW05583-109658


Average of TOTAL SCORE
60
50
40
30
20
10
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
CBW05583-370490
CBW05583-235322
CBW05583-486202
CBW05583-031546
CBW05583-457530
dsgn4-000202
CBW05583-269114
dsgn4-000245
CBW05583-071770
dsgn4-000205
CBW05583-420954
CBW05583-109658


Average of Density (indiv/m²)
25000
20000
15000
10000
5000
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
CBW05583-370490
CBW05583-235322
CBW05583-486202
CBW05583-031546
CBW05583-457530
dsgn4-000202
CBW05583-269114
dsgn4-000245
CBW05583-071770
dsgn4-000205
CBW05583-420954
CBW05583-109658


Average of Whole sample dry mass mg/m²
4500
4000
3500
3000
2500
2000
1500
1000
500
0
CBW05583-099818
dsgn4-000009
CBW05583-280042
CBW05583-148970
CBW05583-206314
CBW05583-468458
dsgn4-000277
CBW05583-321338
CBW05583-370490
CBW05583-235322
CBW05583-486202
CBW05583-031546
CBW05583-457530
dsgn4-000202
CBW05583-269114
dsgn4-000245
CBW05583-071770
dsgn4-000205
CBW05583-420954
CBW05583-109658

Appendix B. Grande Ronde Riparian Vegetation Mapping GIS Data

See file: Grande Ronde Riparian Veg Mapping GIS Data-Crowe-e.pdf

	Type of Data	Original Spatial Data File Name	Current Spatial Data File Name	Source of Spatial Data	Link to Spatial Data	Associated Data Tables	Source of Associated Data	Link to Associated Data	ABR location	Comments
Base Layers	NAIP Photography 2012	N.A.	N.A.	Through the Add Data icon, go to GIS Servers and choose Add ArcGIS Server. On next window choose Use GIS services, then on the next window, type in the address shown in the next cell: Link to Spatial Data. You can find the year and location of NAIP data on the USDA APFO (Aerial Photography Field Office) site.	Stream from: http://gis.apfo.usda.gov/ArcGIS/Services/NAIP/Oregon_2012_1m_NC/ImageServer	N.A.	N.A.	N.A.	N.A.	
	NAIP Photography 2009	ortho_1-1_1n_s_or601_2009_3.sid	ortho_1-1_1n_s_or601_2009_3.sid	CRITFC	This is probably available online but these files were sent by CRITFC.	N.A.	N.A.	N.A.	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\NAIP Imagery 2009\Union	
	Natural Color Aerial Photography	These are .jpg images, not spatial data. Photos are organized in folders corresponding to stream names. Each photo's file name consists of the stream name and the photo number, e.g. Beaver0615.jpg, which is photo 615 along Beaver Creek in the upper Grande Ronde.	same as original file names	CRITFC	NA - not available online	N.A.	N.A.	N.A.	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\ColorImages\Natural_color_Unrectified	
	Natural Color Aerial Photography Indices	Indices are organized into spatial files by stream, e.g. Beaver_Creek.shp.	same as original file names	CRITFC	NA - not available online	N.A.	N.A.	N.A.	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\ColorImages\Natural_color_Photo_Indices	Can use the indices to locate photos. Photos are individual, unrectified images.
	DEM									
	LIDAR	LiDAR.gdb	LiDAR.gdb	CRITFC	NA - not available online	N.A.	N.A.	N.A.	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data	Contains the following rasters: BareEarth_mosaic, HighestHit_mosaic, INTENSITY_mosic (looks a lot like an orthoquad image) Canopy2007_mosaic, Canopy2008_mosaic, Canopy2009_mosaic (these latter 3 rasters are adjoining pieces. I'm not entirely sure how to incorporate these data yet. Maybe Rich and Aaron do.
	NLCD	NLCD2006_LC_N42W114_v1, NLCD2006_LC_N42W117_v1, NLCD2006_LC_N45W114_v1	GRROND_NLCD.tif	National Land Cover Database 2006 (NLCD2006)	http://www.mrlc.gov/nlcd2006.php	table of classes linked to .tif		http://www.mrlc.gov/nlcd06_leg.php	O:\OR_Projects\2013\CRITFC\GIS_Data\Final	
Climate	Precipitation (http://www.prism.oregonstate.edu/)									
	Temperature(http://www.prism.oregonstate.edu/)									

Riparian	Watersheds			11			Water/Valleys
W-W Riparian Habitat Conservation Areas	**Oregon Hydrologic Landscape Regions**	**ODFW Aquatic Habitat Inventories - habitat level**	**ODFW Aquatic Habitat Inventories - reach level**	**Water Bodies (non-stream)**	HUC10 and HUC12	NHD Hi Res dataset	**Valley/Stream Segment Classification**
RHCA.shp	originally part of gronde_gis_data0.gdb\HLR in \PNVData_08-Feb-2013\v10\; Aquifer_Permeability_Class; Climate_Aquifer_Permeability_Class; Climate_Class; DEM_Stream_Network; HLR_Class; Hydrologic_Assessment_Units; Oregon_Aquifer_Groups; Seasonality_Subclass; Soil_Permeability_Class; Terrain_Class	originally part of gronde_gis_data0.gdb\Habitat_Other in \PNVData_08-Feb-2013\v10\; AHI_1990s_habitat; AHI_2000s_habitat; AHI_2010_habitat	originally part of gronde_gis_data0.gdb\Habitat_Other in \PNVData_08-Feb-2013\v10\; AHI_1990s_reach; AHI_2000s_reach; AHI_2010s_reach	Waterbody.shp	NHDH1706.gdb	NHDH1706.gdb	originally part of gronde_gis_data0.gdb\Hydrography in \PNVData_08-Feb-2013\v10\; NetStream_reaches_cu
RHCA.shp	Exported to shapefiles: Aquifer_Permeability_Class.shp; Climate_Aquifer_Permeability_Class.shp; Climate_Class.shp; DEM_Stream_Network.shp; HLR_Class.shp; Hydrologic_Assessment_Units.shp; Oregon_Aquifer_Groups.shp; Seasonality_Subclass.shp; Soil_Permeability_Class.shp; Terrain.shp	Exported to shapefiles: AHI_1990s_habitat.shp; AHI_2000s_habitat.shp; AHI_2010s_habitat.shp	Exported to shapefiles: AHI_1990s_reach.shp; AHI_2000s_reach.shp; AHI_2010s_reach.shp	Waterbody.shp	HU12_17060104, HU10_17060104	NHD_hires_UGR.shp	Exported to shapefile: NetStream_reaches_cu.shp
Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Wallowa-Whitman Riparian Habitat Conservation Areas in Shapefile/Dataset Description column in Theme Management Direction	CRITFC	CRITFC	CRITFC	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Water Bodies in Shapefile/Dataset Description column in Theme Water	NHD / USGS	NHD / USGS	CRITFC
http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	May be available online, but these files were from CRITFC	May be available online, but these files were from CRITFC	May be available online, but these files were from CRITFC	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://nhd.usgs.gov/data.html	http://nhd.usgs.gov/data.html	NA - not available online
N.A.	N.A.	N.A.	N.A.				N.A.
N.A.	N.A.	N.A.	N.A.				N.A.
N.A.	N.A.	N.A.	N.A.				N.A.
ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Rip_Hab_Conserv_Areas	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\OR_Hydrologic_Landscape_Regions	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\ODFW_Aquatic_Habitat_Inventories\AHI_Habitat	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\ODFW_Aquatic_Habitat_Inventories\AHI_Reach	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Water_Bodies	O:\OR_Projects\2013\CRITFC\GIS_Data\Final	O:\OR_Projects\2013\CRITFC\GIS_Data\Final	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Valley_Stream_Segment_Classification
This shapefile consists of a designated riparian buffer along all streams that different management direction/constraints specific to riparian/aquatic protection management goals (probably in W-W Forest Plan).	See Wigington_etal_2012_J_Am_Water_Resources_Assoc_Oregon_hydrologic_landscapes.pdf in Documentation folder for more information.	See Moore_etal_2008_ODFW_Methods_for_Stream_Habitat_Surveys_Aquatic_Inventory.pdf in Documentation folder for more information.	See Moore_etal_2008_ODFW_Methods_for_Stream_Habitat_Surveys_Aquatic_Inventory.pdf in Documentation folder for more information.			Resolution might be too high. Will compare to CRITFC submittal	NetStream_reaches_cu - This is CRITFC's valley type and stream classification layer. Attributes are described in GIS metadata and report by White et al. 2011 (except for the segment-level classification, described by Seth in the Word document "Notes on map package provided by Seth White.docx"). See White_etal_March_2011_CRITFC_stream_valley_classification in Documentation folder for more information.

Soils	W-W and Umatilla NF - Riparian EUI Line Segment Mapping Units	WW_lineseg_fluv.shp	WW_lineseg_fluv.shp	Craig Busskohl, Soil Quality and Ecosystems, NRCS National Soil Survey Center; phone: (402) 437-5316....... If further data or information needed, contact: Rich Williams, who is the current contractor for the TEUI for the Blue Mountains NFs; email: northwestaspectinc@frontier.com	NA - not available online	MUSYM_Crosswalk.dbf	Elizabeth Crowe created this file using the attribute table associated with the shapefile, the Excel workbook CorrelationRecord.xlsx and code descriptions from the following publication: Landtype Association of Blue Mountains Ecoregion (Sasich and Ottersberg 2006), which is available only in paper format, not digitally. Copy obtained from Jim Archuleta, Soil Scientist, Umatilla National Forest (541-278-3817).	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs	Elizabeth Crowe created this file using the attribute table associated with the shapefile and the Excel workbook CorrelationRecord.xlsx. Fields with codes corresponding to MUSYM were reformatted from CorrelationRecord file and descriptions were added according to tables found in Landtype Associations of Blue Mountains Ecoregion (Sasich and Ottersberg 2006). Fields in this file are: MUSYM, CLIMATE, GEOL_GROUP, GEO_SUBGR, DEFINITION, VEG_COMP_CODE, VEG_COMP, GEOL_COMP_CODE, GEOL_COMP, LAND_COMP_CODE, LAND_COP, GLUE_BMS, and ORD. Can Join this table to shapefile using either the MUSYM field or the FLUV_BMS field.
						CorrelationRecord.xls	Craig Busskohl, Soil Quality and Ecosystems, NRCS National Soil Survey Center; phone: (402) 437-5316....... If further data or information needed, contact: Rich Williams, who is the current contractor for the TEUI for the Blue Mountains NFs; email: northwestaspectinc@frontier.com	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs	This is the original Excel worksheet obtained from Craig Busskohl that contains all of the MUSYM values and how they break out into different groups. The crosswalk for these values and the descriptions of them were inserted into right side of the worksheet and were found in the Landtype Associations of Blue Mountains Ecoregion publication. Can't be joined to attribute table.
						Soil_MU_Descrip.dbf	Elizabeth Crowe created this .dbf file using information in the Riparian EUI Soil Map Unit Descriptions and from downloaded soil series descriptions.	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs	Fields in this file are: FLUV_BMS, Mean_Ann_Ppt_in., Soil_Series, Perc_MU, Slp_Range, Fluv_Geom_Surf, Plant_Associations, Parent_Mat, Depth_WatTab_ft., Soil_Taxonomy. NOTE: This table must be associated with the attribute table using a Relate rather than a Join because it's a many-to-many relationship.

Merged Wallowa-Whitman NF, Umatilla County, Union County Upland Soils Map			
WWNF_Union_Co_Umatilla_Co_merged soils.shp			
WWNF_Union_Co_Umatilla_Co_merged soils.shp			
Elizabeth created this by merging the original shapefiles from the three soil survey areas listed in the title.			
Original source of separate shapefiles: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR			
mdstattabs.xlsx	Folder: Soil Series Descriptions_downloaded	Riparian EUI Soil Map Unit Descriptions.xlsx	Line Seg.Narratives_WW.docx
This table is found in every Access database downloaded with a soil survey area. Elizabeth exported it into Excel format. File names were too truncated when tried to export into DBF files.	Downloaded from NRCS Official Soil Series Descriptions web page	Craig Busskohl, Soil Quality and Ecosystems, NRCS National Soil Survey Center; phone: (402) 437-5316....... If further data or information needed, contact: Rich Williams, who is the current contractor for the TEUI for the Blue Mountains NFs; email: northwestaspectinc@frontier.com	Craig Busskohl, Soil Quality and Ecosystems, NRCS National Soil Survey Center; phone: (402) 437-5316....... If further data or information needed, contact: Rich Williams, who is the current contractor for the TEUI for the Blue Mountains NFs; email: northwestaspectinc@frontier.com
Original source of separate tabular data files: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	http://soils.usda.gov/technical/classification/osd/index.html	NA - not available online	NA - not available online
ftp2.abrinc.com...ftpuser\critfc\incoming\Upland Soils	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Riparian_EUIs
This table explains what all of the other associated data tables are so I didn't write descriptions of the other tables in this spreadsheet	This folder contains most of the official NRCS descriptions for the soil series that are part of the mapping units. There were a few descriptions that were unavailable - didn't show up using the search function on the web page.	This workbook is a compilation of the originally separate worksheets giving data on each riparian soil mapping unit (e.g. 0020AW Broady-Caulditch complex, etc.). Each worksheet corresponds to a soil mapping unit.	This file contains narrative descriptions of each of the soil mapping units. Can't be joined to attribute table.

Wallowa-Whitman National Forest Upland Soils Map	**Upper Grande Ronde/Catherine Creek Study Area Upland Soils Map**		
soilmu_a_or631.shp	UGR_Soils.shp		
soilmu_a_or631.shp	UGR_Soils.shp		
NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area to choose W-W NF)	Elizabeth created this by clipping the merged soils shapefile using the study area watershed boundary (HUC 10 from Rich)		
http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	Original source of separate shapefiles: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR		
SSURGO Access database; soildb_OR_2003	mdstattabs.xlsx, mdstattabcols.xlsx, chdesgnsuffix_merged.xlsx, chfrags_merged.xlsx, chorizon_merged.xlsx, chtexture_merged.xlsx, chtexturegr_merged.xlsx, chtexturemod_merged.xlsx, cocanopycover_merged.xlsx, codiagfeatures_merged.xlsx, coecoclass_merged.xlsx, coeplants_merged.xlsx, coforprod_merged.xlsx, cogeomordesc_merged.xsx, cohydriccriteria_merged.xlsx, comonth_merged.xlsx, component_merged.xlsx, copm_merged.xlsx, copmgrp_merged.xlsx, corestrictions_merged.xlsx, cosoilmoist_merged.xlsx, cosurffrags_merged.xlsx, cosurfmorphgc_merged.xlsx, cosurfmorphhpp_merged.xlsx, cotaxmoistcl_merged.xlsx, cotext_merged.xlsx, mapunit_merged.xlsx, muaggatt_merged.xlsx	chdesgnsuffix_merged.xlsx, chfrags_merged.xlsx, chorizon_merged.xlsx, chtexture_merged.xlsx, chtexturegr_merged.xlsx, chtexturemod_merged.xlsx, cocanopycover_merged.xlsx, codiagfeatures_merged.xlsx, coecoclass_merged.xlsx, coeplants_merged.xlsx, coforprod_merged.xlsx, cogeomordesc_merged.xsx, cohydriccriteria_merged.xlsx, comonth_merged.xlsx, component_merged.xlsx, copm_merged.xlsx, copmgrp_merged.xlsx, corestrictions_merged.xlsx, cosoilmoist_merged.xlsx, cosurffrags_merged.xlsx, cosurfmorphgc_merged.xlsx, cosurfmorphhpp_merged.xlsx, cotaxmoistcl_merged.xlsx, cotext_merged.xlsx, mapunit_merged.xlsx, muaggatt_merged.xlsx	mdstattabcols.xlsx
NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area to choose WW NF)	These are the selection of data files from the Access databases that I thought were usable for our project. They were exported into Excel format. File names were too truncated when tried to export into DBF files.	These are the selection of data files from the Access databases that I thought were usable for our project. They were exported into Excel format. File names were too truncated when tried to export into DBF files.	This table is found in every Access database downloaded with a soil survey area. Elizabeth exported it into Excel format. File names were too truncated when tried to export into DBF files.
http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	Original source of separate tabular data files: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	Original source of separate tabular data files: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	Original source of separate tabular data files: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR
ftp2.abrinc.com...\ftpuser\critifc\incoming\Upland_Soils\WW_Soils_NRCS	ftp2.abrinc.com...ftpuser\critfc\incoming\Upland Soils	ftp2.abrinc.com...ftpuser\critfc\incoming\Upland Soils	ftp2.abrinc.com...ftpuser\critfc\incoming\Upland Soils
There are only soil map unit polygons in this dataset. The line and point feature spatial files (.shp) contain no data.	The same associated data tables listed above for the merged upland soils map can be joined to this study area upland soils map.	These tables contain all of the data describing map units and component (soils series) within map units. Tables with just map unit data can be joined directly to the attribute table for the spatial file. Tables with component data need to be linked via the cokey field to the component_merged table to then join to the mukey field in the attribute table.	This table explains what all of the other associated data tables are so I didn't write descriptions of the other tables in this spreadsheet

	Blue Mtns Landtype Associations	W-W Soil Sampling Point Map (SRIDS)	Umatilla County Upland Soils Map	Union County Soils Map	Umatilla National Forest Upland Soils Map
	LTA_02_05_2013.shp	SoilInventory_pt.shp	soilmu_a_or667.shp	soilmu_1_or625.shp	soilmu_a_or607.shp
	LTA_02_05_2013.shp	SoilInventory_pt.shp	soilmu_a_or667.shp	soilmu_1_or625.shp	soilmu_a_or607.shp
	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Land Type Associations in Shapefile/Dataset Description column in Theme Soils	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains SRIDS Soils Database Points in Shapefile/Dataset Description column in Theme Soils	NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area or County to choose Umatilla County)	NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area or County to choose Union County)	NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area to choose Umatilla NF)
	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR
LTA_Hydro_Properties.xlsx	LTA_Management_Components_Geomorph.xlsx	**NONE - these data are not available in digital format. All data are on original field data sheets only.**	SSURGO Access database; soildb_OR_2003	SSURGO Access database; soildb_OR_2003	**NOTE: No associated data currently available; this survey/TEUI is currently being completed by the contractor. Tabular data will download but tables are empty.**
	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Land Type Associations in Associated Tables column (downloaded zip file lta.zip contains all of the associated data tables)		NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area or County to choose Umatilla County)	NRCS Soil Data Mart (after choosing Oregon, click on Select Survey Area or County to choose Union County)	N.A.
	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml		http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OR	N.A.
ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations		ftp2.abrinc.com...\ftpuser\critifc\incoming\Upland_Soils\Umatilla_Co_NRCS	ftp2.abrinc.com...\ftpuser\critifc\incoming\Upland_Soils\Union_Co_Soils_NRCS	N.A.
Most of this information is too coarse for this project (especially since we have CRITFC's stream classification). LTA_Hydro_Properties contains the following fields: Surface Runoff, Stream Flow Duration (intermittent/perennial), Stream Flow Amount (categorical), Aquifer Recharge (categorical), Rosgen Stream Types, Stream Reach Types (source, transport, response). This table can be Joined using the LTA field.	LTA_Management_Components_Geomorph contains the following fields: Landform, PNV Zone, Geology Group, Dominant Bedrock, Dominant PNV (general cover type), Relict Geomorphic Process, Active Geomorphic Process. This table can be Joined using the LTA field.		There are only soil map unit polygons in this dataset. The line and point feature spatial files (.shp) contain no data.	There are only soil map unit polygons in this dataset. The line and point feature spatial files (.shp) contain no data.	

	Upland Vegetation						
W-W Potential Vegetation	**W-W Existing Vegetation**						
PNV.shp	Vegetation_Stand.shp						
PNV.shp	Vegetation_Stand.shp. This file is for entire Wallowa-Whitman, so I clipped the study area portion and created another file called: UGR_Existing_Veg.shp.						
Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Wallowa-Whitman Potential Vegetation in Shapefile/Dataset Description column in the Theme Vegetation	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Wallowa-Whitman Existing Vegetation in Shapefile/Dataset Description column in the Theme Vegetation						
http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml						
I will create an Excel workbook with a crosswalk table using Powell etal 2007 Potential Veg Hierarchy Blue Mtns NE Oreg SE Wash West Central Idaho	UGR_Veg_Type.dbf --- NOTE: this table only corresponds to existing veg polygons in the UGR/Catherine Creek study area	LTA_Unique_features_wildlife	LTA_Management_Suitability_Limits.xlsx	LTA_Veg_Properties	LTA_Soil_Distribution	LTA_Physical_Properties_MgmtSuitability	LTA_Nat_Disturbance_Regimes.xlsx
Powell etal 2007 Potential Veg Hierarchy Blue Mtns NE Oreg SE Wash West Central Idaho	Bob Clemens, Silviculturist, La Grande Ranger District, Wallowa-Whitman National Forest - table obtained from running EVG query. EVG is former existing veg. database used by Wallowa-Whitman. Existing veg. info is now being housed in FSVeg, a national USFS database for vegetation information.						
NA - not available online	NA - not available online						
N.A.	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Existing_Vegetation	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations
It turns out that this shapefile was derived from the Existing Veg shapefile. The existing veg shapefile already contains information on the plant association/community type, and I have added fields to the ExistVeg.dbf file for the PAG (plant association group) and the PVG (potential vegetation group), this layer can be displayed using the Existing Vegetation shapefile.	Bob Clemens sent an Excel table containing the stand tag and the USFS R6 Ecoclass Code (see Hall 1998 Pacific Northwest Ecoclass Codes for Seral and Potential Natural Communities. PNW-GTR-418). I created a .dbf file containing the Stand Tag, the Ecoclass code, the Series, R6 code name for plant association/community type/cover type, the equivalent PLANTS code and the corresponding plant association/community type name in common and scientific form using Hall 1998. Then I added PNV and PAG fields using Powell et al. 2007. Potential Veg. Hierarchy for the Blue Mountains Section of NE Oregon, SE Wash. and West-Central Idaho. The final table is: UGR_Veg_Type.dbf. The fields in the table are: Stand_Tag, Ecoclass, Series, PNV, PAG, R6_Code, PLANTS_Code, Comm_Name, Scient_Name. NOTE: Missing spatial data for Upper Dry Creek, Upper Spring Creek and Upper McCoy Creek, which are on private land. Might be able to fill in vegetation information of some sort from the Umatilla County soil survey polygon layer and associated database.	not applicable to this project	not applicable to this project	not particularly applicable to this project given the vegetation maps we have - this is too coarse	not particularly applicable to this project given the soil maps we have - this is too coarse	not particularly applicable to this project given the soil maps we have - this is too coarse	LTA_Nat_Disturbance_Regimes contains the following fields: Hydrologic Event (high stream flows, convective storm, rapid snowmelt), Hydrologic Response (e.g. colluvial stream downcutting, overland flow and ponding, etc.), Wind Event Response (categorical - low, moderate, high), Fire Regime (Roman numeral categories - no associated description); Response to Fire (categorical - low, moderate, high - may refer to post-fire erosion?). This table can be Joined using the LTA field.

Geology					
	Land Type Assoc - w/ Veg map unit	**Blue Mtns Landtype Associations**	**UGR Effective Shade**	**W-W Invasive Plant Distribution**	**Union County Historical Vegetation -1958**
G_MAP_UNIT.SHP		LTA_02052013.shp	Originally all shapefiles in \PNVData_08-Feb-2013\commondata\data1\; There are separate files for each stream. They have the prefix "eff" and then a version of the stream name. For example, the file for Five Points Creek is: eff_5pts.shp.	InvasivePlant.shp	veghist_union_1958.shp - NOTE: projection seems to be incorrect on this - when you look at it it will be offset. I talked to Andrew Lacey on the Umatilla NF who had dealt with these historical veg. data. He said the problem occured when data were digitized from the original maps/photos. They had a hard time finding good registration points. So, we'll have to use it as is.
Geology_2009_OGDC.shp	LandType_Assoc_Veg_MapUnit_ugr.shp	LTA_02052013.shp	No change in the file names.	InvasivePlant.shp	veghist_union_1958.shp
OR geospatial library / DOGAMI	LTA_DB.mdb	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Land Type Associations in Shapefile/Dataset Description column in Theme Soils	CRITFC	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Wallowa-Whitman Invasive Plants in Shapefile/Dataset Description column in the Theme Vegetation	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Historical Vegetation by County of Eastern Oregon and Southwest Washington - Union 1958 in Shapefile/Dataset Description column in the Theme Vegetation
http://spatialdata.oregonexplorer.info/geoportal/catalog/search/resource/details.page?uuid={D9B42C23-07E9-496F-8188-7C06A6D0E891}		http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	NA - not available online	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
extensive data tables are available in database		LTA_Management_Components_Geomorph.xlsx	N.A.	InvasivePlant.dbf attribute table that comes with shapefile contains common name and USFS Region 6 species code associated with each polygon feature	Hist_Veg_40s_50s_Legend.dbf.
http://spatialdata.oregonexplorer.info/geoportal/catalog/search/resource/details.page?uuid={D9B42C23-07E9-496F-8188-7C06A6D0E891}		Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Land Type Associations in Associated Tables column (downloaded zip file lta.zip contains all of the associated data tables)	N.A.	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Wallowa-Whitman Invasive Plants in Shapefile/Dataset Description column in the Theme Vegetation	Dave Powell, silviculturist, and Don Justice, GIS specialist, Umatilla National Forest
extensive data tables are available in database		http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	N.A.	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	NA - not available online
W:\OR_base\States\OR\geology\2013_data\OGDCv5\geo_gis\DOGAMI\OGDCv5\shp		ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Landtype_Associations	ftp2.abrinc.com...\ftpuser\critfc\incoming\CRITFC_Data\Effective_Shade	ftp2.abrinc.com...\ftpuser\critfc\incoming\WW_Invasive_Plants	ftp2.abrinc.com...\ftpuser\critfc\incoming\Historial_Veg_Union_County_1958
	RJB joined LTA, Map units, and Veg/PNV	NOTE: the LTA shapefile and the following associated data file may provide sufficient bedrock and surficial geology information. The "relict geomorphic process" field can be used to create a surficial geology map for the watershed. LTA_Management_Components_Geomorph contains the following fields: Landform, PNV Zone, Geology Group, Dominant Bedrock, Dominant PNV (general cover type), Relict Geomorphic Process, Active Geomorphic Process	Seth's notes: these files are current effective shade sent to CRITFC by Watershed Sciences on 15 Oct 2012, and are one of several outputs of the updated (Oct 2012) Heat Source model. Effective shade is a function of shade (vegetation cover and stream and valley morphology) and solar radiation load. More details can be found on pp. 10-18 of Boyd and Kasper (2003) in Documentation folder. The files are: eff_5pts.shp, eff_Beaver.shp, eff_Catherine.shp, eff_chicken.shp, eff_clear.shp, eff_fly.shp, eff_GR.shp, eff_ladd.shp, eff_limberjim.shp, eff_little.shp, eff_Little_Catherine.shp, eff_mccoy.shp, eff_meadow.shp, eff_milk.shp, eff_NF.shp, eff_sfork.shp, eff_sheep.shp		Elizabeth Crowe created this by dissecting the stand code into separate pieces of infomation about the stand and filling in descriptive terms using Powell 2004 (Historical Vegetation Mapping USDA-FS White Paper F14-SO-WP-Silv-23). This table can be Joined to the spatial file using the DATA field. Other fields in this table are: Prefix, Main Veg Type [based on upper canopy cover], Stand Size Class, Stocking Density, 1st_Assoc_Sp, 2nd_Assoc_Sp, 3rd_Assoc_Sp. The associated species are listed in decreasing order of abundance based on cubic-foot volume and must comprise at least 20% of the stand based on cubic-foot volume.

Data Points and Associated Data for Existing Riparian Work

USFS Ecology Plot Points and Data	EcologyPlot.shp	EcologyPlot.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Ecology Plots in Shapefile/Dataset Description column in Theme Ecology	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	ecology_data.mdb	Sabine Mellman-Brown, Area Ecologist, USFS Region 6, Area 3 Ecology Program (email: smellmannbrown@fs.fed.us; phone: (541) 523-1282	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	This is the Access database containing all of the data for all of the Area 3 ecology plots.
					PlotClas.dbf	Elizabeth Crowe - created using data from three sources: several classification files (xxxClass.db) Crowe Paradox database (Area 3 ecology plots 1970s-1999) and plot_visits table in current USFS Area 3 Access plot database (ecology_data.mdb)	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	The DBF file references ALL plots (riparian and upland) that are in the EcologyPlot shapefile. Not every plotted location has a vegetation type assigned to it, either because they it is a camera point or monitoring plot or because no vegetation type was assigned. Fields are: PLOT [ID], CLASS. (classified plant association, community type or just temporarily assigned community name), ECOCLASS (USGS Region 6 code assigned to every officially classified plant association or community type).
					R6_plant_codes.dbf	USFS Area 3 ecology program Access database (ecology_data.mdb)	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	This table is a reference to decipher the USFS Region 6 4-letter (plus numbers as tiebreakers) plant codes.
					PAGtoPVG.dbf	USFS Area 3 ecology program Access database (ecology_data.mdb)	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	This table may be of some use in cross-walking plant association groups (PAGs) to potential vegetation groups (PNV).
USFS Riparian Ecology Plot Points and Data	Study_Area_Riparian_Plots.shp	Study_Area_Riparian_Plots.shp	selected and exported from EcologyPlot.shp	N.A.	environment_riparian.dbf	USFS Area 3 ecology program Access database (ecology_data.mdb)	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	Fields are: PLOT_ID, CLUSTER_ID, ECOSYS, SITETY, COWARD, VSHAPE, VGRADE, VWIDTH, VSIDES, VALLEY, VASPECT, ROSGST, ROSGST1, STRGRA, ROSGSS, SINUOS, ROSGOD, STRMAD, TOSGFR, W/D, POOLS, GLIDE, RIFFLE, ENTREN, STRMOR, STRMCL, RIGHTT_TERR (veg. on right terrace), RIGHT_TOESLOPE (upland veg. on right toeslope), RIGHT_SIDESLOPE (upland veg. on right sideslope), LEFT_TERRACE (veg. on left terrace), LEFT_TOESLOPE (upland veg. on left toeslope), LEFT_SIDESLOPE (upland veg. on left sideslope), FLUV (no idea what this field is)
					data_dict_codes.xlsx	USFS Area 3 ecology program Access database (ecology_data.mdb)	NA - not available online	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	This Excel file will help in deciphering the codes in the environment_riparian.dbf file.

Transportation			Infrastructure		Fire Occurrence History				
Blue Mountains Roads	Cities in Blue Mountains area	Constructed polygon features on National Forest lands	Contructed linear features on National Forest lands	Blue Mountains NFs Fire History Polygons	Blue Mountains NFs Fire History Points				
Road.shp	City.shp	cf_pl.gdb	cf_ln.shp	FireHistoryPl.shp	FireHistoryPoints.shp				
Road.shp	City.shp	cf_pl.gdb	cf_ln.shp	FireHistoryPl.shp	FireHistoryPoints.shp				
Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Roads in Shapefile/Dataset Description column in Theme Infrastructure	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Cities in Shapefile/Dataset Description column in Theme Infrastructure	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Constructed Features in Shapefile/Dataset Description column in Theme Infrastructure	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Constructed Features in Shapefile/Dataset Description column in Theme Infrastructure	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains History Polygons in Shapefile/Dataset Description column in Theme Fire	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains Fire Start Locations in Shapefile/Dataset Description column in Theme Fire				
http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml				
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	RipSoilProfile.dbf	RipPlotSoil.dbf	RipSoilSurf.dbf	RipSppCov.dbf
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Elizabeth Crowe - saved in .DBF (version 5) format from Crowe original Paradox database	Elizabeth Crowe - saved in .DBF (version 5) format from Crowe original Paradox database	Elizabeth Crowe - saved in .DBF (version 5) format from Crowe original Paradox database	Elizabeth Crowe - saved in .DBF (version 5) format from Crowe original Paradox database
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	NA - not available online	NA - not available online	NA - not available online	NA - not available online
ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Roads	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Cities	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Constructed_Features_Polygons	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Constructed_Features_Lines	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Fire_History_Polygons	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Fire_History_Points	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Ecology_Plots
		Plantations, trailheads, parking areas, campsites, etc. (polygon features) on FS land	Fences and barriers (linear features) on FS land			Fields are: PLOT_ID, LAYER, HORIZ, HORITHK, MCOLOR, MOTTLE, TEXT, MOIST, CFRAG, ROOTVF, ROOTF, ROOTM, ROOTC, Ph, COMMENT	Fields are: PLOT, HOW_SAMPLED, DEPSAM, WATMAX, WATCUR, WATMIN, RTDPTH, DEPMOT, THKORG, THKEPI, THKMIN, DEPIMP, PARMAT, SOILC, DEPMOIST, DEPWET, DEPCF_10CM, DEPCF_20CM, DEPCF_30CM, DEPCF_40CM, DEPCF_50CM, DEPCF_60CM, DEPCF_70CM, DEPCF_80CM, COMMENTS, TEMP_10_CM, TEMP_50_CM	Fields are: PLOT, SUBM, BRGRD, GRAVEL, ROCK, BDROCK, MOSS, LIVERWORT, LICHEN, LITTER, BASAL	Fields are: PLOT, LAYER, SPP, COVER

	Other							Management Designations	
Blue Mountains Surface Ownership	Netmap detailed info on UGR watershed	**Oregon/Washington County Boundaries**	**Blue Mountains NF Range Pastures**	**Blue Mountains NF Range Allotments**	**Blue Mountains NF Roadless Areas**	**Blue Mountains NF Wilderness Areas**	**Blue Mountains Ranger District Boundaries**	**Blue Mountains National Forest Boundaries**	**Blue Mountains National Forests Foot Trails**
SurfaceOwnership.shp	NetMap_ugr1	County.shp	rum_subunit.shp	rmu_unit.shp	Roadless.shp	Wilderness.shp	RangerDistrict.shp	AdministrativeForest.shp	Trail.shp
SurfaceOwnership.shp	n/a	County.shp	rum_subunit.shp	rmu_unit.shp	Roadless.shp	Wilderness.shp	RangerDistrict.shp	AdministrativeForest.shp	Trail.shp
Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Basic Surface Ownership in Shapefile/Dataset Description column in Boundary	Netmaptools.org	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Region 6 - Counties in Shapefile/Dataset Description column in Boundary	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Range Pastures in Shapefile/Dataset Description column in Theme Management Direction	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Range Allotments in Shapefile/Dataset Description column in Theme Management Direction	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Roadless Areas in Shapefile/Dataset Description column in Theme Management Direction	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Wilderness in Shapefile/Dataset Description column in Theme Boundary	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - District Boundaries in Shapefile/Dataset Description column in Boundary	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Forest Boundaries in Shapefile/Dataset Description column in Boundary	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library - go to Blue Mountains - Foot Trails in Shapefile/Dataset Description column in Theme Infrastructure
http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	Need registration	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
N.A.	http://www.netmaptools.org/coverage	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Range_Surface_Ownership	O:\OR_Projects\2013\CRITFC\GIS_Data\Raw\NetMap_ugr1	ftp2.abrinc.com...\ftpuser\critfc\incoming\Oregon_Washington_Counties	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Range_Mgmt_Units_Pastures	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Range_Mgmt_Units_Allotments	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Roadless_Areas	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Wilderness_Areas	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_District_Boundaries	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Forest_Boundaries	ftp2.abrinc.com...\ftpuser\critfc\incoming\Blue_Mtns_Foot_Trails
Shows land ownership throughout eastern Oregon	Data is no longer available while they update their (paid) tools for Arc10.1 compatibility. Requests for more detailed metadata were not heeded.		Pasture boundaries within range allotments on the Blue Mountains National Forests	Range allotment boundaries on the Blue Mountains National Forests	Designated roadless areas on Blue Mountains NFs	Designated wilderness areas on Blue Mountains NFs			

Appendix C. StreamStats from USGS and basin characteristics derived from BasinTools.

StreamStats were used to compile inherent basin characteristics for use in data analysis. The low flow hydrology modeling was done by our USGS contractor (Val Kelly) using various basin characteristics developed from these two sources.

StreamStats Characteristics

http://water.usgs.gov/osw/streamstats/

Abbreviation	Description
BSLOPD	Mean basin slope measured in degrees
DRNAREA	Area that drains to a point on a stream (mi^2)
DRNDEN	Basin drainage density defined as total stream length divided by drainage area. (km/km^2)
ELEV	Mean Basin Elevation (ft)
ELEVMAX	Maximum basin elevation (ft)
FOREST	Percentage of area covered by forest
IMPERV	Percentage of impervious area
IMPNLCD1	Percentage of impervious area determined from NLCD 2001 impervious dataset
JMAXTMP	Mean Maximum January Temperature (F)
JMINTMP	Mean Minimum January Temperature (F)
MXBSLOPD	Maximum basin slope, in degrees, using ArcInfo Grid with NHDPlus 30-m resolution elevation data.
MAXTEMP	Mean annual maximum air temperature over basin surface area as defined in SIR 2008-5126 (F)
MINBELEV	Minimum basin elevation (ft)
MNBSLOPD	Minimum basin slope, in degrees, using ArcInfo Grid with NHDPlus 30-m resolution elevation data.
MINTEMP	Mean annual minimum air temperature over basin surface area as defined in SIR 2008-5126 (F)
HIPERMA	Percent basin surface area containing high permeability aquifer units as defined in SIR 2008-5126
HIPERMG	Percent basin surface area containing high permeability geologic units as defined in SIR 2008-5126
PRECIP	Mean Annual Precipitation (inches)
RELIEF	Maximum - minimum elevation (ft)
SOILPERM	Average Soil Permeability (inches/hr)
WATCAP	Available water capacity of the top 60 inches of soil - determined from STATSGO data (in/in)
STREAMS	Total stream length (miles)

Basin Tools--Watershed Characteristics Outputs

http://www.nvisionsolutions.com/products/BasinTools.php

BASINNAME	**Basin Name** is derived by looking for similarities in the layer names.
TDA	**Total Drainage Area**, in square miles, is a measurement of the area of the drainage basin and it includes noncontributing areas.
NCDA	**Non Contributing Drainage Area**, in square miles, is the total area of the drainage basin that does not contribute to the surface-water runoff at the basin outlet.
CDA	**Contributing Drainage Area**, in square miles, is the total area of the drainage basin that does contributes to the surface-water runoff at the basin outlet.
BL	**Basin Length**, in miles, is measured alone a line areally centered through the drainage-divide from the basin outlet to where the main channel extends to meet the basin divide.
BP	**Basin Perimeter**, in miles, is measured along the entire drainage basin divide.
BS	**Average Basin Slope**, in feet per mile, is measured by the "contour band" method, within the contributing drainage area.
BR	**Basin Relief**, in feet, is measured as the difference between the elevation of the highest grid cell and the elevation of the grid cell at the basin outlet.

BA	**Basin Azimuth**, in degrees, is the compass direction of a line projected from where the main channel, if extended, meets the basin divide downslope to the basin outlet. Measured clockwise from north at 0°.
BW	**Effective Basin Width**, in miles.
SF	**Shape Factor**, dimensionless, ratio of basin length to effective basin width.
ER	**Elongation Ratio**, dimensionless, ratio of (1) the diameter of a circle of area equal to that of the basin to (2) the length of the basin.
RB	**Rotundity of Basin**, dimensionless.
CR	**Compactness Ratio**, dimensionless, the ratio of the perimeter of the basin to the circumference of a circle of equal area.
RR	**Relative Relief**, in feet per mile.
MCL	**Main Channel Length**, in miles, is measured along the main channel from the basin outlet to where the main channel, if extended, meets the basin divide.
TSL	**Total Stream Length**, in miles, is computed by summing the length of all stream segments within the contributing drainage area.
MCS	**Main Channel Slope**, in feet per mile, is an index of the slope of the main channel computed from the difference in streambed elevation at points 10 percent and 85 percent of the distances along the main channel from basin outlet to the basin divide.
MCSR	**Main Channel Sinuosity Ratio**, dimensionless.
SD	**Stream Density**, in miles per square mile, within the CDA.
CCM	**Constant of Channel Maintenance**, in square miles per mile, within the CDA.

MCSP	**Main Channel Slope Proportion**, dimensionless.
RN	**Ruggedness Number**, in feet per mile.
SR	**Slope Ratio**, dimensionless, is the ratio between the main channel slope to basin slope, within the CDA.
FOS	**Number of First Order Streams** within the CDA, dimensionless, is computed using the Strahler's method of stream ordering and summary statistics.
BSO	**Basin Stream Order**, dimensionless, is the stream order of the main channel at the basin outlet. BSO is computed by intersecting the main channel with the drainage divide and determining the Strahler stream order of the stream at the basin outlet.
DF	**Drainage Frequency**, in number of first order streams per square mile, within the CDA.
RSD	**Relative Stream Density**, dimensionless, within the CDA.
MAXGRD	**Maximum Grid Elevation**, in feet.
MINGRD	**Minimum Grid Elevation**, in feet.
GRDRELF	**Relief in Grid Elevation**, in feet, is the difference of elevations between the maximum and minimum elevations.

Appendix D. Grande Ronde Roads Project Protocol

Protocol version: December 2013

Purpose: To capture, as accurately as possible, the geometry of the current road network that exists in the Upper Grande Ronde study area into a Geographic Information System (GIS), along with a set of attributes that describes basic information about these roads and the source(s) that their information was derived from. The intended benefit of this project is to assist with the estimation of the disturbance and erosion caused by these roads, but it may have other beneficial uses as well.

For the purpose of this project, a road is defined as any identifiable path that is or was used repeatedly for transport by motorized vehicles, and has left some detectable disturbance on the landscape. This includes paved and natural surface roads that are joined across the landscape in a navigable network, and also obsolete or disconnected segments that may have been used previously for operations such as logging, and subsequently may have fallen into disuse, but still present disturbances on the landscape. This definition is not intended to include temporary paths used infrequently by motorized vehicles that have not significantly disturbed the landscape, or trails or routes that exist solely for non-motorized means.

Process: The study area (Upper Grande Ronde River and tributaries including Catherine Creek, in NE Oregon) is divided into 2km * 2km grids and CRITFC staff knowledgeable with GIS (including David Graves, Denise Kelsey, Joe Nowinski, and Dale McCullough) will work through each of these sections in order to digitally capture the geometry representing the correct location of all roads. At the conclusion of the project, they will produce one single roads GIS layer for the entire study area, retaining road source attributes.

All roads from the source data (USFS, TIGER, and CRITFC New Roads, see "data layer list" below) will be included in the output, except where they clearly are duplicates of the same roads. The geometry of these existing road lines will be modified to match that seen on the NAIP imagery wherever they do not appear correct, using the appropriate scale and error tolerance (see "scale and tolerance" below). If roads appear to be evident on the NAIP imagery, but there are no existing road lines in the source data, then they will be added as new lines, also using the appropriate scale and error tolerance. Existing road lines that match the NAIP imagery will be retained, eliminating any duplicate lines for the same roads. Select attributes (see "attribute list" below) will be retained for road lines from the USFS layer. For road lines from other sources (either other layers or newly digitized), attributes will be transferred from the USFS layer if it is clearly the same road and the other road line represents the imagery better than USFS road line as interpreted from the NAIP imagery. Otherwise for non-USFS roads attributes will be assigned the default value (see "attribute list" below). The data sources of the geometry and the attributes will be captured in the attribute table.

Project progress will be tracked in spreadsheets, including an inventory of which grids have been processed, any significant problems or uncertainties that were encountered in each grid, and screen shots of relevant examples. Edge matching between adjoining grid sets will be coordinated by David Graves.

Scale and Error Tolerance: All map editing will be performed at a scale of 1:6,000. The error tolerance will depend on whether a road is within a stream buffer or not. Within a 200-meter 2-sided buffer of the streams layer (see "data layer list" below) all edits will be performed to a maximum error tolerance of 15 meters. Outside of this stream buffer, all edits will be performed to a minimum error tolerance of 30 meters.

Coordinate System: UTM Projection, Zone 11 was used for all editing work. One data layers not already in this coordinate system (USFS Roads) was projected to this coordinate system before editing commenced. The NAIP imagery were originally delivered in this coordinate system so no changes were needed to these images.

Data Layer List:

US Forest Service (USFS) Roads (2013): Obtained from Andrew Lacey, USFS, on 5/2/13 (Data came in a zip file "MAF_UMF_WWF_Roads_20130502.zip" saved to the RoadsIssues folder and unpacked and deleted. Inside zip was a personal geodatabase called "RoadsWithCoreAttributesRSW.mdb". It has a feature data set called "MAF_UMF_WWF_Roads_20130502" from the USFS). After review, this was considered to be the best existing roads layer based on its completeness and attribute data. However, it does appear to be missing roads and/or needing corrections to the geometry of its roads in several places.

TIGER roads (2011): Obtained from the U.S. Census Bureau. Contains geometry on many roads not included in the USFS layer, particularly around towns and in private ownership. The TIGER 2011 layer was found to be better than the TIGER 2012 layer. All roads from this layer will be retained if they are not already included or more accurately mapped in the USFS layer attributes will be retained from the corresponding USFS road, where the TIGER layer provides more accurate geometry.

New Roads_CRITFC: Roads that were previously digitized by Dale McCullough in 2012, CRITFC because they were absent from the USFS and TIGER roads layers. These will be retained (unless the latest road layer from USFS already contains these roads), but attributed in the same fashion as the TIGER layer, and their geometry will also be corrected if they do not match NAIP imagery.

GR_Mixed Scale Hydrography: Obtained from StreamNet. A layer that contains lines representing the hydrography of streams and rivers in the Upper Grande Ronde Study area, generally at the 1:24,000-scale. This layer will be used to create the stream buffer area (for a lower error tolerance) and also to help visually determine whether lines on the NAIP imagery are roads or streams.

NAIP Imagery (2012): 1-meter resolution aerial imagery from the National Agriculture Imagery Program taken in 2012. Visual interpretation of this layer at the appropriate scale (see scale and data tolerances) will be used as the source to determine the appropriate inclusion and placement of all roads.

NAIP Imagery (2009): 1-meter resolution aerial imagery from the National Agriculture Imagery Program taken in 2009. Visual interpretation of this layer at the appropriate scale (see scale and data tolerances) will only be used as an additional supporting layer when imagery in the NAIP 2012 layer is not sufficient to judge the inclusion or placement of roads.

Attribute List:

The following is the list of attributes for the output (deliverable) road layer. Note that attributes from source layers, such as the USFS roads layer, will be also be retained in their native format, so that they may be linked to this product if needed in the future.

USFS_FID: If the attribute source is "USFS" then this field should be filled in with the FeatureID of the segment that this one was derived from in the USFS Roads layer (i.e. this attribute will be populated with the value of the FID attribute from the USFS layer of the matching road segment). This will allow a link back to the additional attributes that are contained on this USFS layer in case the data from these attributes may become useful at a future time.

SurfType: Type of surface that overlays the road ("AC" = Asphalt; "AGG" = Crushed Aggregate or Gravel; "BST" = Bituminous Surface Treatment; "IMP" = "Improved Native Material"; "NAT" = "Native Material"; "P" = "Paved"). This attribute will be derived from the USFS roads layer if the road is defined there or if it is a segment that connects two roads in the USFS layer that have identical surface types and it can be assumed that the segment connecting them would also be the same, or it may be interpreted from the NAIP imagery if the surface type is clearly visible. If unknown, "(NAT)ive" surface type is default value, unless inside of a town, then "(P)aved" is assumed.

Lanes: Number of lanes in the road segment (Single" or "Double"). This attribute will generally only be known if the road is defined in the USFS roads layer, because it is difficult to identify from the NAIP imagery. If unknown, "Single" is default value, unless inside of a town, then "Double" is assumed.

Visible: Denotes whether the road is visible on the NAIP imagery ("Yes" or "No"). New roads will only be added if they are visible on the imagery, but existing roads (USFS or TIGER) may not be visible, in which case they are retained, but noted here as "No". It will be assumed that when USFS or TIGER roads were mapped, there was a valid, original data source, such as presence on a USGS map, a recognizable image on a stereo photo, an earlier NAIP image, or other source. Default value is "Yes" and will be changed if otherwise.

Att_Source: Details the source of the attribute values for this road segment ("USFS", "TIGER", or "CRITFC"). If the attributes were already present in the USFS or TIGER layers, then these will be noted here. If the attributes were interpreted at CRITFC from the NAIP imagery and/or given default values because they were unknown, then "CRITFC" is listed as the source.

Geo_Source: Details the source of the line geometry for this road segment ("USFS", "TIGER", or "CRITFC"). If the linework for a road is derived from the USFS or TIGER layer and unchanged, then these will be noted here. If the road is newly digitized, was digitized in the previous CRITFC_NewRoads layer, or was modified from a USFS or TIGER layer to match the NAIP imagery, then "CRITFC" is listed as the source.

Comments: Additional comments about the road segment are captured here. In particular, road segments that do not appear to be designed as part of the transportation network, but rather to facilitate the movement of cut logs through a logging area should be commented as "Logging Area". If railroads can be determined/identifiable they too will be mapped and “Railroad” will be indicated in this field.

Data Deliverable:

One GIS layer (in an ESRI geodatabase format) that contains lines representing, as best as possible using the data sources specified above, the current network of roads (used or not used) in the Study Area, and a report of data collection methods and summary statistics. Data specifications of this layer are as follows:

Projection: UTM Zone 11, with units in meters, in the NAD83 HARN/NAVD88 datum (Geoid 03).

Scale: 1:6000

Minimum Error Tolerance: 30m, except for 15m inside of 200-meter 2-sided stream buffer.

Examples of the Task of Consolidating USFS and TIGER road Layers

Screen clips were selected from various locations within the UGR or Catherine Creek watersheds to show examples of the difficulties in selecting USFS or TIGER road segments, or their placement in space (Figures 1-4). Sections that were 2-km squares were created as a grid that overlaid the entire area of the basins mapped as an aid in systematically combining the mapped information and digitizing new roads.

Accurate spatial mapping of road location was sometimes better in the USFS version than in the TIGER system. However, it was obvious that often the TIGER system was more accurate. Also, the TIGER system frequently had distinctly visible roads that were not mapped by the USFS. When TIGER roads were mapped, but were not currently visible on the aerial photos, they were indicated as not visible. For purposes of calculating road density, we will have the option to remove from analysis those TIGER roads that are not currently visible. Some USFS roads are not currently visible too. To the extent feasible, these were noted as visible/not visible. However, for purposes of analysis, we will most likely assume that the USFS mapped only valid roads and that if they are not currently visible, it may be due to vegetation regrowth obscuring the road.

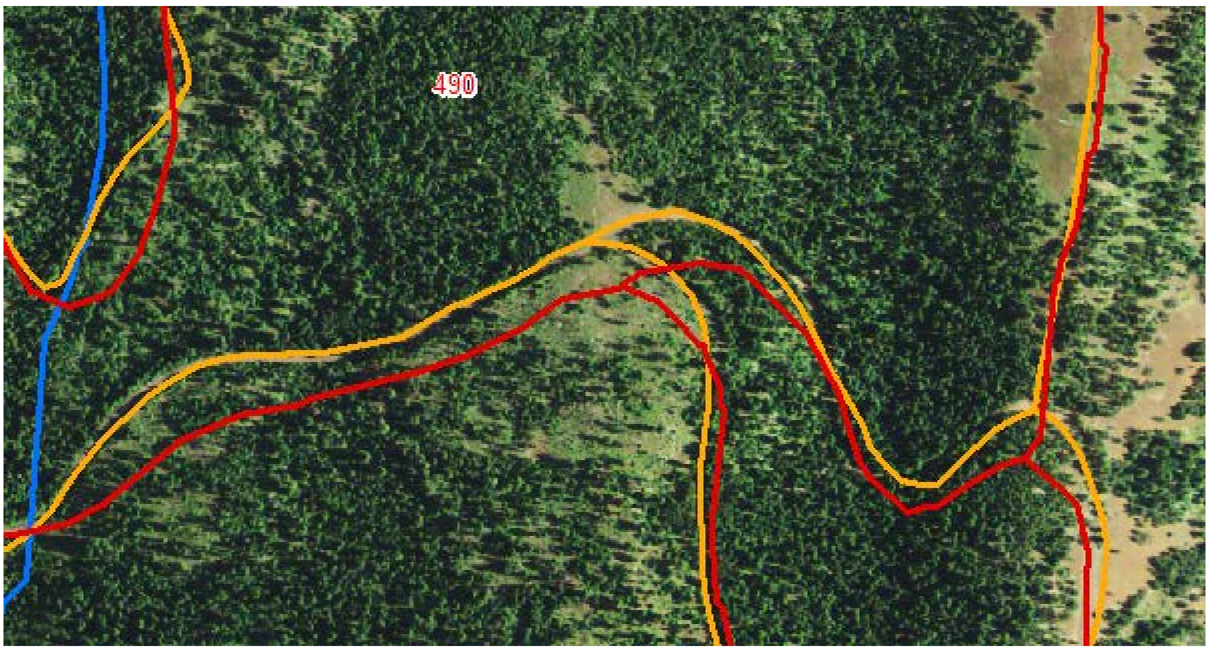


Figure 1. Section 490 of the roads mapping project. Roads in red are USFS; roads in yellow are TIGER. Blue indicates a stream.

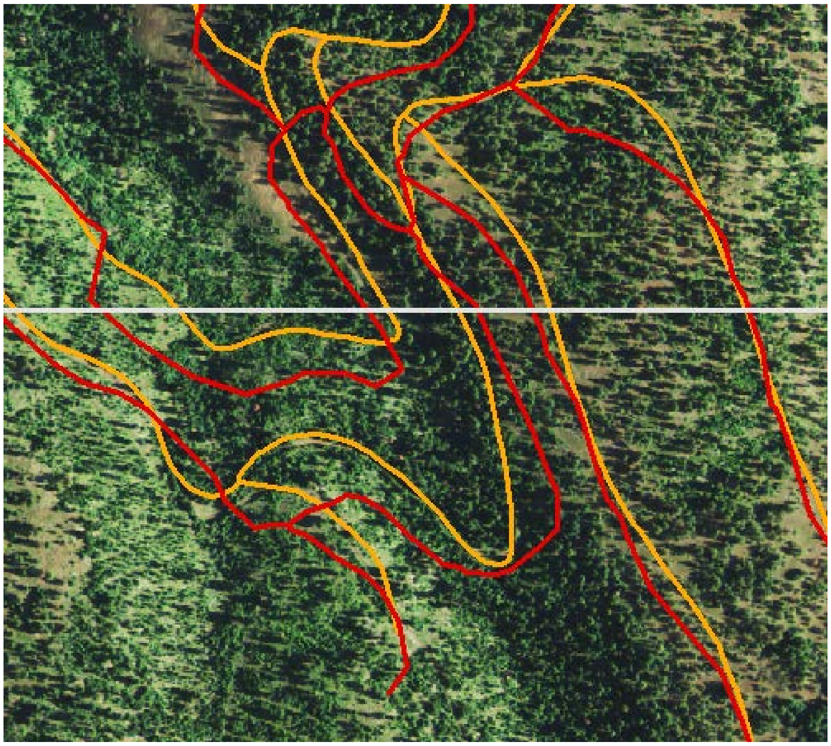


Figure 2. Section 390 of the roads mapping project. Roads in red are USFS; roads in yellow are TIGER. Blue indicates a stream.

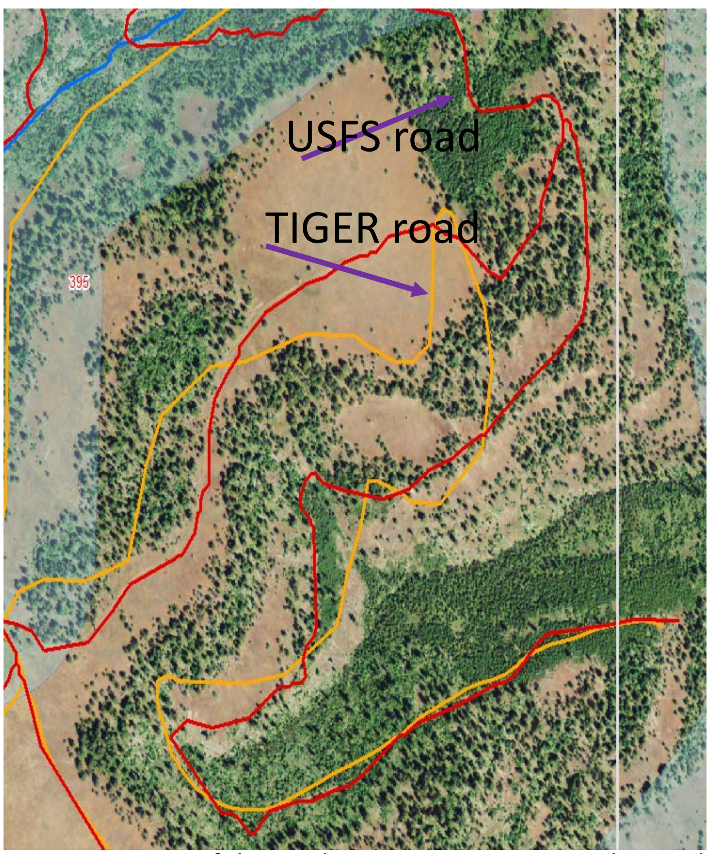


Figure 3. Section 395 of the roads mapping project. Roads in red are USFS; roads in yellow are TIGER. Blue indicates a stream.

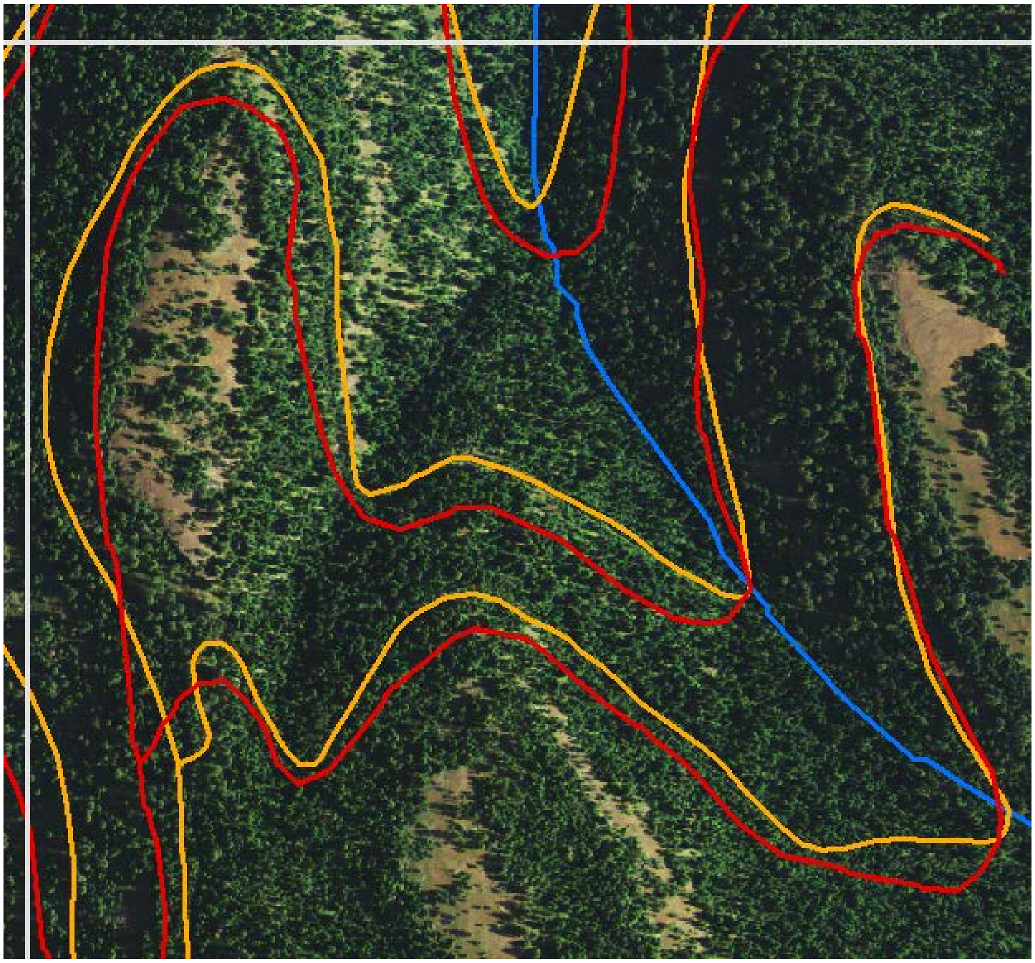
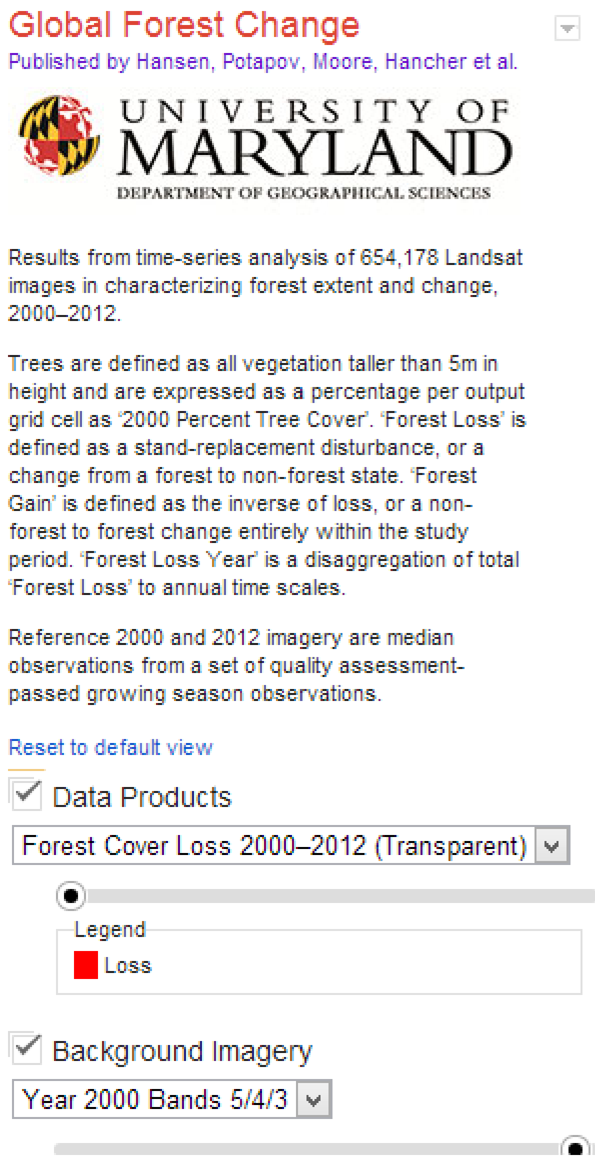
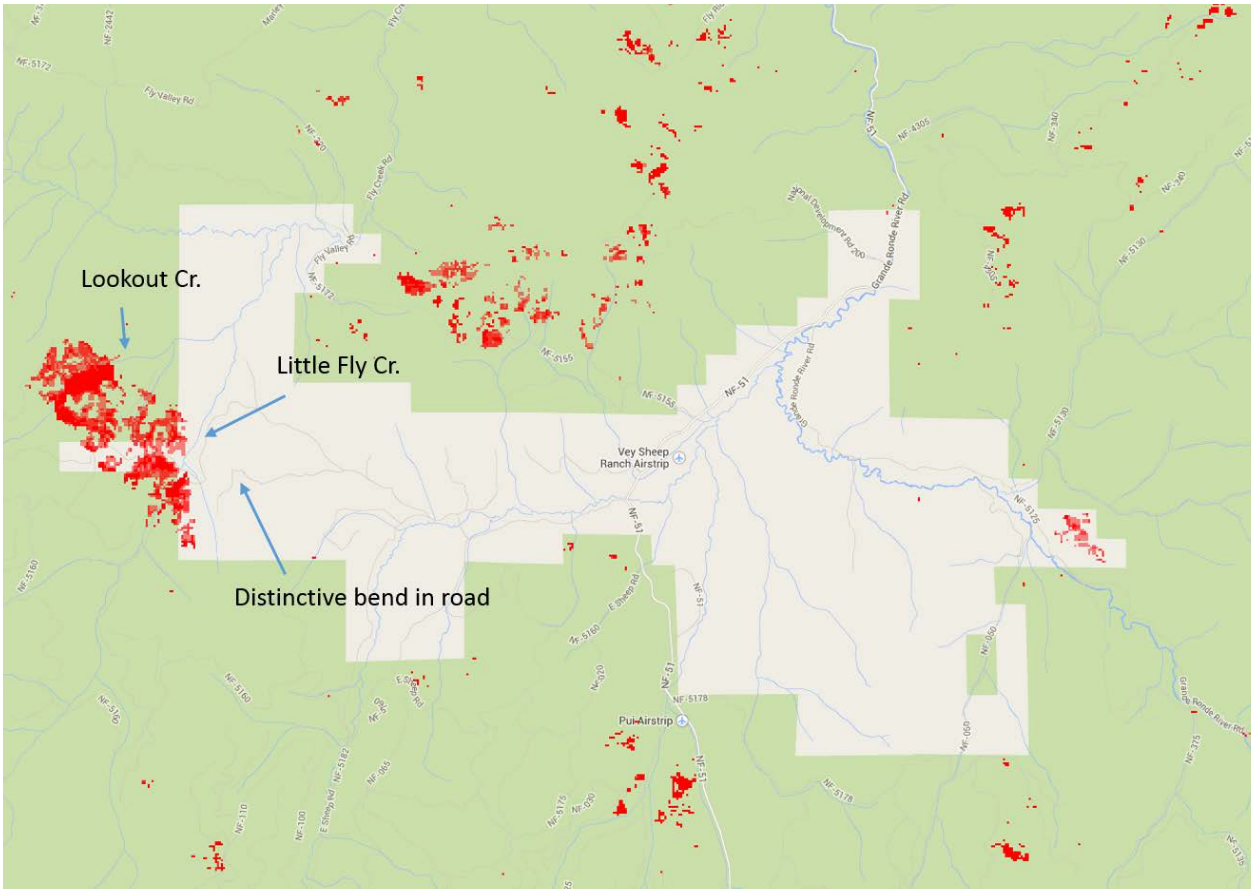


Figure 4. Section 531 of the roads mapping project. Roads in red are USFS; roads in yellow are TIGER. Blue indicates a stream.

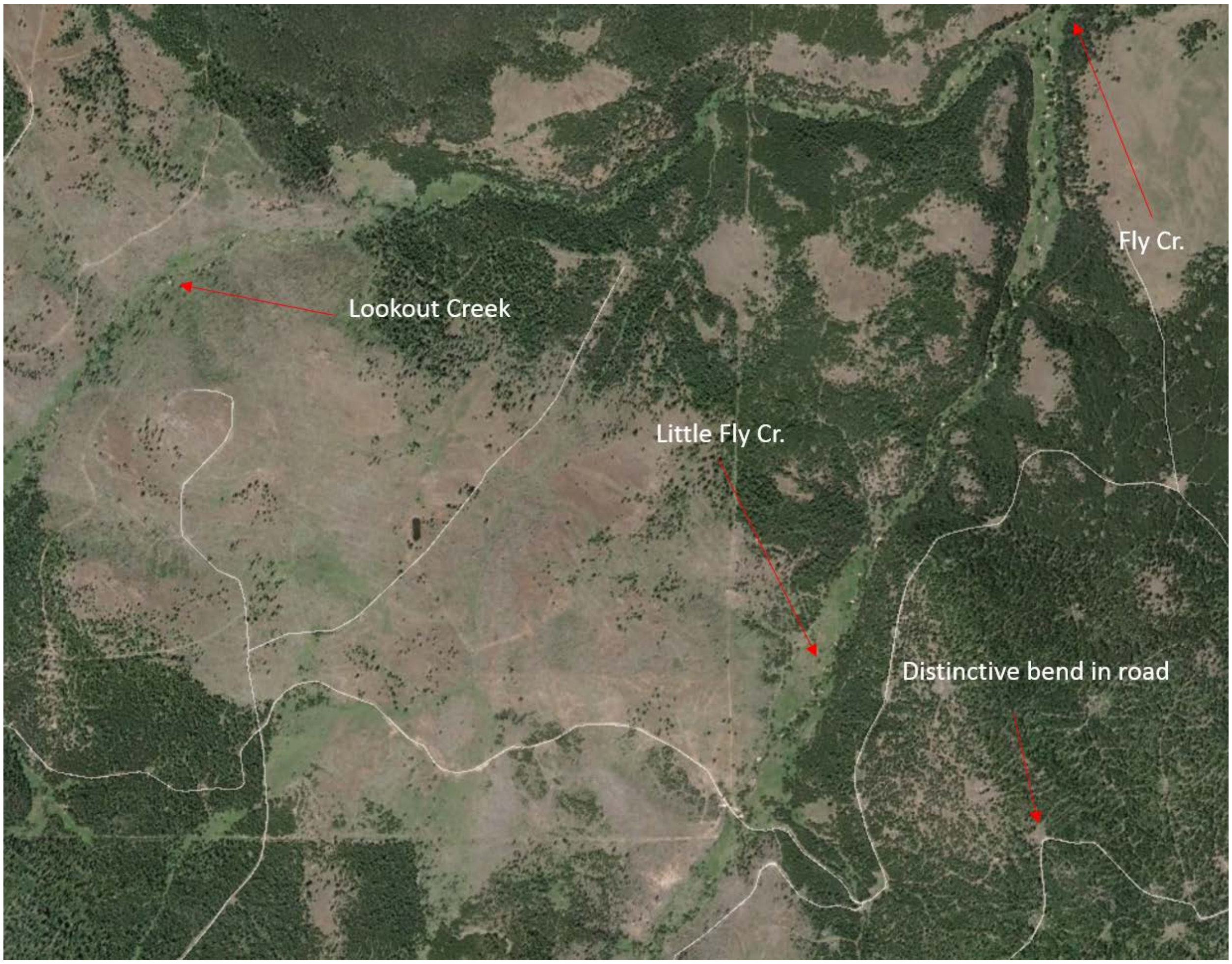
Appendix E. Extent of forest loss

http://earthenginepartners.appspot.com/science-2013-global-forest

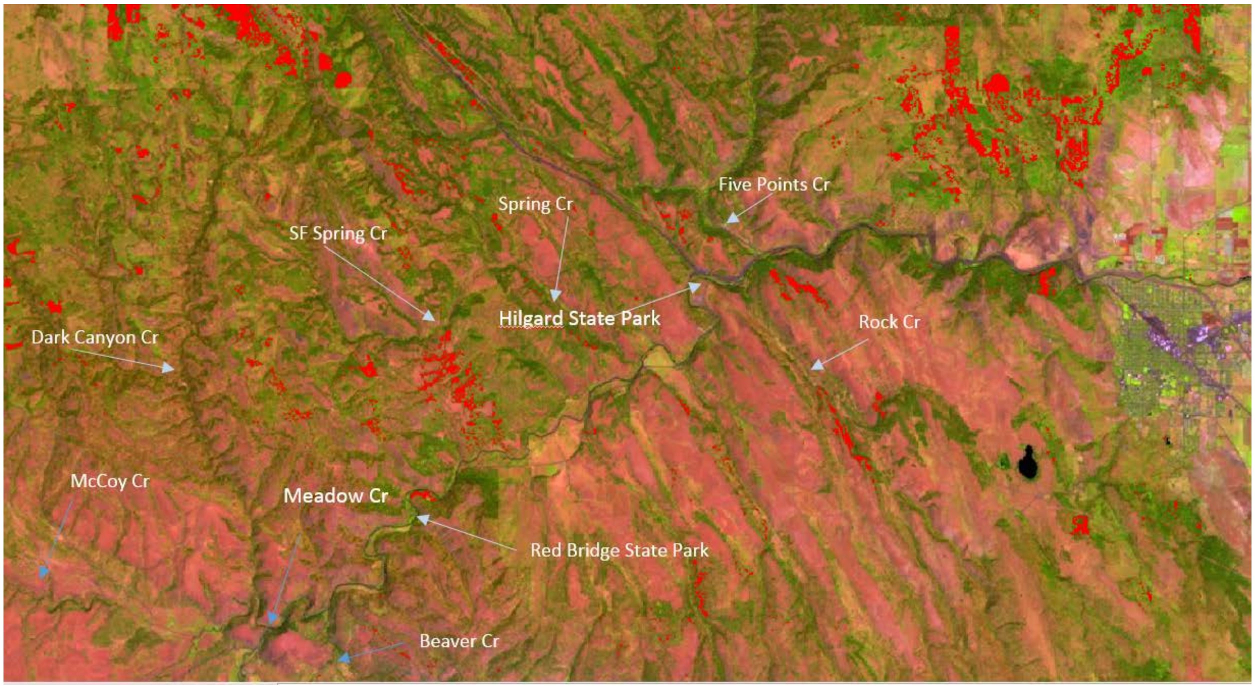




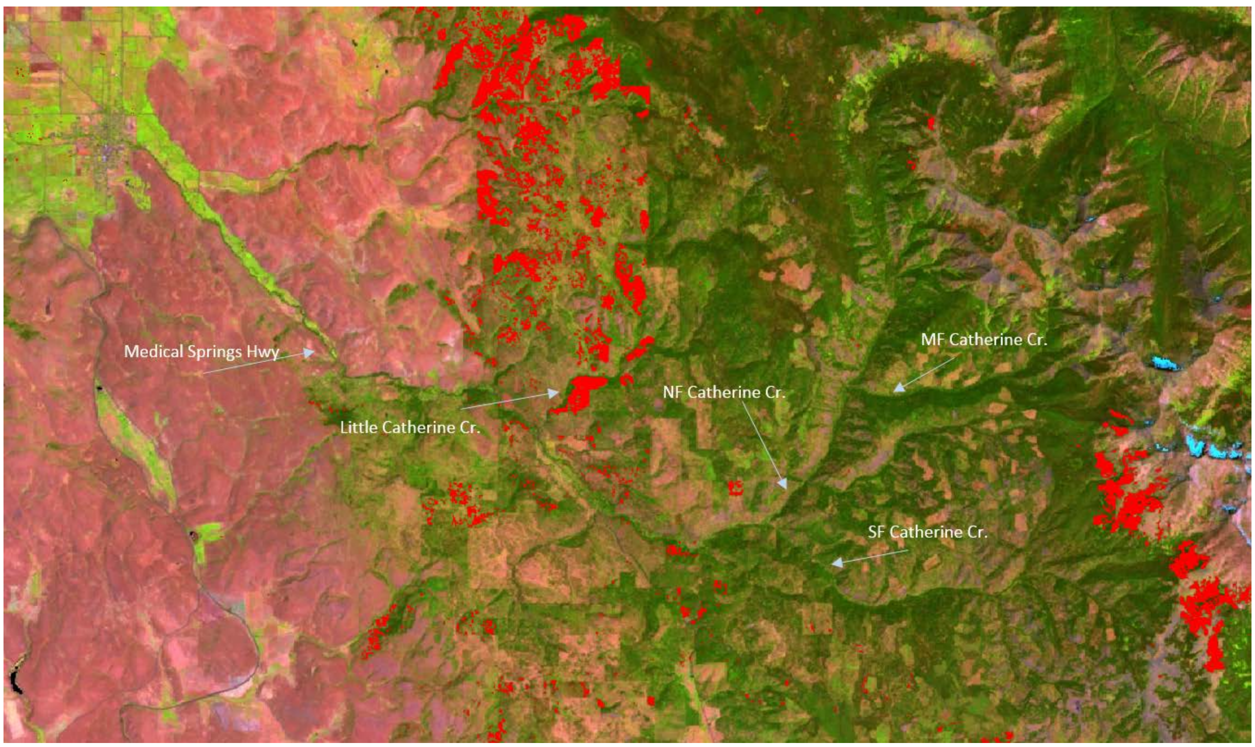
Extent of forest loss from 2000 to 2012 (indicated in red) in the vicinity of Vey Ranch in the upper Grande Ronde basin. Forest loss is high in an area on the northwestern edge of Vey Ranch, extending into USFS property. Lookout Creek and Little Fly Creek join to form Fly Creek, which is a major tributary to the mainstem upper Grande Ronde River.



Google Earth imagery in the vicinity of Vey Ranch in the upper Grande Ronde basin, showing the same features represented on the previous map of forest cover loss. The "distinctive bend in the road" was indicated on this image and the previous map. The Google Earth image also shows Lookout Creek and Little Fly Creek joining to form Fly Creek. This map reveals the road system used to access the areas where forest cover was removed in the previous map. This image also reveals that not all forest cover loss is associated with an apparent high road density.



Extent of forest loss in the lower portion of the upper Grande Ronde basin, upstream of the city of La Grande, Oregon. Hot spots of forest cover loss are apparent within the Spring Creek watershed and also in the headwaters of Five Points Creek in the upper Grande Ronde. More detailed GIS work will reveal exactly the amount of area harvested attributable to each subwatershed.



Extent of forest loss in the Catherine Creek watershed above the city of Union, OR. It appears that there are some hot spots of forest cover loss in the headwaters of SF Catherine Creek and in the Little Catherine Creek drainages.

Appendix F. Catherine Creek life-cycle model with policy optimization

Robert B Lessard (CRITFC)

Executive summary

Fisheries scientists and habitat specialists at the Columbia River Inter-Tribal Fish Commission (CRITC) have been actively engaged in the monitoring of salmon spawning and rearing habitat. Grande Ronde basin Chinook salmon populations have declined significantly from historical levels. Spawning and rearing habitat are thought to be limiting factors to the recovery of the populations. As part of a number Columbia River Accords projects, CRITFC scientists have been developing methods and tools to evaluate population recovery strategies. Consistent with the Columbia Habitat Monitoring Program (CHaMP), CRITFC habitat scientists have been conducting habitat surveys in Catherine Creek, the Upper Grande Ronde, and the Minam rivers. Data have been collected on a variety of stream characteristics including, but not limited to: 1. Flow, 2. Temperature, 3. Fine sediment, 4. Spawning area, and 5. Coarse woody debris. The CHaMP protocol provides the rationale for collecting data on these and other characteristics. Attributes are monitored to ascertain spatial and temporal variability according to a rotating panel system.

As part of recovery planning, CRITFC's goal is to develop a life-cycle model that can reconstruct population trends and be used to identify where habitat restoration efforts might best be targeted. The first stage, which was developed in 2011 and 2012, was to construct a population dynamics model that could represent the spatial variation in habitat condition, and the spatial dynamics of spawning and rearing in tributaries. The model was constructed to account for adult straying and juvenile dispersal among distinct spatial areas. The life cycle model was designed to account for variability in productivity and capacity at each life stage as a function of environmental conditions. As such, a yearly record of the spatial variation in habitat and environmental conditions forms the basis for predicting spatial and temporal variability in productivity and capacity. The historical spatio-temporal record of conditions can be derived from CHaMP data or other historical records. This and historical abundance data can be used to calibrate the model and reconstruct population trends. Supplying the model with forecasts of spatio-temporal conditions in the future can be achieved by means of sub-models such as CRITFC's stream temperature model developed with Watershed Sciences (now Quantum Spatial Inc.), and other physically based models of stream characteristics. In its final form, the life cycle model can both reconstruct historical abundance patterns and predict population trends under alternative future scenarios of stream conditions. For the tributary stages of the life-cycle model this relies on historical habitat data and predicted habitat conditions. For downstream stages, the life-cycle model relies on hydro system operational characteristics and ocean dynamics.

In 2013, the life-cycle modeling effort focused primarily on statistically validating the main stem and ocean dynamics of the life-cycle model. Since most of the salmon life-cycle is spent downstream of the tributaries, and since a major portion of the variability in recruits per spawner can be explained by variation in main stem and ocean conditions, it is essential that the behavior life-cycle model be consistent with empirical evidence in those life stages. Working with the Comparative Survival Studies (CSS) group and the Fish Passage Center (FPC), CRITFC has worked to ensure that the life-cycle model operates in a manner consistent with predictions of main stem and ocean survival.

Population model description

The model CRITFC is developing currently focuses on the Catherine Creek population. It predicts the number of spawners, the number of eggs, the number of emerging fry, the number of juveniles rearing in different reaches of the river, the number of parr that migrate downstream in fall to overwinter, later migrating parr, the number of smolts, the number of fish in the ocean, and the number of returning adults. A simplified schematic of the model is shown in Figure 1. Fish rearing in the ocean are predicted to return to spawn as adults after a certain number years in the ocean. Fish

return to spawn after a number of years rearing in the ocean, which is determined probabilistically, such that the age distribution of returning adults is consistent with the observed age distribution. Throughout the life history, survival from one stage to the next is predicted with a Beverton-Holt survival function.

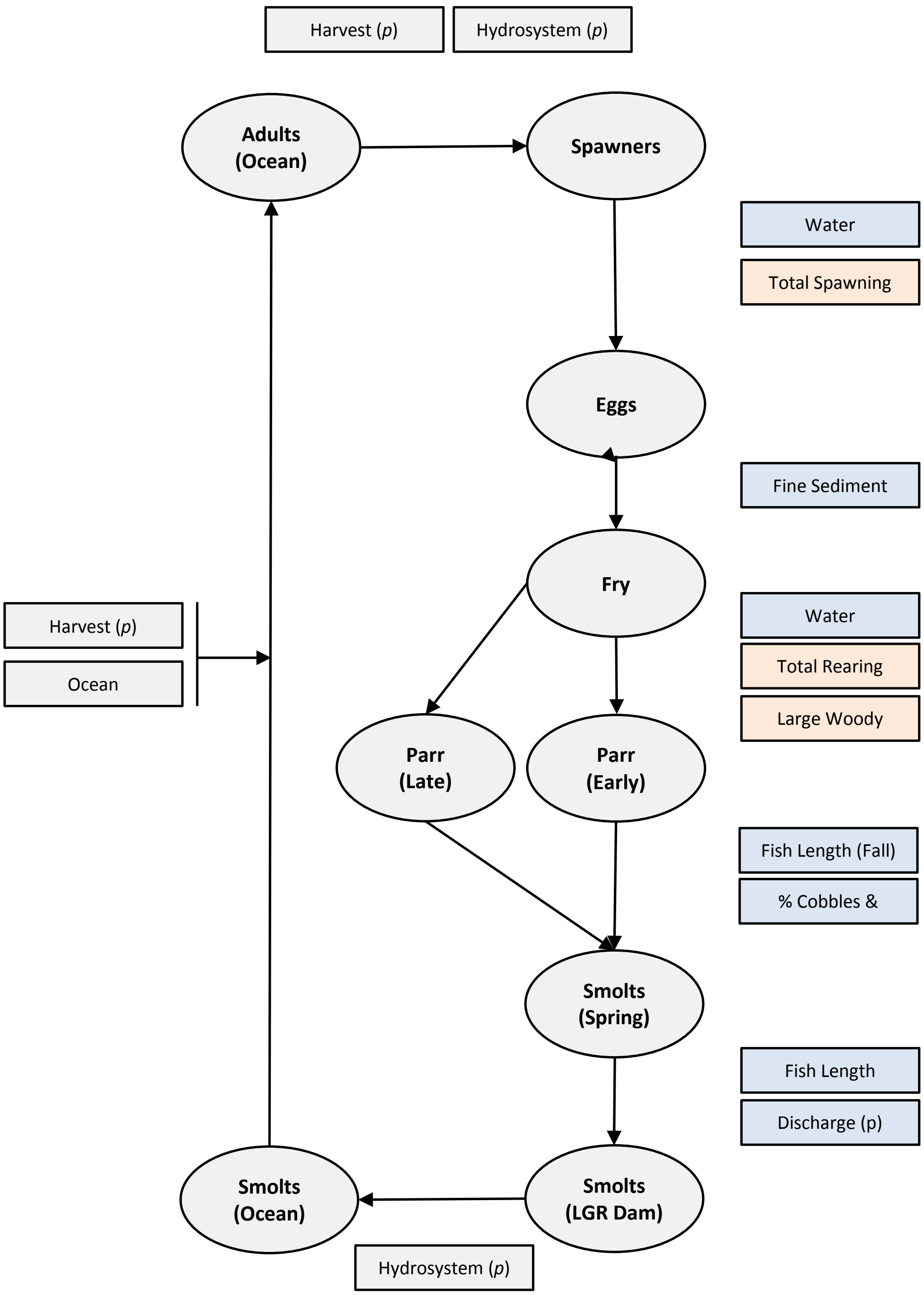


Figure 1: Full life cycle diagram. Each life stage has key environmental variables influencing productivity and capacity.

Figure 2 shows a more detailed perspective of the rationale behind predicting survival at the spawner to eggs stage. Dynamically, survival is predicted by density dependent and independent factors that are influenced by environmental conditions. The proximate conditions are water temperature and total spawning area, but those are driven by static factors like geomorphic conditions that may be categorized by defined channel types, or by dynamic processes like

forest growth and climate change. Forest succession has the effect of shading streams and providing coarse woody debris that enhances spawning area. Climate change can affect discharge and temperatures. Ultimately, management actions can have an impact on those dynamic processes and can be viewed as drivers in the prediction of future environmental conditions as they pertain to the prediction of productivity and capacity, and ultimate, survival. Thus, we can view management actions as predictors of future population trends.

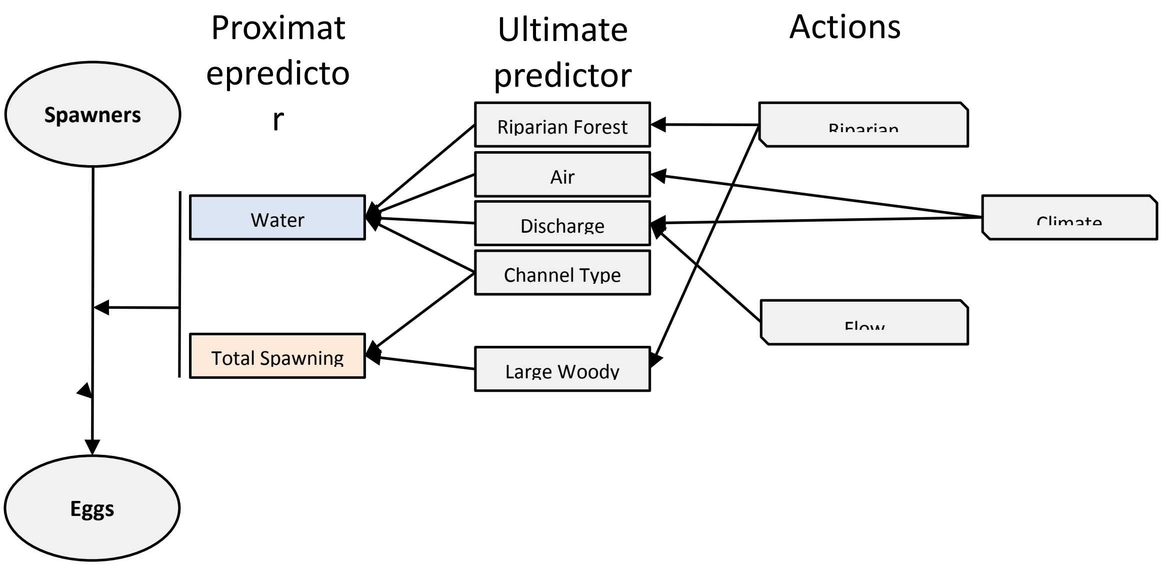


Figure 2: Diagram of dynamics of state variables. Dynamic processes affect main drivers of productivity and capacity.

Further to having stages shown in **Error! Reference source not found.**, the model explicitly captures spatial dynamics by breaking the population down into distinct population sub-units that have independent spawning and rearing (see Figure 3). Each population is specific to a segment of the river. Even if no fish initially spawned in an area, fish may disperse into that area after spawning in another. Fish may also stray to an area instead, despite having originally been the product of spawning in a different area.

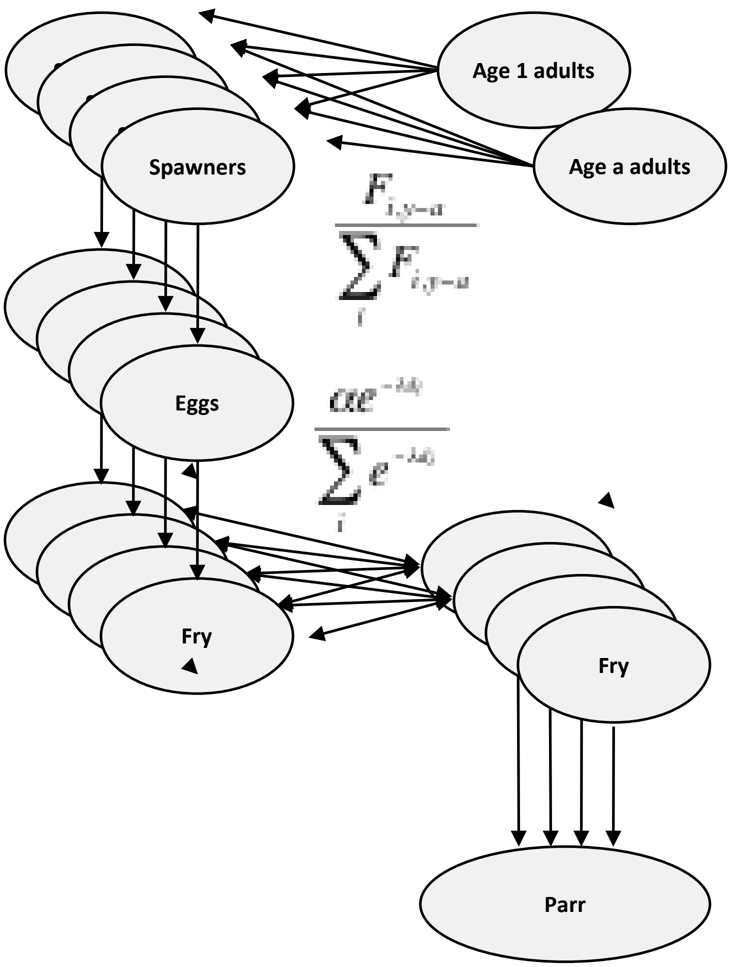


Figure 3: Spatial dynamics of spawning and rearing. Adults return to natal spawning areas in proportion to the number of fry that emerged the appropriate number of years prior to the age of maturity. Fry rearing and dispersal involves fry dispersing to spatial units other than the one from which they emerged from gravel. Illustration shows a distance scaled dispersal.

When fish return to spawn, fish of a given age are redistributed to natal spawning areas in proportion to the number of fry that were produced from each spawning area the year that the adult age-class returns would have reared as juveniles. Following spawning, eggs are produced, followed by fry. The model then simulates juvenile dispersal by redistributing a portion of fry to other rearing areas in proportion to the relative distances between rearing areas. If fry disperse to other areas, other fry may already be present, whether they emerged from the gravel there, or dispersed there from other areas.

Survival

Survival rates from one stage to the next are predicted with a Beverton-Holt (BH) survival function. The basic formula for the BH survival function is p/(1+pN/k), where N is the abundance, p is the density independent productivity and k is the carrying capacity term. When N approaches k/p, survival approaches p/2. All survival estimates by life stage use this assumption, though the values for p and k are not necessarily constant. Both p and k can vary with environmental conditions such as those described in **Error! Reference source not found.**. In the simplest form of predicting survival, p and k do not vary with environmental conditions and so survival does not vary either. However, for generality, survival is assumed to be predicted by productivity and capacity, both of which have the potential to change with environmental conditions. The relationship between productivity and environmental variables is described below.

Environmental conditions

The model keeps track of environmental conditions at all stages and at all spawning and rearing sites, even if it is assumed that conditions are constant. Let $X_{i,j,k,t}$ be the environmental condition for the i^{th} population, j^{th} stage, k^{th} variable in the t^{th} year, where j=1,2,3 are egg, fry and rearing stages. Let $Y_{j,k,t}$ be the environmental variable for the j^{th} stage, where j=1 is parr and j=2 is smolts, and the k^{th} variable in the t^{th} year. Let $Z_{j,k,t}$ be the k^{th} environmental variables for the j^{th} age of ocean residency in year t. The X, Y and Z variables are all normalized to historical means and standard deviations so that 95% of the values are on the range (-1.96,1.96). Productivity is calculated according to the following equation:

$$p = \frac{1}{1 + e^{-\beta_0 - \sum_{n=1} \beta_n V_n}}$$

where V_n is an environmental variable such as X, Y, or Z variables, depending on which stage or spatial location the productivity calculation applies to. This form predicts a productivity on the order of (0,1), with a mean value of p^* when $\beta_0 = \ln(p^*/(1-p^*))$ and all other $\beta_n = 0$. Similarly, the capacity is calculated as follows:

$$k = e^{\gamma_0 + \sum_{n=1} \gamma_n V_n}$$

where the mean is k^* when $\gamma_0 = \log(k^*)$ and all other $\gamma_n = 0$. These equations predict productivities and capacities that increase or decrease with environmental variables in increments determined by the scaling coefficients β and γ. If there is deemed to be no variation with environmental conditions, only β_0 and γ_0 are non-zero. Positive values of the scaling coefficients cause productivity and capacity to increase with an increase in the value of the environmental conditions. Values of the scaling coefficients can range from negative to positive infinity, but values on the range of (-3,3) for β_0 predict mean productivities between 0.05 and 0.95 and values on the range of (0,20) for γ_0 predict mean capacities between 1 and 485 million. For n>0, the scaling factors can take on any value, but a value of $\beta_0 = 0$ would predict mean of 0.5, so $\beta_1 = 1$ and V = 1 would imply that when V is one standard deviation from its mean, productivity would increase from the mean value of 0.5 to 0.73, a 50% increase in productivity with one standard deviation increase in the value of the environmental factor. Capacity operates at the scale of γ_0.

Spawning migration

The model predicts the number of adults returning in a given year and a given age. Some of those fish will have spent a single year in the ocean, others will have spent several years. Fish returning as age *a* will have been fry *a*-1 years ago. If fish are aged 2, 3, 4, 5, and 6 years old, they will have come from fry 1-5 years prior. In order to allocate the total abundance of each age of fish back to the spawning areas from which they originate, the model takes into account the number of fish from each spawning area that survived to be parr for a given time lag. For example, 4 year old adults will redistribute to the spawning areas in proportion to the number of fry that emerged from each spawning area relative to the total across all areas.

Straying

The model implements straying as a function of two factors: 1. Random stray rates, and 2. Distance scaled straying. The random rate merely dictates the portion of the total returns that stray outside of natal streams. The distance scaling determines the portion of the total straying that strays to neighboring spatial areas. The model uses a distance scaling factor to make closer sites more attractive than farther sites. The relative desirability decays exponentially with distance. Rather than use physical distance, we are developing a method to define stray distance as a relative measure of

accessibility. In other words, a nearby upstream site may not be as accessible as a downstream site farther away. Similarly, if a spawning group swims through a site to get to its own natal site, the transit site might be considered very close in relative terms.

Egg production

The model assumes that the number of potential eggs produced is predicted by multiplying the number of spawners on a site by a fecundity (eggs per spawner) and applying a BH survival to those eggs. The resulting density dependent viable eggs are a BH function where productivity depends on water temperature and capacity depends on total spawning area. Eggs are calculated at each of the spatial sites.

Fry production

Fry are predicted by a BH function where productivity is dependent on the proportion of fine sediment, i.e., β_1 is non-zero and V is fine sediment. Capacity is kept constant by setting γ_0 to a fixed value and other γ_n to zero. Fry production is predicted for each spatial site.

Fry rearing

After fry emerge from gravel, they can rear in their natal streams, or disperse to other locations. The model will implement several dispersal mechanisms: 1. Random dispersal, 2. Distance scaled dispersal, and 3. Ideal free distribution. Random dispersal merely disperses a fixed portion of fry to rear in other spatial units in equal proportions. Distance scaled dispersal starts with a fixed portion α of fish dispersing, but scales dispersal such that the probability of dispersal to any given location upstream or downstream decays exponentially with distance of that point from the origin (as shown in **Error! Reference source not found.**). The equation below shows the calculation of the distance scaled dispersal.

$$\frac{\alpha e^{-\lambda d_i}}{\sum_i e^{-\lambda d_i}}$$

A portion α of fry disperse and are allocated to the neighboring streams in proportion to their relative distance scaling factors.

Parr

Following fry rearing, all spatially distributed fry are collected into a common pool of late summer fry. The recruitment to fry follows a BH function with productivity varying with water temperature on rearing sites, and capacity varying with total rearing area and percent pools in rearing sites. Following the pooling of parr into a single unit, parr then migrate downstream either in fall or mid-late winter. The single pool of parr is recruited into each of the early and late parr stages with BH functions.

Smolt

Early and late migrating parr are recruited to the smolt stage using a BH function that has a fixed capacity, but has productivity varying with fish length, water temperature, and percent cobbles and boulders.

Mainstem and ocean

Smolts leaving upstream spawning and rearing areas and migrating through the main stem of the Columbia River are being modeled in close connection with main stem passage survival estimates coming from the Comparative Survival Studies (CSS) group and the Fish Passage Center (FPC). A CSS model was developed to work in close association with the Catherine Creek life cycle model, such that both models simulate main stem and ocean dynamics using the same survival rate. When smolts enter the main, the dynamics through the hydro system uses a survival rate from an empirically derived estimate. The CSS model estimates survival of Snake River Chinook through the hydro system using a functional relationship that relates survival to hydro activities (e.g., percent spill) and ocean conditions (e.g. PDO and upwelling). The model estimates the relationship between the fraction of outmigrating smolts detected at Lower Granite Dam that

are also detected as returning adults, and the anthropogenic and environmental effects (i.e., spill, PDO, and upwelling). As such, the CSS model provides a statistical underpinning and model validation for the tributary dynamics of the Catherine Creek life cycle model.

Fish that leave the mainstem enter the ocean in spring and spend up to four years in the ocean, making returning fish 3-6 years old. Each year at the time of spawning migration, a portion of ocean rearing adults returns to spawn. The probability that a fish returns to spawn is a fixed rate such that the number of returning adults is consistent with empirical patterns. Fish of a given age that do not return to spawn spend an additional year in the ocean. After the fourth year in the ocean, all fish return to spawn. Each year in the ocean, the survival is predicted by a BH function with productivity varying with ocean conditions such as PDO, SST, or upwelling, depending on the year in the ocean.

Appendix G. Historical vegetation of three salmon-bearing watersheds in the interior Columbia River basin

Portland State University McNair Research Journal 2014

By Tyanna Smith

Mentor: Seth White

Abstract

Land use practices can be a contributing factor to environmental degradation and have been the focus of many ecological studies. One aspect that is less addressed is land use history and the effects that past practices, such as logging and grazing, can have on the current landscape. This paper describes research and the synthesis of material on the environmental history and watershed characteristics for three watersheds located within spawning and rearing areas for Chinook salmon in the Grande Ronde River Basin in Northeast Oregon: upper Grande Ronde River, Catherine Creek, and Minam River. The Grande Ronde Basin is critical spawning and rearing habitat for salmonids listed under the Endangered Species Act. The primary historical data sources for reconstructing 19th century stream and riparian conditions are the General Land Office township survey notes from 1863 - 1901. Data about the habitat conditions of the landscape were extracted from notes of each township survey source regarding vegetation, stream crossings, and other features found on the landscape in tabular and spatial forms. Data were organized to describe common stream and riparian conditions for the historical time period using a geographic information system. Watershed basin, Chinook salmon life history, ecoregion and surveyor were analyzed using multivariate techniques to determine which parameters were strongly connected to historical vegetation. Ecoregion had the strongest correlation with plant communities. For future research, these historical data could be compared to current habitat survey data, such as the Oregon Department of Fish & Wildlife's Aquatic Habitat Inventories, to evaluate the degree of change over time of stream and riparian conditions.

Introduction

Land use practices, past and current, in watersheds can have negative impacts on the structure and proper function of water bodies (Maloney et al. 2008, Harding et al. 1998). Humans have influenced the environment on a landscape scale and have disrupted the geomorphic and riparian processes that maintain streams and rivers and their biota. This can result in stream habitat that is degraded and less heterogeneous (Allan 2004). Agriculture is the main land use activity by humans that covers the largest fraction of land area, or watershed catchment areas, in many developed watersheds (Allan 2004). Urban areas usually make up a small percentage of total catchment areas, but often have a large influence on the associated rivers and streams. Other types of land use that negatively affect streams are forestry, mining and recreation (Allan 2004), which are predominant within the study area.

The negative impacts from land use come in various forms. Agriculture is present in the project area and has many different effects on watersheds. Effects that can harm salmon habitat include soil erosion, sediment transport and deposition downstream, on-site pollution from overuse and secondary effects of fertilizers and pesticides, off-site

pollution of adjacent areas, deforestation, desertification, degradation of aquifers, salinization, accumulation of toxic metals and organic compounds, and loss of biodiversity (Botkin & Keller 2009). An overload of nutrients can lead to algal growth, deposition, and decomposition by bacteria which consume a majority of the dissolved oxygen in the stream (Murdoch et al. 2001). Deforestation caused by agriculture, forestry, or long-term grazing can increase soil erosion and delivery of sediment into the stream channels, expose impermeable lower soil layers, and reduce the amount of canopy cover over the streams. In general, an overload of sediment into streams can result in channels being less sinuous, broader and shallower (Charlton 2008).

Another important impact within our project area is cattle grazing. Cattle, grazing in the riparian zones of streams, trample the banks and consume high amounts of vegetation, destabilizing the bank and resulting in erosion. At high grazing densities, cattle can consume the vegetation faster than it can grow, which results in the loss of some plant species and a dominance of less beneficial species (Botkin & Keller 2009). Overgrazing of riparian areas can result in destruction of fish habitat by removing overhanging vegetation, which fish use for cover and by sloughing stream banks (White & Rahel 2008).

These land use types have negative effects on the environment and have been well studied. However, there has been comparatively less research on historical agricultural practices and other types of historic land use and how this may still be affecting the environment or determining its current state. Recently there have been articles published on the environmental history of an area from the recognition that it plays a large role in its evolution. Historical land use has been shown to be a major contributor to current environmental composition from local to landscape scales. It has also been shown to affect forests by controlling the modern vegetation patterns by decreasing species diversity and homogenizing soils (Foster et al. 2003), as well as reducing the amount of woody debris located in riparian areas of streams and rivers, which negatively impacts the entire stream or river food web (Clarke & Bryce 1997, Foster et al. 2003).

Riparian vegetation plays a major role in understanding environmental history of a watershed. This vegetation has an important impact on water temperature and the amount of suspended solids entering the stream from bank stabilization. The loss of canopy cover can result in an increase in stream temperature, which can reduce the dissolved oxygen levels (Murdoch et al. 2001). The absence of riparian vegetation can destabilize stream banks and increase soil erosion entering the stream which will increase the amount of suspended solids and decrease dissolved oxygen levels (Clarke & Bryce 1997, Murdoch et al. 2001). Sparse riparian vegetation can also lead to a decrease of large woody debris (LWD). Stream complexity is increased by LWD as water flows around and through it and creates areas in the water with different depths, velocities, substrate types, and amount of cover. Woody debris increases the amount of depth of pools large enough for salmon to use as cover and creates more diverse physical habitat. It may also create pockets of cool water which would aid survival of salmonid species (Quinn 2005).

Classifying the landscape by ecoregion where Chinook salmon (Oncorhynchus tshawytscha) currently spawn and rear can provide an ecological basis to establish boundaries that assist in identifying stream potential for supporting freshwater species distribution, unlike applying administrative boundaries that merely define states and counties. Classifying watersheds within ecoregions can help in describing the expected conditions and riparian vegetative characteristics of the watersheds and help make predictions of how watersheds in similar ecoregions will respond to certain types of land use and/or degradation (Clarke & Bryce 1997).

The objective of this research was to describe patterns of historical vegetation of the mainstems of the Upper Grande Ronde River, Catherine Creek, and the Minam River and their corresponding ecoregions in the locations where Chinook salmon currently spawn and rear using information from the Government Land Office (GLO) township surveys (1863 – 1901). The larger project objective is to classify the historical landscape of this area in order to conduct further research

to be able to make comparisons with current vegetation and analyze how land use has altered the environment since the GLO surveys were conducted. Questions analyzed for this research paper are:

1. How were historical plant communities distributed in the watershed area?

2. Which watershed scale factors (life use area, watershed basin, or ecoregion) best explain variation in historical vegetation patterns?

3. Are individual plant taxa indicative of these watershed scale factors?

Methods

Study Area

The study area is located in Northeast Oregon in the Grande Ronde Basin and includes the upper Grande Ronde River, Catherine Creek and the Minam River (Figure 1). The Upper Grande Ronde River, Minam River, and Catherine Creek have drainage areas of 1,896 km2 , 1,051 km2 , and 618 km2 respectively. The headwater topography consists of rugged mountains and a low gradient valley between the Blue and Wallowa Mountains for the Upper Grande Ronde River and Catherine Creek. The majority of these watersheds' surface geology consists of Columbia River Basalt rocks, granitic intrusive rocks and older volcanic rocks. These watersheds have a climate of cold, moist winters and warm, dry summers. In the valleys, the average annual precipitation is 36 cm (14 in) with 152 cm (60 in) in the mountains and consisting mainly of winter snow fall (McCullough et al. 2013).

Very recent vegetation descriptions of the study area include low elevation regions which consist of grasslands with Idaho fescue-bluebunch wheatgrass (*Festuca idahoensis-Agropyron spicatum*) and bluebunch wheatgrass-Sandberg's bluegrass (*Agropyron spicatum-Poa sandbergii*). The higher elevations consist of shrub/scrub plants and coniferous forests, with species such as Ponderosa pine (Pinus ponderosa), lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), subalpine fir (*Abies lasiocarpa*), and mountain hemlock (Tsuga mertensiana).The majority of vegetation in the riparian zone are black cottonwood (Populus trichocarpa), mountain alder (*Alnus incana*), willow (Salix spp.), black hawthorn (*Crataegus douglasii*), and mountain maple (*Acer glabrum*) (McCullough et al. 2013).

This area has been influenced by humans since before the European settlers. Early travelers noted that Native Americans used fire as a land management technique and grazed horses (Robbins & Wolf 1994). Many explorers and fur traders came to this area for beavers and commodity purposes which also altered the land. The Grande Ronde River has undergone much larger changes since the very early European settlement. A study conducted in 1990 retrieved stream surveys from1941 and found that there has been a 60% loss in pool habitat and an increase in concentrations of fine sediments in Chinook salmon spawning areas since the surveys (Wissmar et al. 1994). A more recent study demonstrated that pool frequencies have increased or remained the same in 96% of minimally disturbed streams but have decreased in 52% of streams managed for the extraction of natural resources (McIntosh et al. 2000). Surveys from the Wallowa-Whitman National Forest claim that more than 70% of stream miles do not meet current Forest Plan standards for sediment, shading, temperature and adequate LWD. These factors indicate that there has been severe degradation of the stream and riparian habitat throughout the Grande Ronde Basin (Wissmar et al. 1994).

Spring Chinook Salmon in Study Area

The three watersheds contain populations of spring Chinook salmon, which were listed as threatened in 1992 under the Endangered Species Act. Decreases in these populations can be attributed in large part to degradation of their habitat. Anthropogenic disturbances in this area consist of timber harvest, cattle grazing, levee and road construction, and stream diversions for irrigation. Limiting factors for Chinook salmon habitat quality include stream temperature, stream flow, fine sediment, habitat diversity, and large pools (McCullough et al. 2013).

Chinook salmon are the largest of the Pacific salmon species and have populations that migrate upstream in the spring, summer and fall. The Grande Ronde basin currently has spring and fall Chinook populations. They spawn in areas with large gravel and cold waters in the mainstem of the Grande Ronde River and its major tributaries. In order for Chinook salmon to successfully spawn and produce offspring, there are certain habitat requirements that need to be met. Two of the most important requirements for development of salmon are cold water temperatures and high dissolved oxygen levels (Quinn 2005). Water temperature has shown to be lacking and limiting salmon production in varying degrees in the study area (McCullough et al. 2013). Riparian vegetation is important for the survival of fish in the summer months by providing shade but also in the winter months where it moderates the loss of heat from the stream and prevents ice forming (Clarke & Bryce 1997).

Government Land Office Surveys

The GLO surveys conducted in the mid to late 19th century were originally intended to provide information to prospective settlers regarding timber harvest, agriculture and animal grazing. During the GLO survey, a surveyor walked each 1 mile section line in which the township was broken up into 36 sections of 1 square mile. Surveyors also walked to boundaries of all townships. Distance at the time of the surveys was measured in chains and chain links, where 80 chains equals one mile. Most surveyors recorded when vegetation, streams/rivers/wetlands, human structures, trails/roads, or other noteworthy features or landscape objects were located on the one mile line representing a section border. Upon completing a township, the surveyor usually noted a general description of the township.

Methodologies for extracting information from GLO surveys were adapted and revised from McAllister (2008). GLO survey notebooks were viewed online at the Bureau of Land Management website (http://www.blm.gov/or/landrecords/survey/) and used as a primary data source to spatially locate on a map the vegetation types, landscape characteristics, and human features described in the handwritten notes. ESRIs geographic information system (GIS) ArcMap 10 was used to map the data extracted from surveys.

A point was plotted in GIS for each feature at the location along the township section line (Figure 2) and the information about the feature was recorded in a GIS attribute table. A general description was written about each section line's vegetation and soil quality. Data recorded in the GIS attribute table which originated from the surveys consist of date surveyed, surveyor, stream crossing names, width and depth, soil type, human structures, and a number of vegetative species. Data created from the surveys include an accuracy rating of exact feature location versus point placement, animals, and Native American uses. Township summaries were recorded in a separate document along with an image of the original data (Figure 3) and hand drawn maps (Figure 4).

Data Analysis

In order to select the points for analysis of the research questions, township and section lines were selected that crossed the GIS line features representing current spawning and rearing of Chinook salmon along the mainstem of the Grande Ronde River, Catherine Creek and Minam River. Each section line was given its own unique identifying code. The transect data, which was representative of the section lines, were then entered into tabular from to classify by their vegetation summary category which fell mutually according to Chinook salmon spawning or rearing areas. Transects were also attributed by level IV ecoregion. Nonmetric multidimensional scaling (NMS) was used to describe multivariate patterns of upland versus riparian plants across the project area. Upland and riparian plants were categorized using the Natural Resources Conservation Service riparian plant identification field guide (NRCS 2008). A multiple response permutation procedure (MRPP) was used to test for categorical (salmon life history use, basin, ecoregion) differences in plant community taxa. Indicator species analysis (ISA) was used to test whether particular taxa were good indicators of categorical descriptors such as life stage use, basin and ecoregion. Only the taxa with an occurrence of 5% or greater were included in the analysis (Table 1). Two ecoregions were excluded from MRPP and ISA analyses due to containing only one transect (Table 2). Because GLO surveyors had varying ability to identify vegetation taxa, we also tested for the effect of surveyor on the recorded plant community structure.

Results

Question 1: Distribution of plant community types

Throughout the study area, upland versus riparian plants displayed a difference in key taxa describing the community composition, as demonstrated by their NMS scores (Table 3). Riparian plants had higher positive NMS values and upland plants had lower negative values (Figure 5). This helps to display the differences in areas of growth and development of each plant taxa. The plant taxon with the highest NMS score was cottonwood (1.192) and was the most representative of a riparian taxon, while pine (-0.612) had the lowest NMS score representing upland plants.

Question 2: Watershed-scale factors affecting plant communities

Ecoregion, basin, life history and surveyor all were significantly representative of historical plant taxa distribution. Of the environmental factors, ecoregion revealed the strongest relationship to historic plant spatial distribution (A-statistic = 0.255), followed by basin (A-statistic = 0.108) and Chinook salmon use (A-statistic = 0.019, Table 4). Surveyor was also strongly correlated with the highest NMS score representing the vegetative distribution (A-statistic = 0.484). An ordination plot revealed that the ecoregions Wallowas/Seven Devils Mts and Mesic Forest had similar species composition, while the Maritime Influenced Zone represented more upland plants and the Blue Mt Basin was more reflective of riparian plant species (Figure 6).

Question 3: Plant taxa indicators

The ISA phi scores show that individual plant taxa were statistically indicative of certain ecoregions ($p = 0.05$) (Table 5). Species with statistically significant relationships with the Maritime Ecoregion were grass (phi = 0.409), pine (phi = 0.457) and tamarack (phi = 0.230). Species with statistically significant relationships with the Blue Mt Basin were cottonwood (phi = 0.587) and willows (phi = 0.470), while balm (phi = 0.378) was indicative of the Wallowas/Seven Devils Mts (Figure 7). The Mesic forest zone was included in the analysis but did not have any statistically significant indicator taxa. Fir, spruce and alder were not statistically indicative of any of the ecoregions analyzed.

Discussion

GLO survey data for key plant taxa revealed a significant difference when data were stratified by position on the landscape (e.g., riparian vs. upland). A study conducted by Pabst and Spies (1998) demonstrated the composition of vegetation as representing a complex environmental gradient from the streamside to the lower hillslopes with the vegetative patterns being related to specific landforms and topography. This helps to explain expected plant taxa composition and distribution with emphasis on their location. The differences in the NMS scores between the community types show that the GLO surveys exhibited consistency regardless of observer which matches what we know about major vegetative transitions from riparian to upland areas (Pabst and Spies 1998).

Spawning versus rearing areas were analyzed only in the Upper Grande Ronde River and Catherine Creek because data in the rearing areas of the Minam River were not retrievable on the BLM site. This factor may be important to explain why the smallest A-statistic is in the life history and not any of the other parameters analyzed. Though surveyor had the strongest statistical significance, there needs to be more data exploration in order to conclude its legitimacy. Therefore, ecoregion is interpreted to display the closest connection to vegetation distribution due to its lack of potential biases. This result is supported by McAllister (2008) study who also found that some plant taxa are highly ecoregion specific and others are not. This helps to verify the use of ecoregions when displaying plant characteristics and distribution. Not including the surveyor data, basin has the second highest connection to vegetation type. The Maritime Influenced Zone ecoregion contains only transects in the upper Grande Ronde River. The Wallowas/Seven Devils Mts contains part of the Minam River and Catherine Creek while the Blue Mt basin contains the Minam River and the upper Grande Ronde River. Since each ecoregion contains only one or two of the study basins boundaries within it, basin in conjunction with ecoregion can be used as a second predictor of the plant communities present.

Analyzing plant distribution from various factors can show how it can be predicted by landscape attributes, such as ecoregion and basin. A study conducted by Kooch et al. (2008) identified indicator species to show differential distributions between plant groups and to help distinguish between different plant groups which validated how certain species can be indicative of a plant type or location. Clarke & Bryce (1997) describe the Maritime Influenced Zone as receiving some of the most precipitation within the Blue Mountains. The higher relative precipitation across the Maritime Influenced Zone causes xeric (e.g., characterized by Ponderosa pine and bunchgrass) upland habitats to be found at lower elevations than in other ecoregions of the Blue Mountains. Pine was indicative of the maritime influenced zone in our ISA results. Willow was an indicator species for the Blue Mt basin ecoregion which has a dynamic relationship with its floodplain and is heavily grazed by cattle and elk. Balm, which is believed to be the evergreen shrub *Ceanothus velutinus*, has common names mountain balm and snowbrush and was indicative of the Wallowas/Seven Devils Mountains. Clarke & Bryce (1997) described the native vegetation of this ecoregion to include pines, firs, and various types of evergreen and deciduous shrubs (i.e., Mountain big sagebrush (*Artemisia tridentata vaseyana*) mallow ninebark (*Physocarpus malvaceus*), and western serviceberry (*Amelanchier alnifolia*)).

This study showed the significance of ecoregions influencing the distribution of upland and riparian vegetation. Chinook salmon habitat conditions are being monitored in three study watersheds within the Grande Ronde basin (the upper Grande Ronde River, Catherine Creek, and the Minam River) (McCullough et al. 2013). Riparian vegetation restoration to potential natural conditions is essential to the full recovery of the listed spring Chinook salmon populations in these watersheds. Identifying historical indicator plant communities within the riparian zones of various local ecoregions from historical surveys could be a means to identify reference conditions for restoration goals of Chinook salmon spawning and rearing areas which have been affected by anthropogenic land use practices. Monitoring the current landscape for the indicator plant species distribution and abundance, which are assumed to be the representative plant communities

of historical ecoregions, could be a gage on how much change has occurred and how much effort will be needed for restoration.

A source of error in the data could be surveyor bias. Methodologies and protocols used to survey the land were different for regions and time periods in which the surveys were conducted. “Bearing” trees (i.e., trees used to sight compass bearings from points on the section lines) were recorded only if they had a diameter greater than 2.95 in (7.5 cm) and the level of completeness in data entry varied from surveyor to surveyor (Collins & Montgomery 2001). Some surveyors presumably had more knowledge about vegetation than others and some may have had more familiarity with Eastern U.S. plants and not of Western plants. Therefore, plants may have been misidentified due to surveyor lack of knowledge of plant species of the Pacific Northwest. Surveyors were also looking at the landscape for potential resource extraction and were biased in describing plants that could be harvested for timber or were indicators of rich soil for farming. Settlements and roads were recorded in the GLO surveys indicating that there has been some land use activity in this area before the surveys were conducted, meaning that some areas may have already had their vegetation altered and did not represent the true historical vegetation. Since we have not collected all the data yet for the study area, another source of error is variation in sample sizes and the exclusion of the Minam River basin in the rearing data. Excluding the Minam River basin in the rearing analysis does not provide a complete analysis of the study area and may be biasing the results due to potential differences in vegetation among basins.

This preliminary analysis showed that the ecoregion may be the best predictor of vegetation communities and that some plant species may be indicators for an ecoregion. The historical data can be used as a tool to determine reference conditions for comparison of past and current vegetation located within a site and help predict which plant communities are to be expected at the site location. Further analysis of the different types of data noted in GLO surveyor notes could include surveyor biases, changes in stream complexity and sinuosity, changes in abundance and distribution of historical vegetation, and identifying the leading land use practices which led to changes in environmental conditions.

Acknowledgements

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Figures

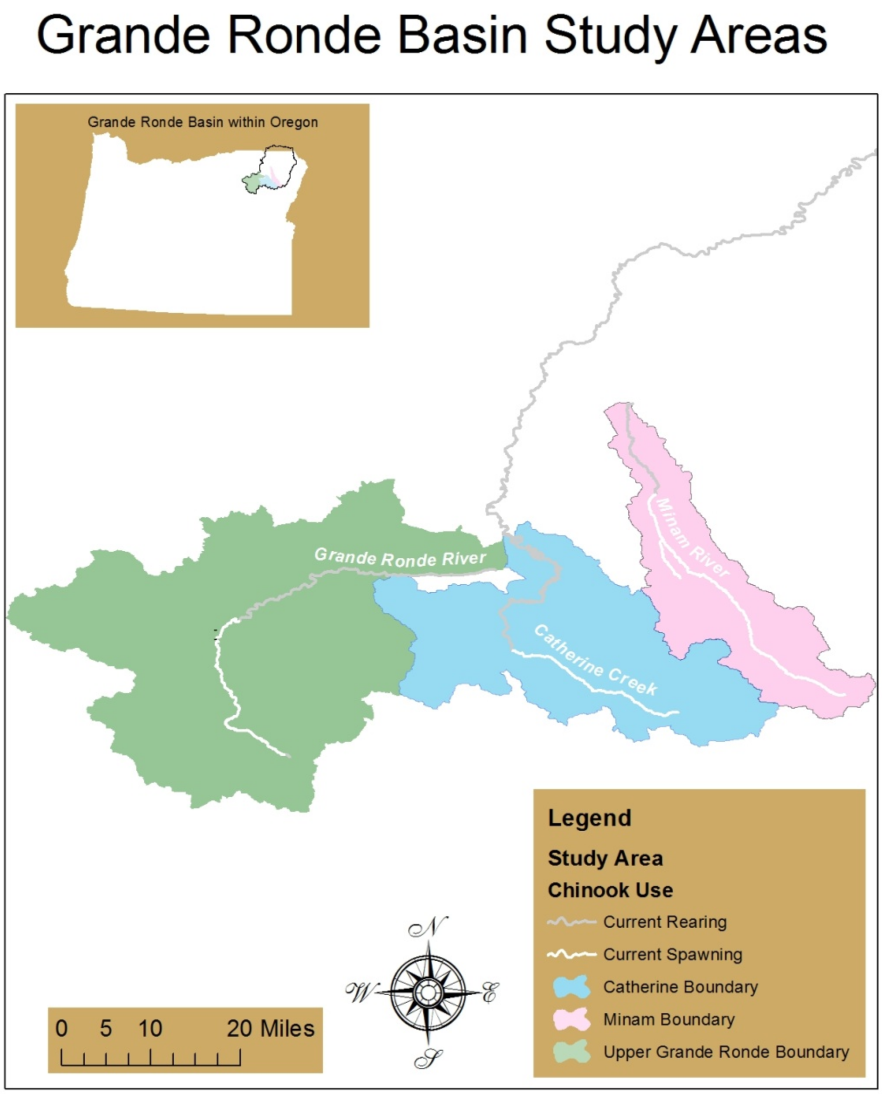


Figure 1: Study areas located in the Grande Ronde Basin which includes the mainstems of the Upper Grande Ronde River, Catherine Creek, and the Minam River.

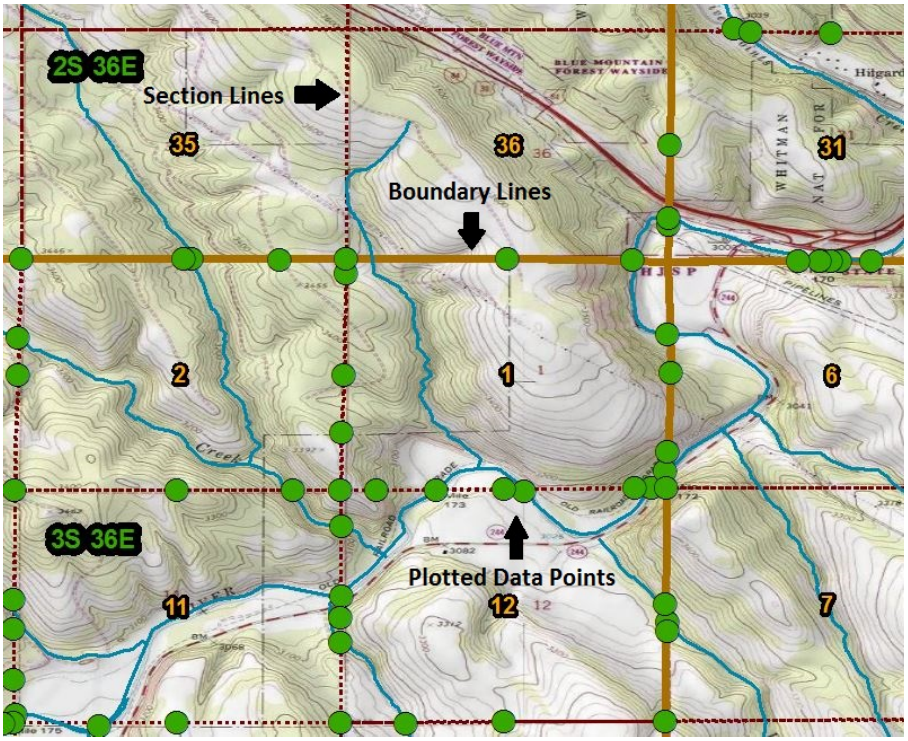
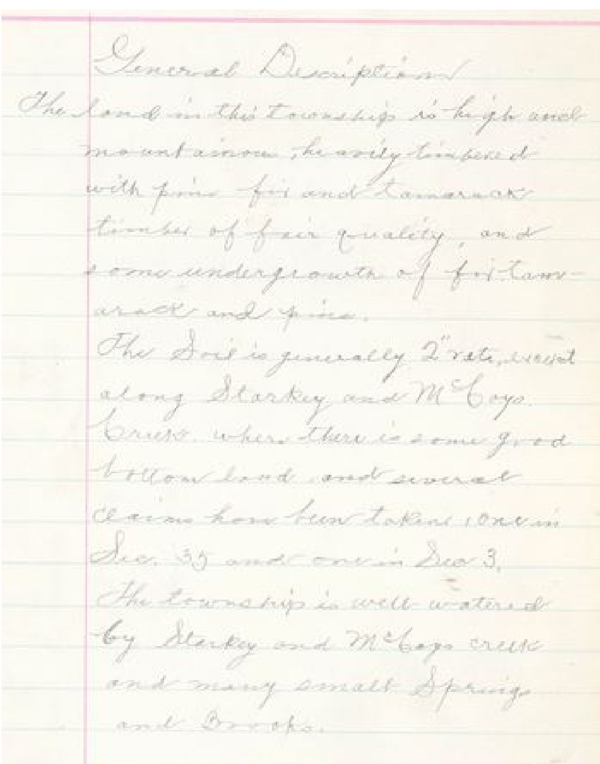


Figure 2: Use of Geographic Information System to plot data points (colored in green) retrieved from Government Land Office Township surveys in the Grande Ronde Basin.



General Description
The land in this township is high and
mountainous, heavily timbered
with pine fir and Tamarack
timber of fair quality, and
some undergrowth of fir tam-
arack and pine.
The Soil is generally 2nd rate, except
along Starkey and McCoys
Creeks where there is some good
bottom land and several
claims have been taken, One in
Sec. 35 and one in Sec 3.
The township is well watered
by Starkey and McCoys creek
and many small Springs
and Brooks.

Figure 3: Example of hand written Government Land Office township summary survey document circa 1882 for the Grande Ronde River basin.

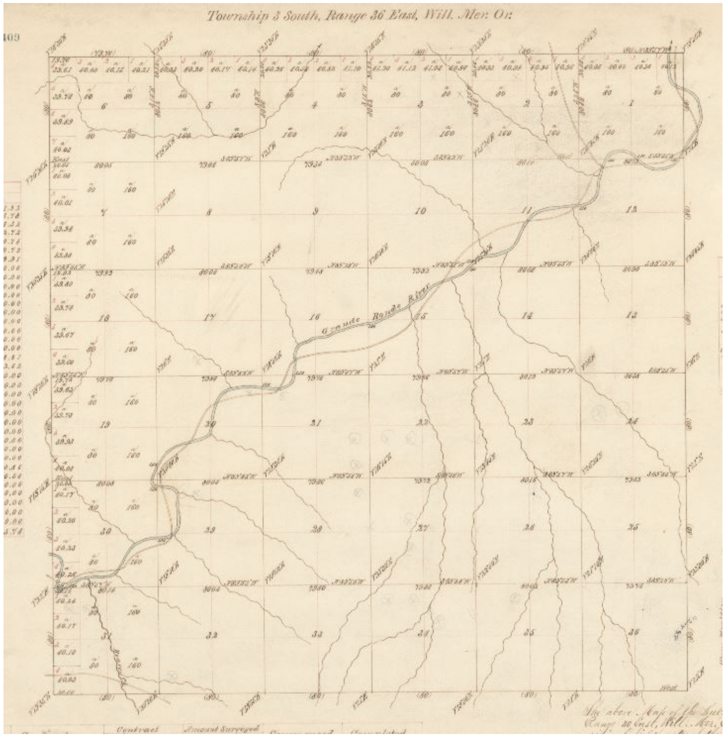


Figure 4: Example of hand drawn map based off of Government Land Office township surveys circa 1874 upon completion of township survey in the Grande Ronde Basin.

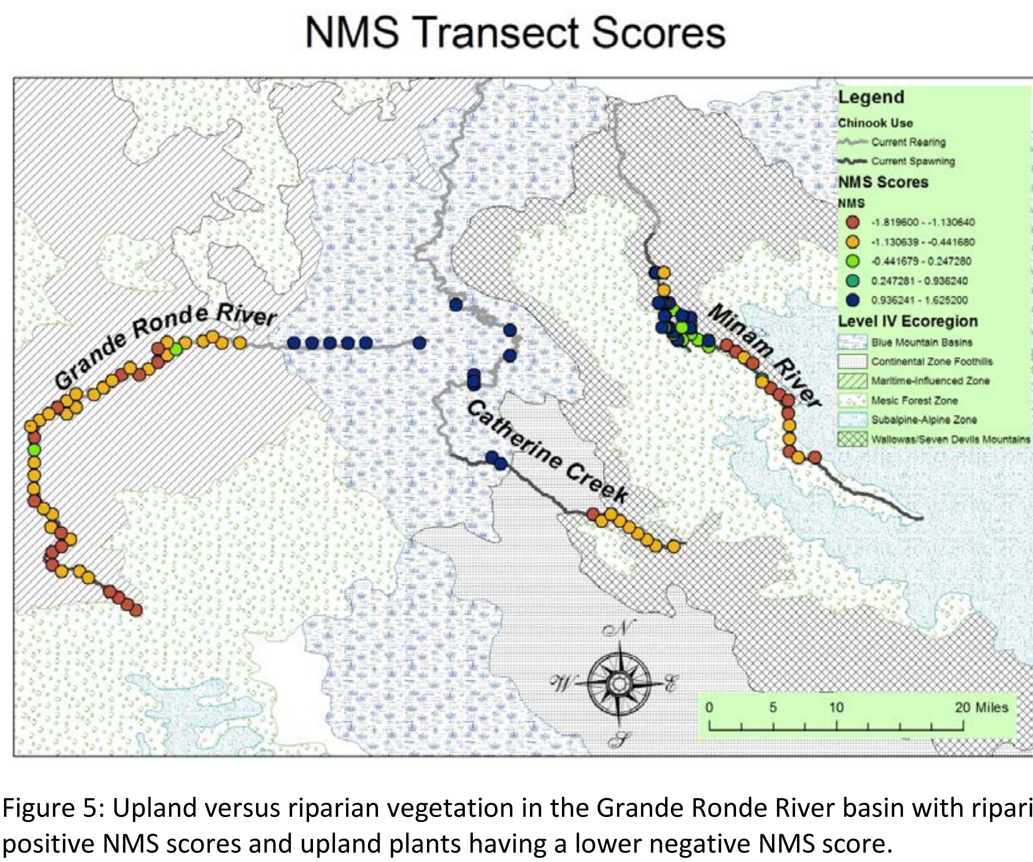


Figure 5: Upland versus riparian vegetation in the Grande Ronde River basin with riparian plants consisting of the higher positive NMS scores and upland plants having a lower negative NMS score.

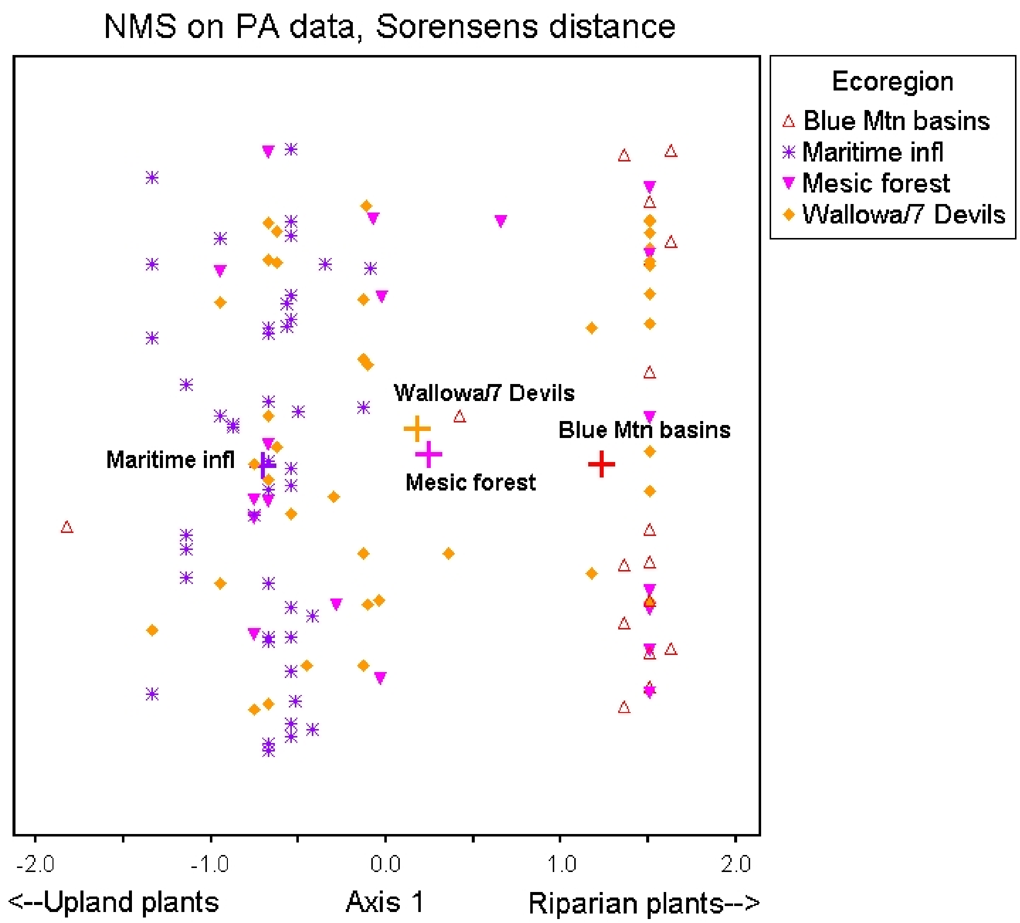


Figure 6: Nonmetric Multidimensional Scaling ordination plot of upland versus riparian plants located within each ecoregion present.

Tables

Table 1: All plant taxa present in study area. Species with asterix (*) had a presence of 5% or greater and were used in analysis.

Taxa	
Alder*	Hemlock
Balm*	Maple
Birch	Mt Mahogany
Cottonwood*	Mt Laurel
Crabapple	Pine*
Fir*	Rose
Grass*	Spruce*
Willow*	Tamarack*

Table 2: Ecoregions within study area. Ecoregions with asterix (*) had locations on more than one transect.

Ecoregions	
Blue Mt Basin*	Continental Zone Foothills
Mesic Forest Zone*	Wallowas/Seven Devils Mts*
Maritime Influenced Zone*	Subalpine/Alpine Zone

Table 3: Nonmetric Multidimensional Scaling values for presence/absence of each species.

Taxa	NMS Value
Cottonwood	1.192
Willow	1.017
Alder	0.212
Spruce	-0.103
Balm	-0.220
Grass	-0.478
Fir	-0.498
Tamarack	-0.521
Pine	-0.612

Table 4: Multi-Response Permutation Procedures against riparian vegetation data using Sorensen (Bray-Curtis) distance measures and rank transformed distance matrix.

Category	Number of Groups	A-Statistic	P-value
Chinook Use	2	0.019	0.021
Basin	3	0.108	4.70E-07
Ecoregion	4	0.255	< 1.0E-08
Surveyor	11	0.484	< 1.0E-08

Table 5: Indicator values for taxa type versus ecoregion.

Ecoregion	Taxa	Phi Scores	P-value
Blue Mt Basin	Willow	0.378	0.0014
	Cottonwood	0.587	0.0002
Maritime Influenced Zone	Grass	0.409	0.0004
	Pine	0.457	0.0002
	Tamarack	0.230	0.0310
Wallowas/Seven Devils Mts	Balm	0.470	0.0004

Appendix H. A list of all unique monitoring sites in the Upper Grande Ronde River and Catherine Creek sampled by CRITFC and ODFW.

Table distinguishes latest sample date for annual sites (sampled every year from 2011-2013), rotating panel sites, and extra sites (added to the rotating panel in 2013). Lat/long coordinates (UTM) indicate the bottom of site for each site. Also given are the most currently known number of active benchmarks serving as the reference points for Total Station surveys.

SiteID	Sample Date	VisitID	Measure Nbr	Crew	Stream Name	Panel	Bottom Of Site UTMZone	Bottom Of Site UTM Easting	Bottom Of Site UTM Northing	Number of bench marks
CBW05583-228666	7/17/2013	1333	171697890	CRITFC	Sheep Creek	Annual	11	384623	4988280	3
CBW05583-405674	9/23/2013	1347	174485438	CRITFC	Catherine Creek	Annual	11	434103	5005125	4
CBW05583-421786	7/25/2012	796	168397	CRITFC	Rock Creek	Annual	11	406959	5017229	3
CBW05583-487322	7/23/2012	797	168043	CRITFC	Rock Creek	Annual	11	407504	5016354	3
dsgn4-000006	8/30/2011	179	140605	CRITFC	West Chicken Creek	Annual	11	389626	4990427	3
dsgn4-000009	7/11/2013	1339	171394170	CRITFC	Grande Ronde River	Annual	11	397787	4989997	4
dsgn4-000010	8/9/2013	1350	174669630	CRITFC	Catherine Creek	Annual	11	444089	4998107	4
dsgn4-000092	8/31/2011	139	140613	CRITFC	Spring Creek	Annual	11	400292	5020270	3
dsgn4-000094	9/1/2011	140	140621	CRITFC	Fly Creek	Annual	11	385811	4997843	3
dsgn4-000202	7/19/2013	1340	171425674	CRITFC	Grande Ronde River	Annual	11	390902	5010925	5
dsgn4-000204	8/28/2013	1385	174375439	CRITFC	Catherine Creek	Annual	11	432089	5006604	5
dsgn4-000245	7/30/2013	1341	171728207	CRITFC	Grande Ronde River	Annual	11	392832	5013601	6
dsgn4-000277	7/15/2013	1342	171394430	CRITFC	Grande Ronde River	Annual	11	392554	4998782	3
CBW05583-099818	7/10/2013	1331	171151601	CRITFC	Grande Ronde River	Extra	11	398350	4989411	3
CBW05583-325034	8/20/2013	1353	174375151	CRITFC	Catherine Creek	Extra	11	444476	4997642	3
CBW05583-370490	9/5/2013	1804	172825604	CRITFC	Grande Ronde River	Extra	11	391992	5000498	3
CBW05583-108010	7/11/2011	16	140443	CRITFC	Limber Jim Creek	Rotating Panel 1	11	395302	4995285	3
CBW05583-138554	7/13/2011	18	140450	CRITFC	Sheep Creek	Rotating Panel 1	11	385423	4990679	3
CBW05583-138666	9/13/2011	334	140451	CRITFC	North Fork Catherine Creek	Rotating Panel 1	11	449908	4997197	3
CBW05583-148970	7/24/2011	83	140447	CRITFC	Grande Ronde River	Rotating Panel 1	11	396639	4991084	3
CBW05583-155818	9/6/2011	84	140453	CRITFC	Little Catherine Creek	Rotating Panel 1	11	443666	4999598	3
CBW05583-206314	9/14/2011	86	140474	CRITFC	Grande Ronde River	Rotating Panel 1	11	395756	4992159	3
CBW05583-217258	9/8/2011	87	140475	CRITFC	Catherine Creek	Rotating Panel 1	11	430865	5006831	3
CBW05583-235322	8/9/2011	89	140482	CRITFC	Grande Ronde River	Rotating Panel 1	11	391708	5001197	3
CBW05583-269114	8/4/2011	93	140503	CRITFC	Grande Ronde River	Rotating Panel 1	11	391128	5012067	3
CBW05583-280042	7/27/2011	27	140507	CRITFC	Grande Ronde River	Rotating Panel 1	11	397642	4990201	3
CBW05583-321338	8/15/2011	97	140516	CRITFC	Grande Ronde River	Rotating Panel 1	11	392691	4999647	3
CBW05583-368042	9/21/2011	99	140530	CRITFC	Catherine Creek	Rotating Panel 1	11	448013	4996286	3
CBW05583-430250	9/19/2011	138	140553	CRITFC	Catherine Creek	Rotating Panel 1	11	430541	5006856	3
CBW05583-456106	8/25/2011	104	140556	CRITFC	Catherine Creek	Rotating Panel 1	11	445093	4996877	3
CBW05583-457530	8/18/2011	105	140561	CRITFC	Grande Ronde River	Rotating Panel 1	11	390371	5009661	3
CBW05583-490810	8/17/2011	107	140564	CRITFC	Sheep Creek	Rotating Panel 1	11	384880	4989154	3
CBW05583-512938	9/20/2011	333	140569	CRITFC	South Fork Catherine Creek	Rotating Panel 1	11	454223	4994742	3
CBW05583-013226	9/11/2012	972	244987	CRITFC	South Fork Catherine Creek	Rotating Panel 2	11	455944	4995020	3
CBW05583-015162	7/16/2012	791	159665	CRITFC	McCoy Creek	Rotating Panel 2	11	389446	5013221	3
CBW05583-086954	8/29/2012	968	218302	CRITFC	South Fork Catherine Creek	Rotating Panel 2	11	452340	4994341	3
CBW05583-109994	9/19/2012	1086	272305	CRITFC	Middle Fork Catherine Creek	Rotating Panel 2	11	454289	4999943	3
CBW05583-285498	7/18/2012	792	160013	CRITFC	Meadow Creek	Rotating Panel 2	11	387308	5010321	4
CBW05583-335162	8/2/2012	793	188036	CRITFC	Sheep Creek	Rotating Panel 2	11	385075	4989867	3
CBW05583-340138	9/24/2012	1087	272656	CRITFC	Catherine Creek	Rotating Panel 2	11	434250	5004561	3

CBW05583-381866	8/27/2012	969	218658	CRITFC	South Fork Catherine Creek	Rotating Panel 2	11	455061	4994526	3
CBW05583-417962	9/12/2012	973	280544	CRITFC	Catherine Creek	Rotating Panel 2	11	443763	4998235	3
CBW05583-453946	6/26/2012	555	144947	CRITFC	Sheep Creek	Rotating Panel 2	11	384469	4987664	3
CBW05583-498490	8/20/2012	880	208044	CRITFC	Meadow Creek	Rotating Panel 2	11	386120	5010440	3
CBW05583-506682	7/11/2012	556	158969	CRITFC	Fly Creek	Rotating Panel 2	11	390051	5006738	3
CBW05583-514874	7/9/2012	557	159322	CRITFC	Meadow Creek	Rotating Panel 2	11	388866	5011831	3
CBW05583-531882	8/13/2012	963	219377	CRITFC	North Fork Catherine Creek	Rotating Panel 2	11	450849	4998263	3
ORW03446-137980	8/16/2012	964	257635	CRITFC	Catherine Creek	Rotating Panel 2	11	440167	5000114	3
CBW05583-031546	7/25/2013	1329	171727947	CRITFC	Grande Ronde River	Rotating Panel 3	11	390576	5007683	3
CBW05583-036266	8/26/2013	1343	172825102	CRITFC	Catherine Creek	Rotating Panel 3	11	446791	4996091	3
CBW05583-071770	8/2/2013	1330	171849016	CRITFC	Grande Ronde River	Rotating Panel 3	11	397266	5017497	3
CBW05583-109658	9/4/2013	1332	172824837	CRITFC	Grande Ronde River	Rotating Panel 3	11	403826	5021688	3
CBW05583-204202	9/12/2013	1344	172895122	CRITFC	South Fork Catherine Creek	Rotating Panel 3	11	450416	4995568	3
CBW05583-253354	9/10/2013	1345	172894636	CRITFC	North Fork Catherine Creek	Rotating Panel 3	11	451111	4999024	4
CBW05583-294202	6/26/2013	1335	171020098	CRITFC	West Chicken Creek	Rotating Panel 3	11	389474	4989197	3
CBW05583-311466	8/15/2013	1346	172825343	CRITFC	Catherine Creek	Rotating Panel 3	11	439053	5000514	5
CBW05583-442266	6/25/2013	1336	170998458	CRITFC	Rock Creek	Rotating Panel 3	11	406178	5018511	3
CBW05583-449962	9/16/2013	1348	174359423	CRITFC	Middle Fork Catherine Creek	Rotating Panel 3	11	452002	4999939	3
CBW05583-468458	7/2/2013	1337	171393900	CRITFC	Grande Ronde River	Rotating Panel 3	11	395107	4992651	3
CBW05583-502586	8/7/2013	1338	171849268	CRITFC	Fly Creek	Rotating Panel 3	11	388807	5003357	3
CBW05583-515498	9/18/2013	1349	174375699	CRITFC	North Fork Catherine Creek	Rotating Panel 3	11	452375	5001652	3
ORW03446-071176	8/29/2013	1351	172771971	CRITFC	Milk Creek	Rotating Panel 3	11	443651	4998115	3
CBW05583-086186	9/9/2013	1797	172824220	ODFW	Catherine Creek	Annual	11	428505	5007537	3
CBW05583-147626	8/27/2013	1798	172336796	ODFW	Catherine Creek	Annual	11	436695	5002449	3
CBW05583-240730	6/21/2012	483	142899	ODFW	Rock Creek	Annual	11	403950	5021634	3
CBW05583-252730	7/29/2013	1501	171502652	ODFW	Meadow Creek	Annual	11	389670	5012415	3
CBW05583-527786	8/20/2013	1443	171998118	ODFW	Catherine Creek	Annual	11	445901	4996416	3
dsgn4-000001	8/20/2013	1444	171998381	ODFW	North Fork Catherine Creek	Annual	11	449378	4996719	3
dsgn4-000006	6/20/2013	1322	170808739	ODFW	West Chicken Creek	Annual	11	389645	4990436	3
dsgn4-000094	7/2/2013	1446	170975147	ODFW	Fly Creek	Annual	11	385822	4997835	3
dsgn4-000161	8/26/2013	1717	172613680	ODFW	South Fork Catherine Creek	Annual	11	455515	4994703	3
dsgn4-000168	9/23/2013	1718	174481158	ODFW	North Fork Catherine Creek	Annual	11	451458	5000050	4
dsgn4-000205	8/6/2013	1719	171836053	ODFW	Grande Ronde River	Annual	11	400037	5018984	3
dsgn4-000213	7/29/2013	1502	171515098	ODFW	Meadow Creek	Annual	11	390655	5013164	3
CBW05583-062890	7/1/2013	1441	170970858	ODFW	Milk Creek	Extra	11	444485	4997219	3
CBW05583-278698	9/3/2013	1799	172667458	ODFW	Catherine Creek	Extra	11	435188	5003951	3
CBW05583-316330	8/31/2011	234	140515	ODFW	South Fork Catherine Creek	Rotating Panel 1	11	453290	4994596	3
CBW05583-420954	9/8/2011	232	140549	ODFW	Grande Ronde River	Rotating Panel 1	11	401278	5019473	3
CBW05583-446634	8/29/2011	102	140552	ODFW	Catherine Creek	Rotating Panel 1	11	433286	5006178	3
CBW05583-073130	9/12/2012	661	243625	ODFW	South Fork Catherine Creek	Rotating Panel 2	11	451381	4994477	3
CBW05583-486202	8/20/2012	662	207695	ODFW	Grande Ronde River	Rotating Panel 2	11	390935	5004334	3
ORW03446-159368	7/10/2012	581	153874	ODFW	Chicken Creek	Rotating Panel 2	11	390100	4990155	3
CBW05583-020282	8/19/2013	1581	172030651	ODFW	Meadow Creek	Rotating Panel 3	11	383425	5011663	3
CBW05583-269738	8/27/2013	1442	172293240	ODFW	South Fork Catherine Creek	Rotating Panel 3	11	449897	4996010	3
ORW03446-139144	8/14/2013	1582	171934994	ODFW	Meadow Creek	Rotating Panel 3	11	385211	5010725	3

Appendix I. List of map files in geodatabase and in ArcCatalog database-2014-b.pdf - Shortcut

- GRonde_GIS.gdb
  - Bio_Fish
    - brkt_v09
    - bull_v12
    - coho_v12
    - critfc_chinook_extent
    - CRITFC_Chinook_Extent_March2014
    - CRITFC_Chinook_Target_Frame_April2012
    - Dist_Anadromous_GrandeR
    - Dist_Fall_Chinook_GrandeR
    - Dist_Spring_Chinook_GrandeR
    - Dist_Spring_Chinook_GrandR_Historic
    - Dist_Summer_Steelhead_GrandeR
    - fish_barriers
    - GR_AU_chinook_20120426
    - GR_AU_steelhead_20120508
    - juv_release
    - ofpbds_barriers
    - rain_v09
    - TRT_granderonde200ms
  - Bio_Invert
  - Bio_Other
  - CHaMP
    - BM_CRITFC_ODFW_2011_2013
    - BOS_CRITFC_ODFW_2011_2013
    - CHaMP18_Buildout

- CHaMP
  - BM_CRITFC_ODFW_2011_2013
  - BOS_CRITFC_ODFW_2011_2013
  - CHaMP18_Buildout

- Climate
- Coop_USGS
  - RisleyGages
  - RisleyWatersheds
- GR_Atlas
  - AU
  - CathCr_BOR_Trib_ReachBreaks
  - ccc_allreachbndry_new
  - HUC6_AU
- H20_Temp_Model
  - BeaverCr
  - CatherineCrabvUnion
  - ChickenCr
  - ClearCr
  - FivePoints
  - FlyCr
  - GR_streams
  - GrRonde
  - LimberJimCr
  - LittleCr
  - MeadowCr
  - MilkCr
  - MWMT_Combined
  - NFCatherine
  - SFCatherine
  - SheepCr
- Habitat_Flow
  - CRITFC_Flow_Gauges
  - critfc_flow_sites_2009
  - flow_station
  - gauges_gr_v2a
  - GRgaugesRaFTdatabase
- Habitat_Other
  - AHI_1990s_habitat
  - AHI_1990s_reach
  - AHI_2000s_habitat
  - AHI_2000s_reach
  - AHI_2010s_habitat
  - AHI_2010s_reach
  - critfc_habitat_survey_reaches_2010
  - external_agency_water_quality_sites
- Habitat_Sed
  - critfc_sediment_sites
- Habitat_Temp
  - critfc_temp_sites_09_10
  - external_agency_temp_sites
  - MasterTempLocations
  - wq_station
- HLR
  - Aquifer_Permeability_Class
  - Climate_Aquifer_Permeability_Class
  - Climate_Class
  - DEM_Stream_Network
  - HLR_Class
  - Hydrologic_Assessment_Units
  - Oregon_Aquifer_Groups
  - Seasonality_Subclass
  - Soil_Permeability_Class
  - Terrain_Class

- Hydro_paek
  - beaver_natpaek_pts
  - catherinenatpaek_pts
  - clear_natpaek_pts
  - fivepoint_natpaek_pts
  - flynatpaek_pts
  - ladd_nhd_natpaek_pts
  - limberjim_natpaek_pts
  - littlecathnatpaek_pts
  - littlenatpaek_pts
  - mccoy_natpaek_pts
  - meadow_natpaek_pts
  - milknhd_spchonly_pts
  - mill_nhd_natpaek_pts
  - nfcathnatpaek_pts
  - oldgr_natpaek_pts
  - pelican_natpaek_pts
  - pyles_natpaek_pts
  - rock_natpaek_pts
  - sfcathnatpaek_pts
  - sheep_natpaek_pts
  - spring_natpaek_pts
  - ugr_natpaek_pts
  - whiskey_natpaek_pts

- Hydrography
  - Cath_boundary
  - Cath_boundary_Buf
  - Cath_boundary_updated
  - cath_cut_layer
  - Cath_HUC6
  - CHaMP_watersheds_fullbuildout
  - cu_modeled_reaches
  - GR_boundary
  - GR_HUC6
  - GR_mixed_hydro
  - GR_mixed_hydro_Buffer
  - GR_mixed_hydro_named
  - Hydro100k
  - Minam_boundary
  - minam_cut_layer
  - minam_huc6
  - Netstream_reachesCU
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  - NHD_unnamed
  - NHDPlus_Flowline_Strahler
  - NHDPlus_Flowline_Strahler_BigStreams
  - str_303d02
  - str_303d98
  - StudyArea_boundary
  - StudyArea_HUC6
  - ugr_cut_layer
  - UpGR_boundary
  - UpGR_HUC5
  - UpGR_HUC6
  - Wallowa_boundary
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  - wen_cut_layer
  - Wenaha_boundary
  - Wenaha_HUC6
  - WildScenicRiv_GrandeR

- Landscape
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  - Contour200ft
  - WhittierLandscapeClassifications
- LandUse
  - allstatehwy_GR
  - allushwy_GR
  - Blm_Vale_GR
  - dams
  - dynaroads_GR
  - GR_Hwys_all
  - LandOwners
  - LandOwners_revised
  - NF_Trail
  - Quad24k_GrandeR
  - Towns_GrandeR
  - Union_County_tax_lots_2008
- NetMap
  - basin_ugr1
  - lake_ugr1
  - reach_ugr1
  - roaddrain_ugr1
  - roads_ugr1
  - roadseg_ugr1
  - roadX_ugr1
  - tribs_ugr1

- ODFVeg
- ODFW_ReddSurveys
  - AllRedds_09_13
  - ODFW_spawnindex04
  - ODFW_spawnindex09_13
  - Redds_odfw_2004_2008
  - SnapRedds09_12
  - SnapRedds2013
- Photos
  - PhotoPoints
- PNV
  - HS_extent_mult_buff
  - NHD_extent
- RestProjects
  - bpa_projects_GrandeR
  - GRMW_project_pts
- Soils
  - soilmu_a_or625
  - soilmu_l_or625
  - soilmu_p_or625
  - soilsa_a_or625
- SubPlan_Data
  - obstructions_edt
  - reach_edt

- Survey_Design
  - cu_use_extent_GRTSfixed2
  - cu_use_extent_GRTSfxpts
  - grts_output_dsgn4_pts1
  - grts_reaches_2010_points_panels1_2
- USFSVeg
  - existingvegetation
  - historicvegetation_1900
  - potentialvegetation
  - RHCA
  - USFS_RiparianPlots
- WatershedSciences
  - FLIR_flight_modified
  - LIDAR_FlightCoverage
  - MonSites
  - Simulated_Streams_CRITFC
  - TIR_Recommended

- gr_dem10m
- gr_dem10m_hillshade
- GR_OBST
- GR_ratings_edt
- GR_SPCH_
- GRDEM10m_Mos
- NetStream_reaches_cu
- precip01p
- precip02p
- precip03p
- precip04p
- precip05p
- precip06p
- precip07p
- precip08p
- precip09p
- precip10p
- precip11p
- precip12p
- precip_anp
- tmean01p
- tmean02p
- tmean03p
- tmean04p
- tmean05p
- tmean06p
- tmean07p
- tmean08p
- tmean09p
- tmean10p
- tmean11p
- tmean12p
- tmean_anp
- ugr_cath_GRTS_1

- Explore Kasper data.mxd
- GrandeRonde-GIS data directory-Jan7-2014.txt
- ListofDataTypes.txt

- MOA_Habitat_Monitoring
  - Database Requests
  - GIS Requests
  - Grande Ronde
    - CHaMP_data
      - CHaMP_GrandeRonde_data
        - Grande_Ronde_CHaMP_GDB.gdb
        - Dams_2002_StreamNet.lyr
        - DEM.lyr
        - Eco_Level_III_US.lyr
        - Eco_Level_IV_US.lyr
        - Geomorphic_Class_20091030.lyr
        - Hatchery_2006_StreamNet.lyr
        - Land_Cover_NLCD.lyr
        - Land_Ownership.lyr
        - NHD_Waterbody_R17.lyr
        - NHDPlus_Flowline_Strahler.lyr
        - Precipitation.lyr
        - Road_100K_Tiger_2000.lyr
        - Temperature.lyr
    - FLIR
      - DELIVERABLE
        - Hydrography
        - Longprofiles
        - Natural_Color_Photo_Indices
        - Natural_Color_Unrectified
        - Thermal_Mosaics
        - Thermal_Singles_Unrectified
        - Thermal_Surveys
        - CRITFC_Grande_Ronde_TIR_2010.mxd

- GIS working files
  - AnnualReportsInfo
    - 2012Work_forReport
  - ArcReader
  - Basin_Projects
    - OriginalData
  - Created_Data
    - CheckGPSLatLong.dbf
    - GR_Cath_grad.shp
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    - KMLpolygons.shp
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      - Road
      - SnowMobile
      - Trail
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  - 45118c6_pro
  - 45118d2_pro

- Field_Files
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      - Bear_own.jpg
      - Beaver.jpg
      - Beaver_own.jpg
      - BridgeDownPole.jpg
      - BridgeUpUnion.jpg
      - BurntCorral.jpg
      - Chicken.jpg
      - Clear.jpg
      - CoveHwy342.jpg
      - DarkCanyon.jpg
      - DownEnsign.jpg
      - DownEnsign_own.jpg
      - DownESheep.jpg
      - DownLitDarkCan.jpg
      - DownMarion.jpg
      - DownPotters.jpg
      - DownSquaw.jpg
      - DownSquaw_own.jpg
      - DownTanner1.jpg
      - DownTanner2.jpg
      - DownTribSheep.jpg
      - FivePoints.jpg
      - FivePoints_own.jpg
      - Fly.jpg
      - Fly_own.jpg
      - HeadwatersNFCath.jpg
      - Jordan.jpg
      - Jordan_own.jpg
      - LimberJim.jpg
      - LimberJim_own.jpg
      - Little.jpg
      - LittleCatherine.jpg

- LittleCatherine.jpg
- LittleFly.jpg
- McCoy.jpg
- Meadow.jpg
- Meadow_own.jpg
- MFCatherineCr.jpg
- MidFlySheep.jpg
- NFCatherine.jpg
- NFCatherine_own.jpg
- Pelican.jpg
- Pelican_own.jpg
- RM4.5Fly.jpg
- Sheep.jpg
- UpBeatty.jpg
- UpCougarCan.jpg
- UpDryBeaver.jpg
- UpEndTIRClear.jpg
- UpEndTIRDarkCanyon.jpg
- UpEndTIRFivePoints.jpg
- UpEndTIRMeadow.jpg
- UpJim.jpg
- UpLadd.jpg
- UpLaGrande.jpg
- UpLittleJD.jpg
- UpNFLimberJim.jpg
- UpSyrup.jpg
- UpWFBeaver.jpg
- UpWFBeaver_own.jpg

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    - Grande Ronde - Model Input
    - Heat Source 6.0
    - Old Files from Matt Zip Disk
    - Topo_Shade
    - Upper Grande Ronde TMDL Library
    - Vegetation Assessment
      - Associated Files
      - Buffered Vegetation - Basin
    - Vegetation Assessment - Current
      - Mitch Presentation 5-13
      - Worksheets (& Old Drafts)
- ODFVeg
  - CrownC
  - Size
  - Species
  - Structure

- ODFVeg
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Appendix J. Life Cycle Model Table of Variables Representing Productivity and Capacity by Life Stage.

Example of tabular data that could be entered into the life cycle model. This table indicates for each life stage of spring Chinook, the kinds of variables that would be used to express productivity or capacity, the mathematical formulation of the metric and the time period over which it is calculated, and the spatial scale at which it is evaluated.

Productivity (P) or Capacity (C)	C	C	C	C	P/C	P
Life Stage	Adult spawners					
Intent to map	Spawning habitat area	Holding area	Holding area	Spawning habitat area	Pre-spawning temperature	Spawning temperature
Variable	September mean daily streamflow	Undercut area	Pool volume	Area available to spawn	July-August-15 7DADM	August 15-Sept 15 7DADM
Location of measurement	Averaged throughout the HUC using RBT	Entire HUC	Entire HUC	Entire HUC	Dstr end of HUC	Dstr end of HUC

Productivity (P) or Capacity (C)	P	P	P/C	P/C	P/C	P	P	P
Life Stage	Eggs		Summer parr					
Intent to map	Egg-to-fry	Egg-to-fry	Summer Parr-to-fall resident/migratory parr	Summer Parr-to-fall resident/migratory parr	Summer Parr-to-fall resident/migratory parr	Summer Parr-to-fall migratory parr	Summer Parr-to-fall migratory parr	Summer Parr-to-fall migratory parr
Variable	% fines <6 mm prior to spawning	winter 7DAD Min in HUC	July-August 7D ave. low flow	July-August 7DADM water temperature	July-August % of time T > 22C	October - November 7D ave. low flow	October-November 7DADM water temperature	October - November % of time T > 22C
Location of measurement	Mean for entire spawning habitat in HUC	Dstr end of HUC	Dstr end of HUC	Dstr end of HUC	Dstr end of HUC	Dstr end of lowest AU or main GR in Wallowa valley	Dstr end of lowest AU or main GR in Wallowa valley	Dstr end of lowest AU or main GR in Wallowa valley

Productivity (P) or Capacity (C)	P	P	P		P	P	P
Life Stage	Smolt to LGD						
Intent to map	Smolt to LGD--spring migrant	Smolt to LGD--spring migrant	Smolt to LGD--spring migrant	Smolt to LGD--spring migrant	Smolt to LGD--fall migrant	Smolt to LGD--fall migrant	Smolt to LGD--fall migrant
Variable	March-April mean daily flow	Smolt length	March-April mean daily water temperature	Pool volume	March-April mean daily flow	Smolt length	March-April mean daily water temperature

Location of measurement	Dstr end of HUC	At smolt trap	Dstr end of HUC	Dstr end of HUC	Dstr end of lowest AU or main GR in Wallowa valley	At LGD	Dstr end of lowest AU or main GR in Wallowa valley

Assuming that there are six HUCs or other appropriate spatial units over which habitat conditions and trends are evaluated, data for each of the columns represented in the LCM table above are tabulated for each year for each HUC. Below is a representation of the data needed for a single metric.

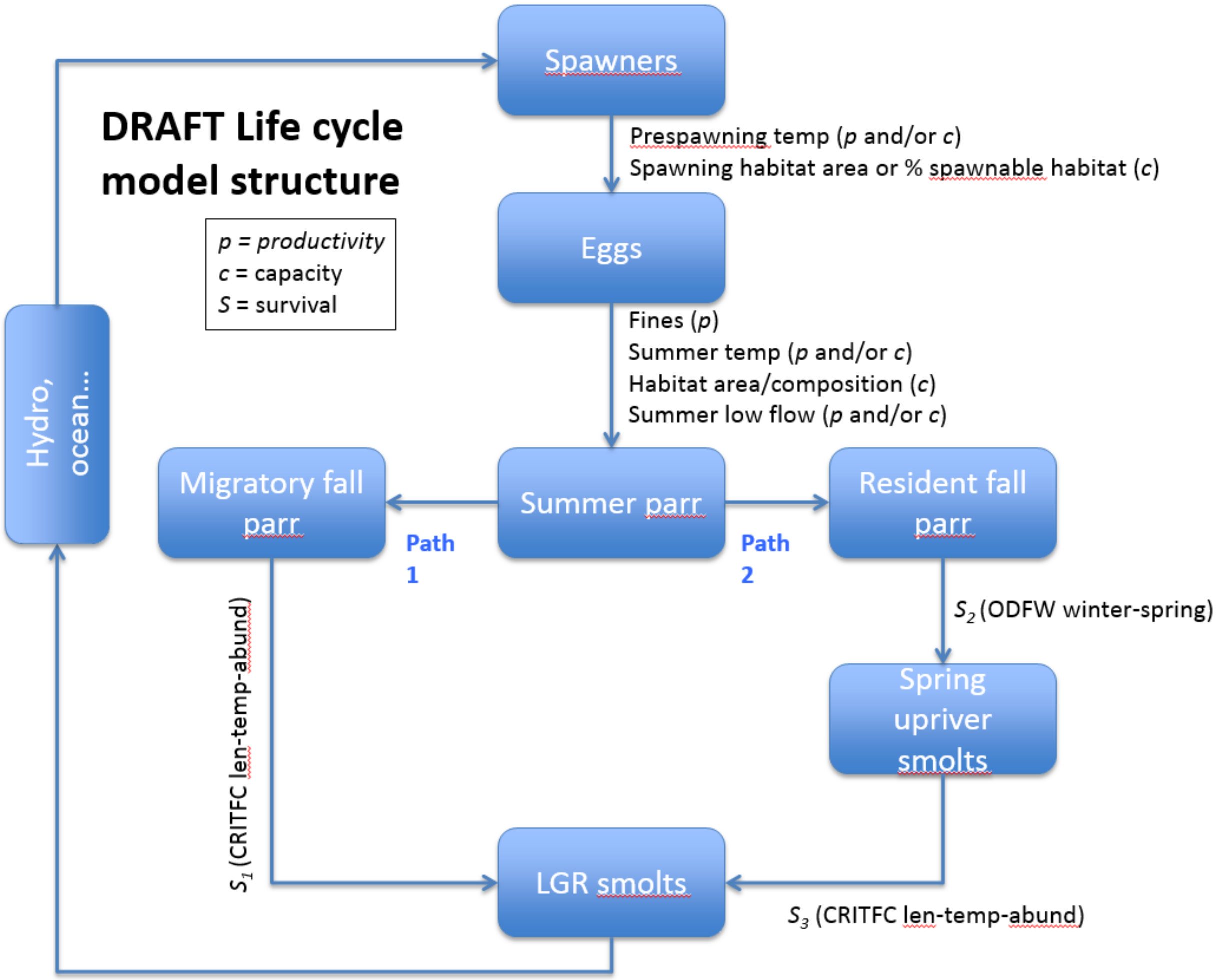
HUC 1	
2011	
2012	
2013	
HUC 2	
2011	
2012	
2013	
HUC 3	
2011	
2012	
2013	
HUC 4	
2011	
2012	
2013	
HUC 5	
2011	
2012	

2013	
HUC 6	
2011	
2012	
2013	

In order to evaluate the influence of spatially-specific habitat variables (e.g. water temperature) on a portion of the entire spring Chinook population, the proportion of the population that occupies each HUC, or other spatial assessment unit, must be known or assumed based on a specified logic. In addition, rules for migration among HUCs or downstream or upstream during development must be developed.

Percentage occupying HUC at various life stages

	Date	July-August 15	August 15-September 15	March 1-May 1	June-July	August	Dec-Jan
	Stage	Pre-spawning Adult	Spawning Adult	Fry	Early Summer Parr	Late Summer Parr	Late Winter Parr
HUC							
HUC 1		50	50	50	35	50	30
HUC 2		30	30	30	25	30	20
HUC 3		10	10	10	20	10	30
HUC 4		5	5	5	10	5	10
HUC 5		0	0	0	5	0	5
HUC 6		0	0	0	5	0	5


Spawners
DRAFT Life cycle model structure
p = productivity
c = capacity
S = survival
Prespawning temp (p and/or c)
Spawning habitat area or % spawnable habitat (c)
Eggs
Fines (p)
Summer temp (p and/or c)
Habitat area/composition (c)
Summer low flow (p and/or c)
Hydro, ocean…
Migratory fall parr
Summer parr
Resident fall parr
Path 1
Path 2
S2 (ODFW winter-spring)
Spring upriver smolts
S1 (CRITFC len-temp-abund)
LGR smolts
S3 (CRITFC len-temp-abund)

Appendix K. Factors influencing body size and survival of juvenile Chinook salmon migrants in the Upper Grande Ronde River basin

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700 NE Multnomah St., Suite 1200, Portland, OR 97232

Executive Summary

Body size of juvenile salmonids can greatly influence their survival during seaward migration. We analyzed passive integrated transponder (PIT) tag data collected by the Oregon Department of Fish and Wildlife from migration years 1994 to 2012 to evaluate factors influencing growth and survival of juvenile Chinook salmon captured in rotary screw traps in the Upper Grande Ronde River and Catherine Creek, eastern Oregon. We developed a set of linear models to test a series of *a priori* hypotheses about the factors influencing both fish length and survival. We used Akaike's Information Criterion (AIC) to select the best fitting model from the candidate set of models.

The best fitting model for mean fish length included migration group (i.e., early or late migrants), spawner abundance and average summer water temperature (July-August) as independent variables. The top model explained approximately 82 percent of the variation in average fish length for Catherine Creek migrants and 72 percent for Upper Grande Ronde migrants (Figure 1). Migration group explained the largest proportion of the variation in average fish length among the variables examined, accounting for approximately 46 and 37 percent of the total variation in fish length in Catherine Creek and the Upper Grande Ronde respectively. Late migrants were approximately 7.4 mm larger on average than early migrants in Catherine Creek, and 6.3 mm larger in the Upper Grande Ronde.

Fish length was negatively correlated with both spawner abundance and average summer temperature in both populations (Figure 2). Spawner abundance accounted for approximately 25 and 20 percent of the variation in mean fish length in Catherine Creek and the Upper Grande Ronde populations respectively. The slope of the relationship between length and spawner abundance was very similar between the two populations, with average fish length declining by approximately 1.3 and 1.2 mm for every increase of 100 spawners in Catherine Creek and the Upper Grande Ronde respectively (Figure 3a).

Summer temperature explained about 12 percent of the variation in mean fish length in Catherine Creek and 16 percent in the Upper Grande Ronde River. Average length of Catherine Creek migrants declined by approximately 1.5 mm for every 1 degree increase in average summer temperature (Figure 3b). The effect of temperature on fish size was somewhat more pronounced in the Upper Grande Ronde population, where average fish length declined by approximately 2.7 mm for every 1 degree increase in average summer temperature.

The best fitting capture-recapture model for survival and recapture probability of juvenile Chinook salmon for all release groups included sampling period (i.e. period 1 = release to Lower Granite Dam (LGD); period 2 = LGD to below LGD), year, and length effects for survival, and a period and year effect for recapture probability. AIC differences between the

top model and all other competing models ranged from 16 to 397, indicating overwhelming empirical support for the top model as the best fitting model in the candidate set.

Survival from release to Lower Granite Dam varied substantially across years as evidenced by the inclusion of a year effect in the best fitting model for all release groups. Year-specific survival estimates and associated confidence intervals for all release groups are provided in Figure 4. For example, survival estimates for average-sized fish (fork length = 82 mm) for Catherine Creek early migrants ranged from a low of 0.13 in 2001 to a high of 0.38 in 1997 (mean = 0.24; Figure 4). Variation in survival across years did not follow a consistent pattern across release groups and did not appear to be related to differences in average spring flow as evidenced by the relatively high ΔAICc values for models that included a flow effect.

Inclusion of a length covariate for survival vastly improved the model fit for all release groups, suggesting that body size had a strong positive influence on survival from release to Lower Granite Dam. A likelihood ratio test comparing models 1 and 6 confirmed that the length effect was statistically significant ($P < 0.001$). The intercepts of the survival-length curves varied substantially across release groups, which is not surprising given the differences in release time (early versus late migrants), rearing type (wild versus hatchery) and population (Upper Grande Ronde versus Catherine Creek (Figure 5). In contrast, the slopes of the curves were generally very similar across release groups, with survival increasing by an average of 6 % for every 10 mm increase in length for all release groups (range = 4.1 – 7.4 % per 10 mm).

These results provide useful information for natural resource scientists, managers, and other stakeholders seeking to understand the complex relationships between environmental factors (e.g., flow and temperature), biological factors (e.g., fish density, fish size) and productivity of Chinook salmon populations in the Upper Grande Ronde River and other populations in general. We intend that the models presented here will be used to parameterize the emigration survival component of a broader life cycle model for the Upper Grande Ronde basin which will be used to evaluate how land use, habitat restoration actions, and climate change influence long-term viability of ESA-listed Chinook salmon populations.

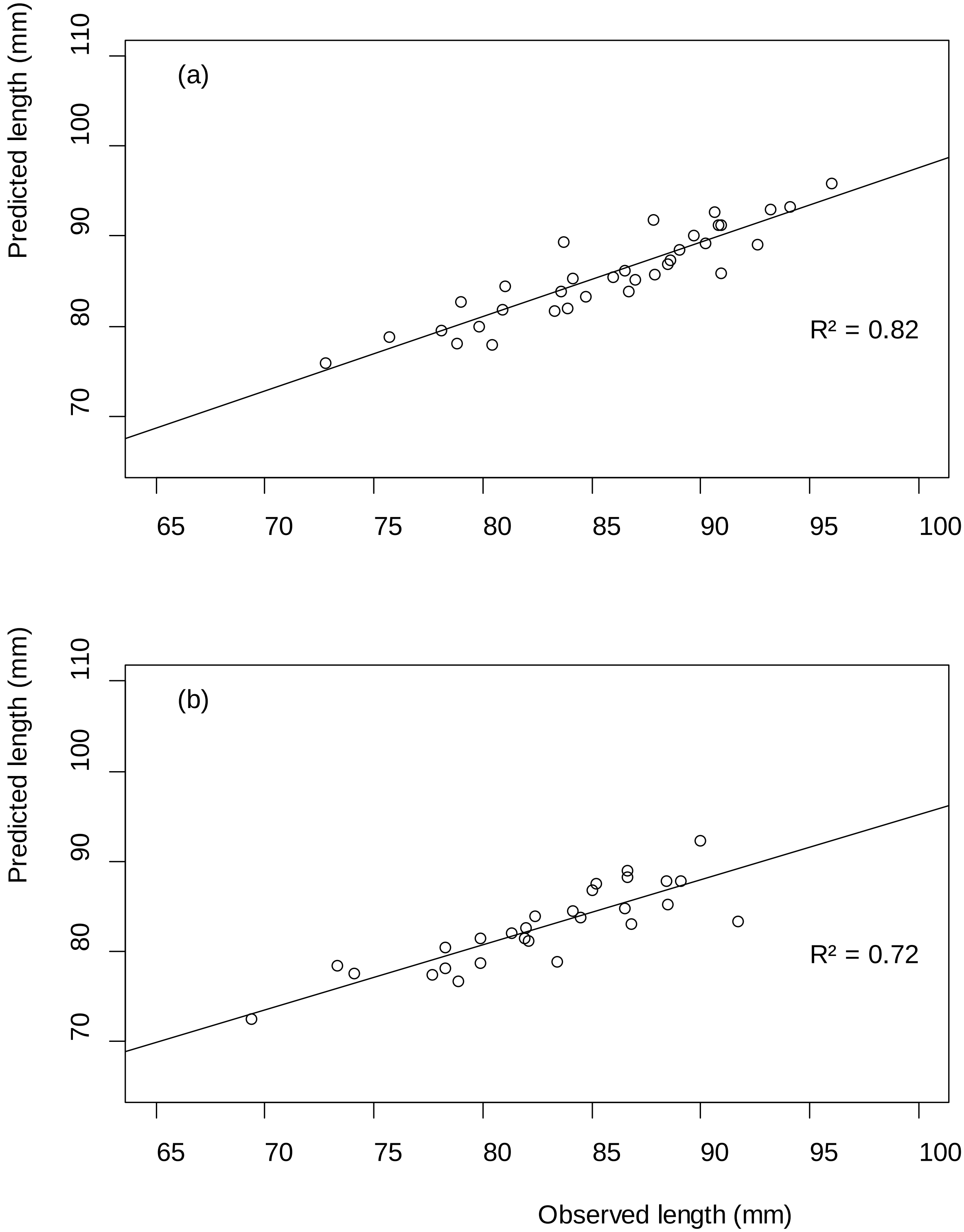


Figure 1. Relationships between observed and predicted length (mm) of juvenile Chinook salmon from the best fitting models for Catherine Creek (a) and Upper Grande Ronde (b) populations.

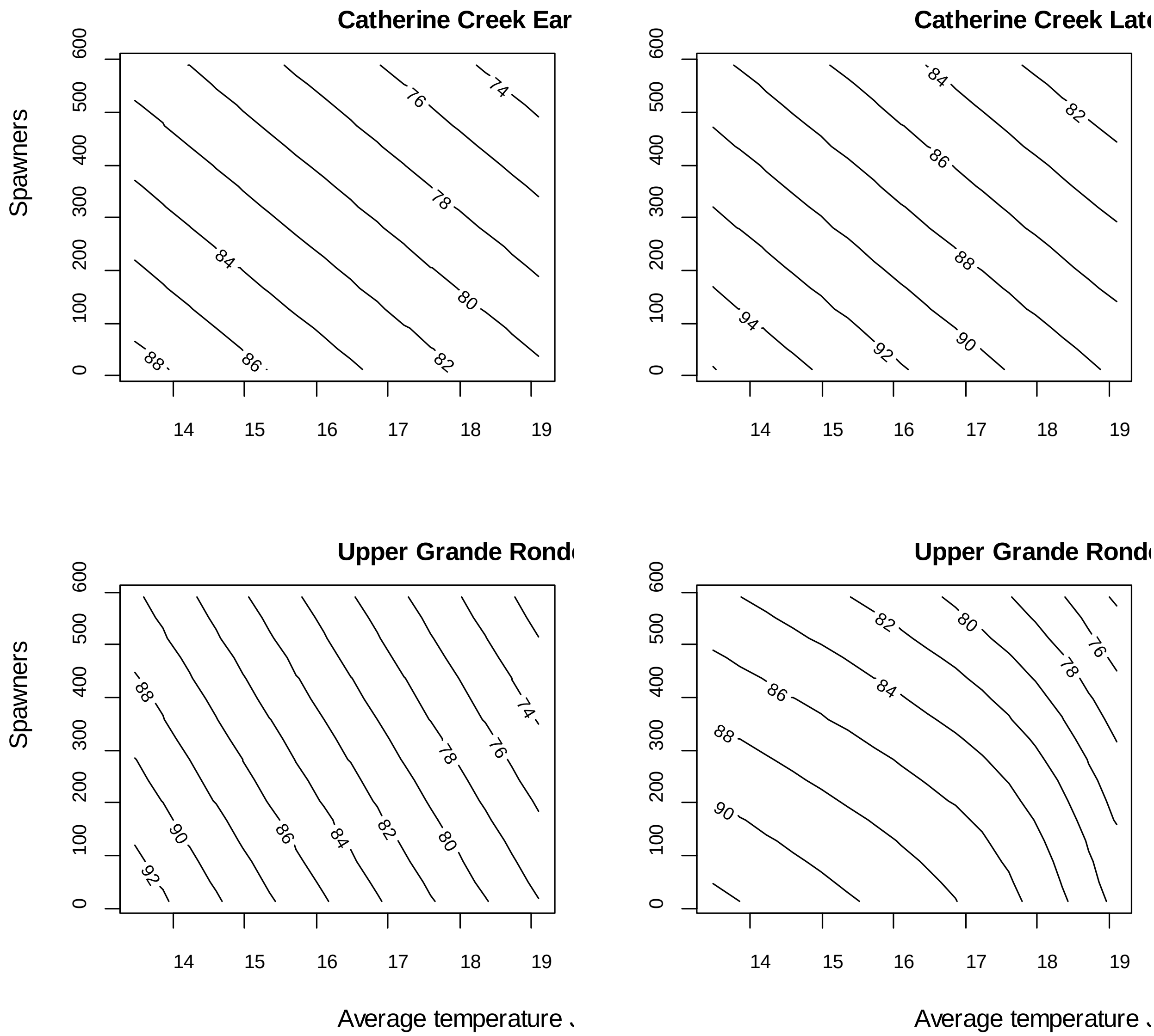
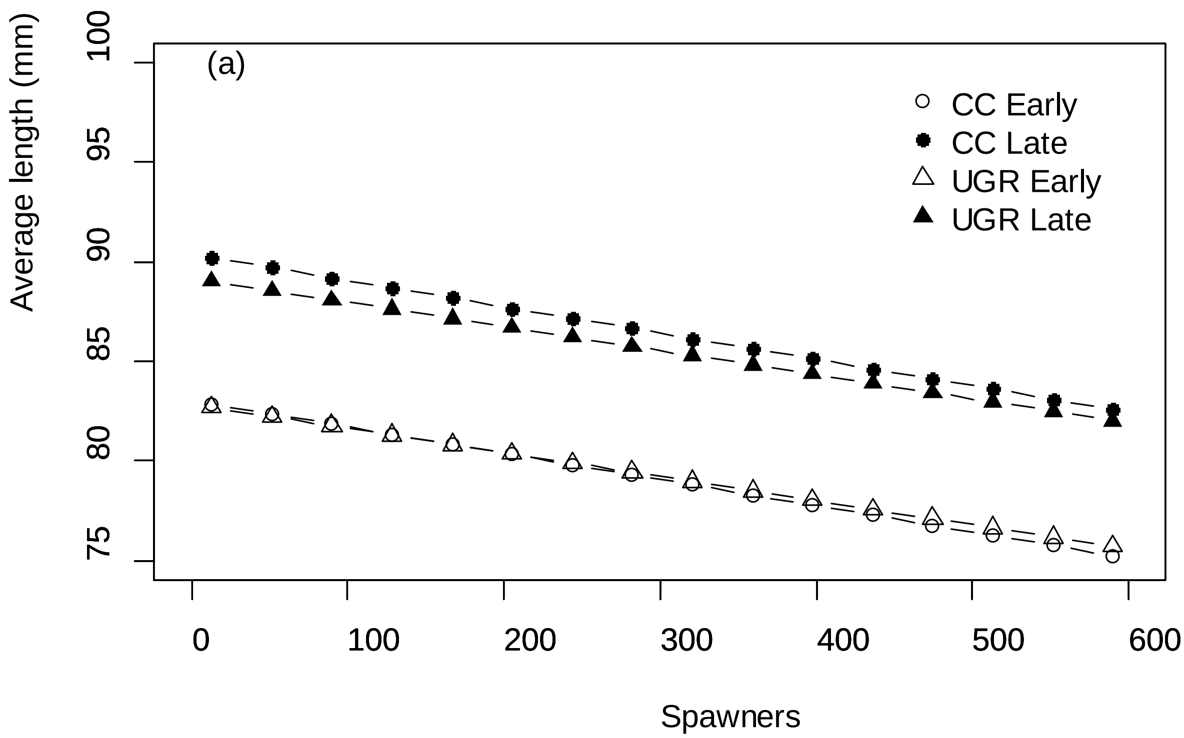


Figure 2. Contour plots from the best fitting linear models showing predicted fish length (mm) as a function of spawner abundance and average daily stream temperature (°C) from July-August.



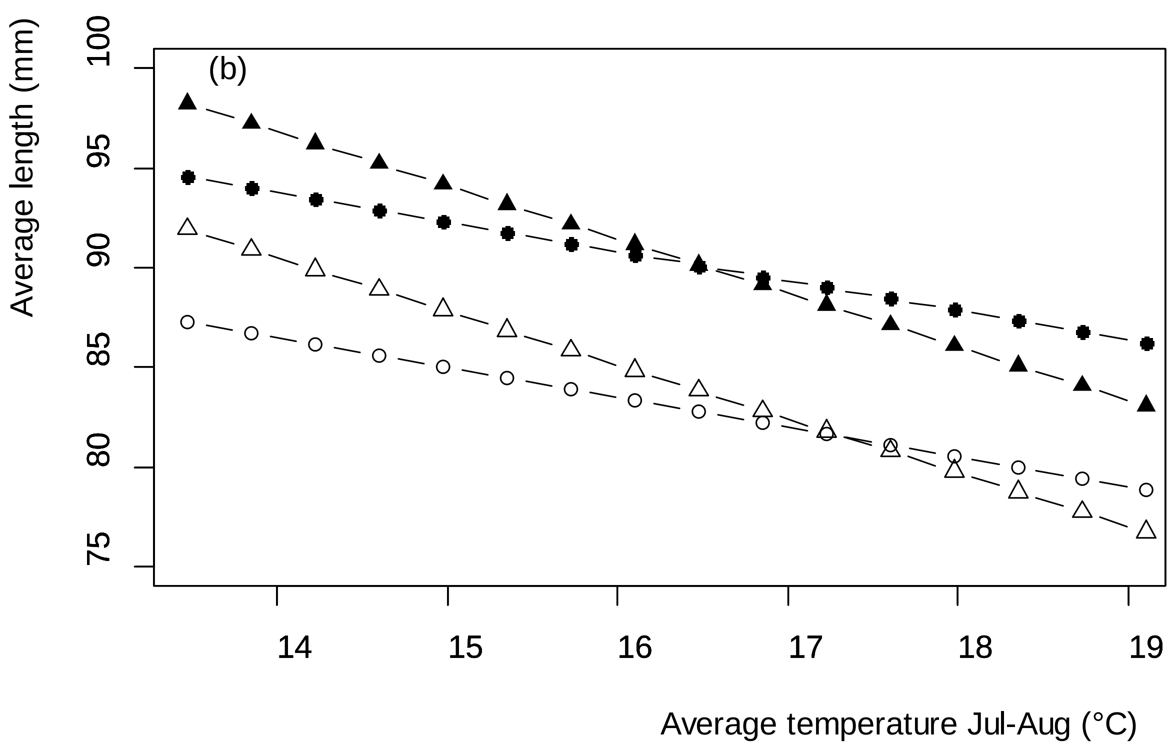


Figure 3. Predicted fish length (mm) as a function of spawner abundance (a) and average daily stream temperature (°C) from July-August (b). The spawner-length relationship in (a) was generated using a fixed value for temperature corresponding to the median summer temperature for Catherine Creek and Upper Grande Ronde combined (median temperature = 17.4 °C). The temperature-length relationship in (b) was generated using a fixed value for spawner abundance corresponding to the median spawner abundance for Catherine Creek and Upper Grande Ronde combined (median spawner abundance = 124).

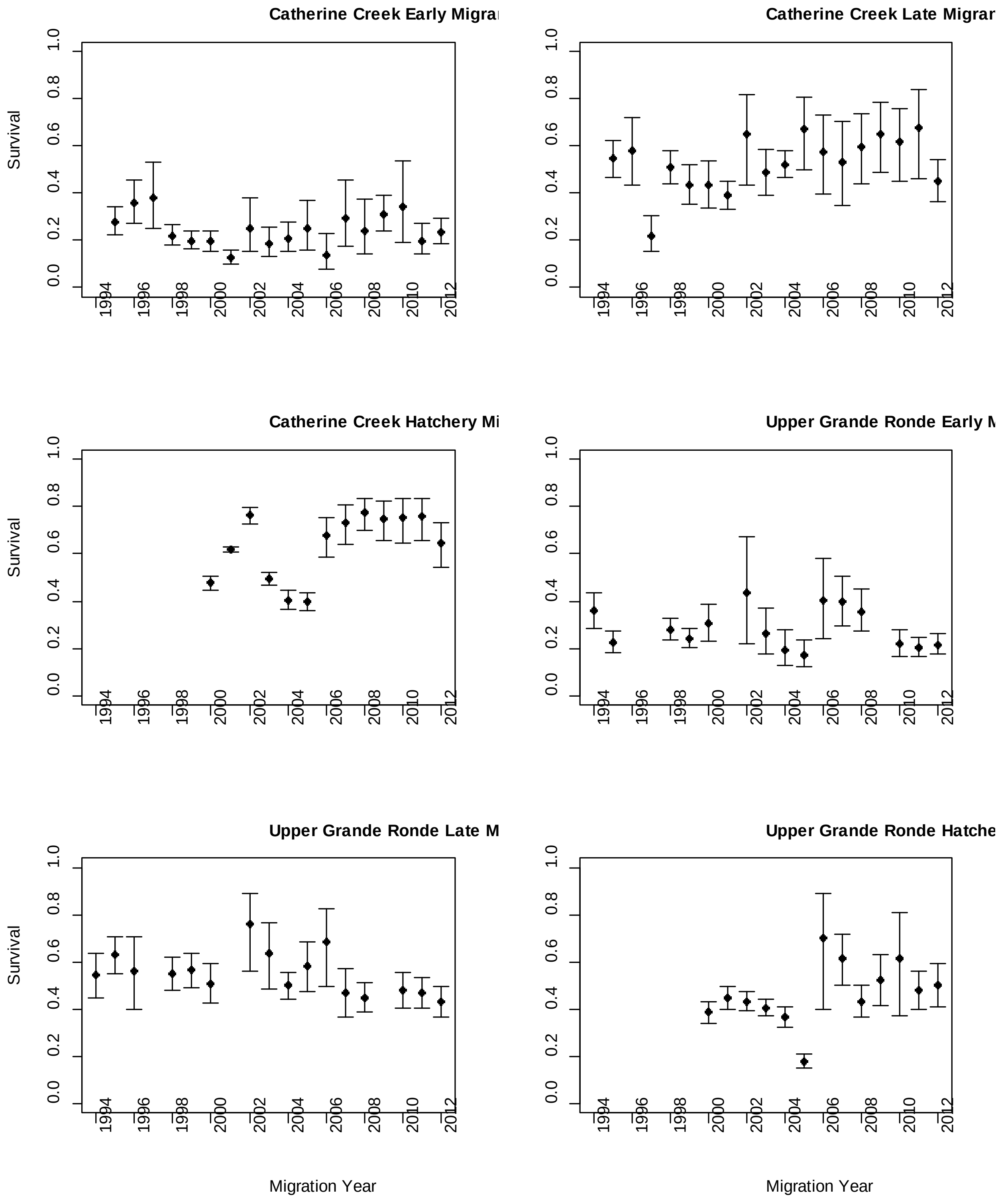


Figure 4. Survival estimates from release to Lower Granite Dam for average-sized fish generated from the best-fitting model for all release groups during migration years 1994-2012. Error bars represent 95% confidence limits.

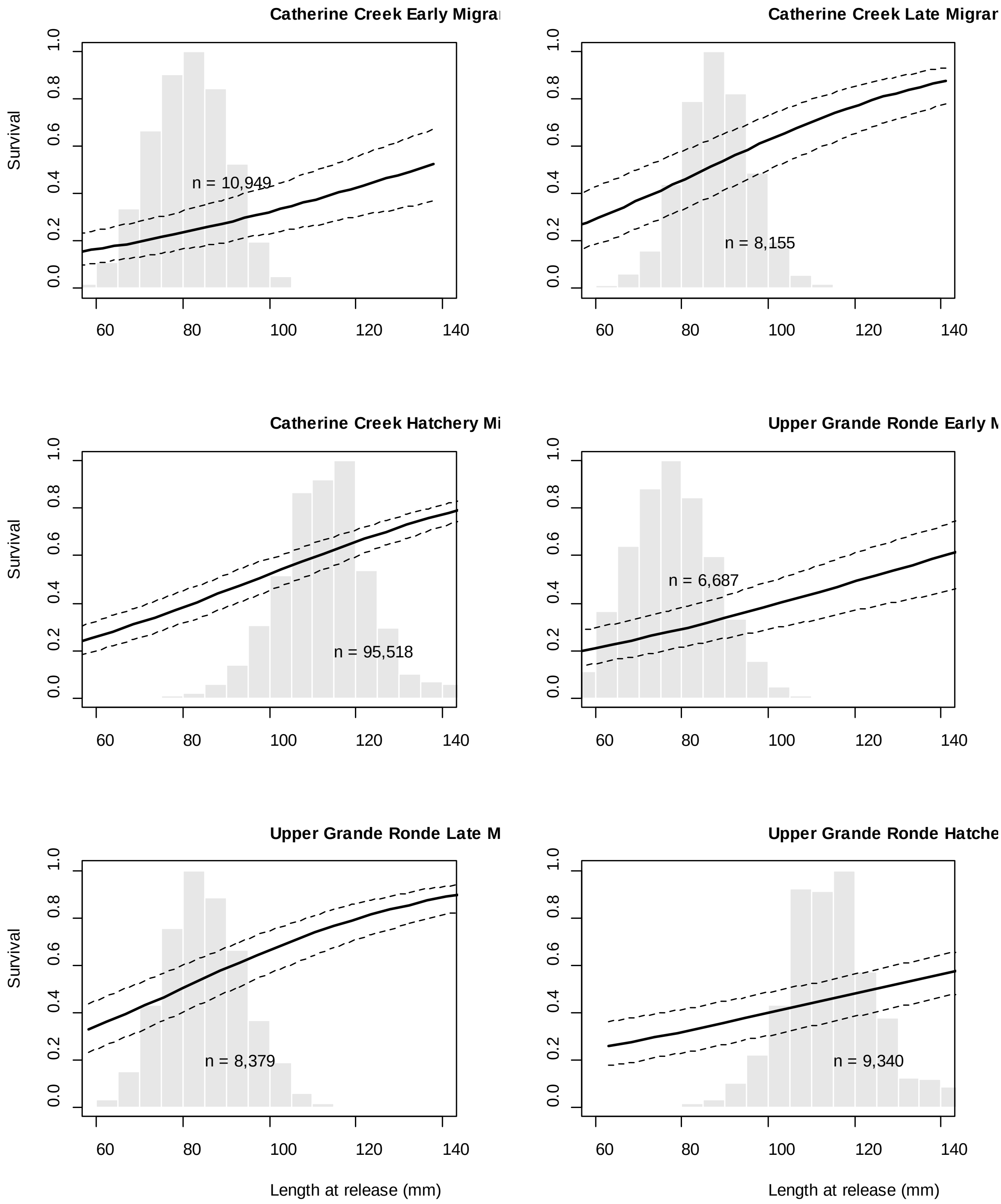


Figure 5. Relationship between length at release (mm) and survival to Lower Granite Dam for all six release groups generated from the best fitting model. Survival-length relationships were averaged across all migration years 1994-2012. Dashed lines represent 95% confidence intervals. Histograms of size at release for all release groups are also shown, along with the total number of releases (n).

Appendix L. Stream Temperature Modeling – Riparian Vegetation Restoration

Prepared by: Casey Justice, Columbia River Inter-Tribal Fish Commission, Portland, OR

See file: Stream Temperature Modeling-cj.docx

March 24, 2014

Introduction

We simulated the potential influence of riparian vegetation restoration on stream temperature in the Upper Grande Ronde River using the Heat Source model (Boyd and Kasper 2003). As part of a previous contract with The Columbia River Inter-Tribal Fish Commission (CRITFC), Quantum Spatial Inc. (formerly Watershed Sciences) completed stream temperature modeling of 17 streams in the Upper Grande Ronde River basin covering the extent of current and historic Chinook salmon habitat in the Upper Grande Ronde River and Catherine Creek (Watershed Sciences 2012a; Watershed Sciences 2012b). We ran the model using a suite of different riparian restoration scenarios to evaluate potential changes in the magnitude and spatial distribution of water temperatures that may result from restoration of riparian vegetation in different portions of the Upper Grande Ronde basin. We used the Upper Grande Ronde River and its tributaries (upstream of but not including Catherine Creek) as a test case for demonstrating the utility of the Heat Source model because of the severely degraded status of riparian conditions and water temperatures throughout much of the basin, and because the diversity of tributary inputs provides an informative template for evaluating the relative contribution of each tributary or stream segment to overall water temperature. Understanding how stream temperature responds to restoration of riparian vegetation in the Grande Ronde basin is critical to evaluating how imperiled salmonid populations may respond to stream restoration actions in the future.

Methods

Heat Source models were set up and calibrated for a 10-week time period spanning July 10 – September 20, 2010 in order to assess critical summertime conditions. A detailed description of the remote sensing and ground level data as well as the expanded stream temperature modeling results are provided in Watershed Sciences (2012b). Model output includes stream temperature at points (i.e., model nodes) spaced every 100 meters along the stream network for every hour of the day during the simulation period (Jul 10 - Sep 20).

For each model node, we calculated two metrics to summarize water temperature conditions including 1) the maximum weekly maximum temperature (MWMT °C; the maximum of the 7-day running average of the daily maximum temperature), and 2) the proportion of time in hours that the stream temperature exceeded 18 °C. Eighteen degrees was selected because it represents the approximate upper end of the preferred temperature range for rearing juvenile salmonids as reported in USEPA (2003), and is equivalent to the temperature standard used in the Upper Grande Ronde Total Maximum Daily Load (TMDL) analysis (ODEQ 2000). In addition, we calculated the total area (m^2) and proportion of potential Chinook habitat where the MWMT was greater than 16, 18, and 20°C. Estimates of potential Chinook habitat area came from the National Oceanic and Atmospheric Association's (NOAA's) Interior Columbia Technical Recovery Team (ICTRT) analysis of habitat intrinsic potential (Cooney et al. 2007). This analysis used reach level habitat factors such as stream width, gradient, valley width, and vegetative cover to estimate the production potential for the entire interior Columbia River basin.

Temperature metrics were summarized for the entire Upper Grande Ronde River basin as well as by assessment unit. Assessment unit boundaries correspond approximately to the HUC6 watershed boundaries, but were aggregated or modified to better represent significant breaks in physical channel morphology (e.g., tributary junctions or major changes in valley confinement), land ownership, or fish use. The assessment units were developed by scientists and other local experts associated with the Federal Columbia River Power System (FCRPS) Biological Opinion expert panel and restoration implementation group (i.e., Atlas Group) for use in planning and implementing stream restoration actions.

We developed a set of 14 Heat Source model scenarios (henceforth referred to as model runs) representing riparian vegetation restoration in various combinations of tributaries or mainstem river segments (Table 1). This set of model scenarios generally followed the ecological principal of restoring from the core. That is, riparian conditions in areas currently supporting the most fish production were restored first, and additional tributaries or mainstem stream segments were sequentially added in a downstream direction.

Table 1. Description of riparian vegetation restoration scenarios used to model stream temperature in the Upper Grande Ronde River.

Subareas	Above Vey Meadows	Vey Meadows	Below Vey Meadows to Meadow Cr	Meadow Cr	Meadow Cr to Five Points Cr	Five Points Cr	Five Points Cr to Catherine Cr
Detailed Description	Grande Ronde R from RKM 97.2 to 86.45, Clear Cr from RKM 3.5 to mouth, Limber Jim Cr from RKM 5.9 to 0.85, Chicken Cr from RKM 6.45 to 6.15, Sheep Cr from RKM 21.3 to 14.5	Grande Ronde R from RKM 86.45 to 75.45, Limber Jim Cr from RKM 0.85 to mouth, Chicken Cr from RKM 6.15 to mouth, Sheep Cr from RKM 14.5 to mouth	Grande Ronde R from RKM 75.45 to 55.6, Fly Cr from RKM 13.1 to mouth	Meadow Cr from RKM 30.9 to mouth	Grande Ronde R from RKM 55.6 to 32.1, Beaver Cr from RKM 22.9 to mouth	Five Points Cr from RKM 16.4 to mouth	Grande Ronde R from RKM 32.1 to RKM 0 (Catherine Cr confluence)
Model runs							
1 (Current)	*current*	*current*	*current*	*current*	*current*	*current*	*current*
2	**RESTORE VEG**	*current*	*current*	*current*	*current*	*current*	*current*
3	*current*	**RESTORE VEG**	*current*	*current*	*current*	*current*	*current*
4	*current*	*current*	**RESTORE VEG**	*current*	*current*	*current*	*current*
5	*current*	*current*	*current*	**RESTORE VEG**	*current*	*current*	*current*
6	*current*	*current*	*current*	*current*	**RESTORE VEG**	*current*	*current*
7	*current*	*current*	*current*	*current*	*current*	**RESTORE VEG**	*current*
8	**RESTORE VEG**	**RESTORE VEG**	*current*	*current*	*current*	*current*	*current*
9	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	*current*	*current*	*current*	*current*
10	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	*current*	*current*	*current*
11	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	*current*	*current*
12	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	*current*
13 (PNV)	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**	**RESTORE VEG**

14	**RESTORE VEG**	*current*	**RESTORE VEG**	*current*	*current*	*current*	*current*

Note. Stream distance on the Grande Ronde River is calculated as the number of river kilometers upstream of the Catherine Creek confluence.

Estimating Potential Natural Vegetation (PNV)

To simulate restoration of riparian vegetation, it was necessary to estimate the potential height and density (i.e., canopy cover) for riparian areas under natural historic conditions (i.e., prior to intensive anthropogenic disturbance). We used a modified version of the classification system developed by Crowe and Clausnitzer (1997) to identify likely plant association groups that would be present in riparian areas throughout the stream network under natural historic conditions. We used this classification system to develop a potential natural vegetation (PNV) map for the Upper Grande Ronde basin. In the classification system, the landscape is divided into broad physiographic units based largely on the level IV ecoregions for the Columbia Plateau and Blue Mountains described in Clarke and Bryce (1997) (Figure 1). The level IV ecoregions were simplified and combined in Crowe and Clausnitzer (1997) to better reflect differences in wetland/riparian plant associations.

Each physiographic unit was further subdivided into vegetation classes based on breaks in elevation and channel gradient (Table 2; Figure 2). Elevation and gradient breaks were modified slightly to ensure no overlap between classes. In addition, large meadows were manually delineated using aerial photographs and were assigned to a unique class. We assumed that the soil in meadows would be saturated to the surface for most or part of growing season, so only plant associations that prefer these soil types were assigned to the meadow class. Heat Source model nodes were then attributed with the appropriate vegetation class by overlaying the model nodes with the vegetation class layer in ArcGIS.

Table 2. Vegetation classes based on the landform key described in Crowe and Clausnitzer (1997).

Physiographic Unit	Gradient	Elevation (m)	Meadow (T/F)	Class
Continental and Blue Mountain Basin Zone	< 2%	<= 1372	F	cbza
Continental and Blue Mountain Basin Zone	< 2%	<= 1372	T	cbzam
Continental and Blue Mountain Basin Zone	< 2%	> 1372	F	cbzb
Continental and Blue Mountain Basin Zone	2-4%		F	cbzc
Continental and Blue Mountain Basin Zone	> 4%		F	cbzd
Mesic Forest Zone 1	< 2%	<= 1219	F	mfz1a
Mesic Forest Zone 1	< 2%	> 1219	F	mfz1b
Mesic Forest Zone 1	2-4%		F	mfz1c
Mesic Forest Zone 1	> 4%		F	mfz1d
Mesic Forest Zone 2	< 2%	<= 1463	F	mfz2a*
Mesic Forest Zone 2	< 2%	> 1463	F	mfz2b
Mesic Forest Zone 2	2-4%		F	mfz2c
Mesic Forest Zone 2	> 4%		F	mfz2d

*This class did not occur within the study area.

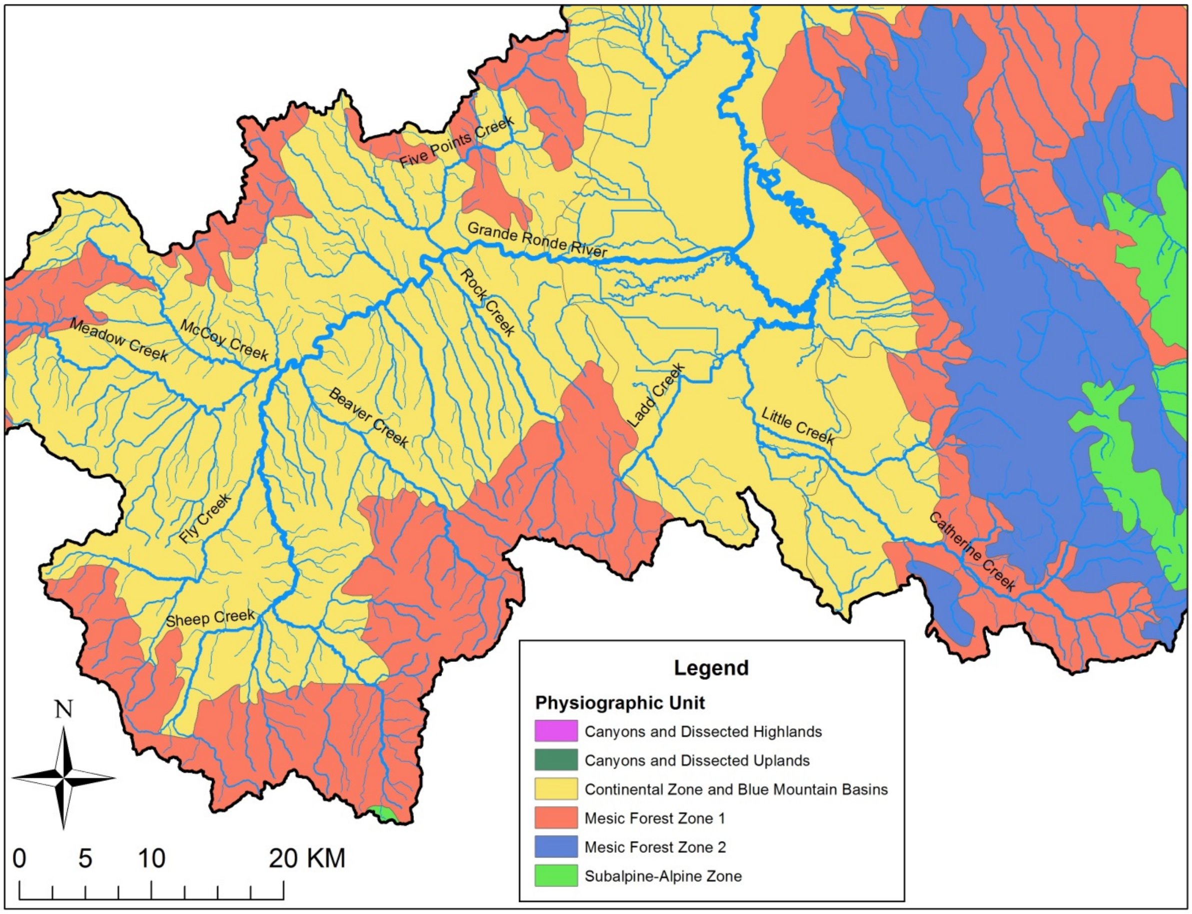


Figure 1. Map of physiographic units as described in Crowe and Clausnitzer (1997) for the Upper Grande Ronde basin.

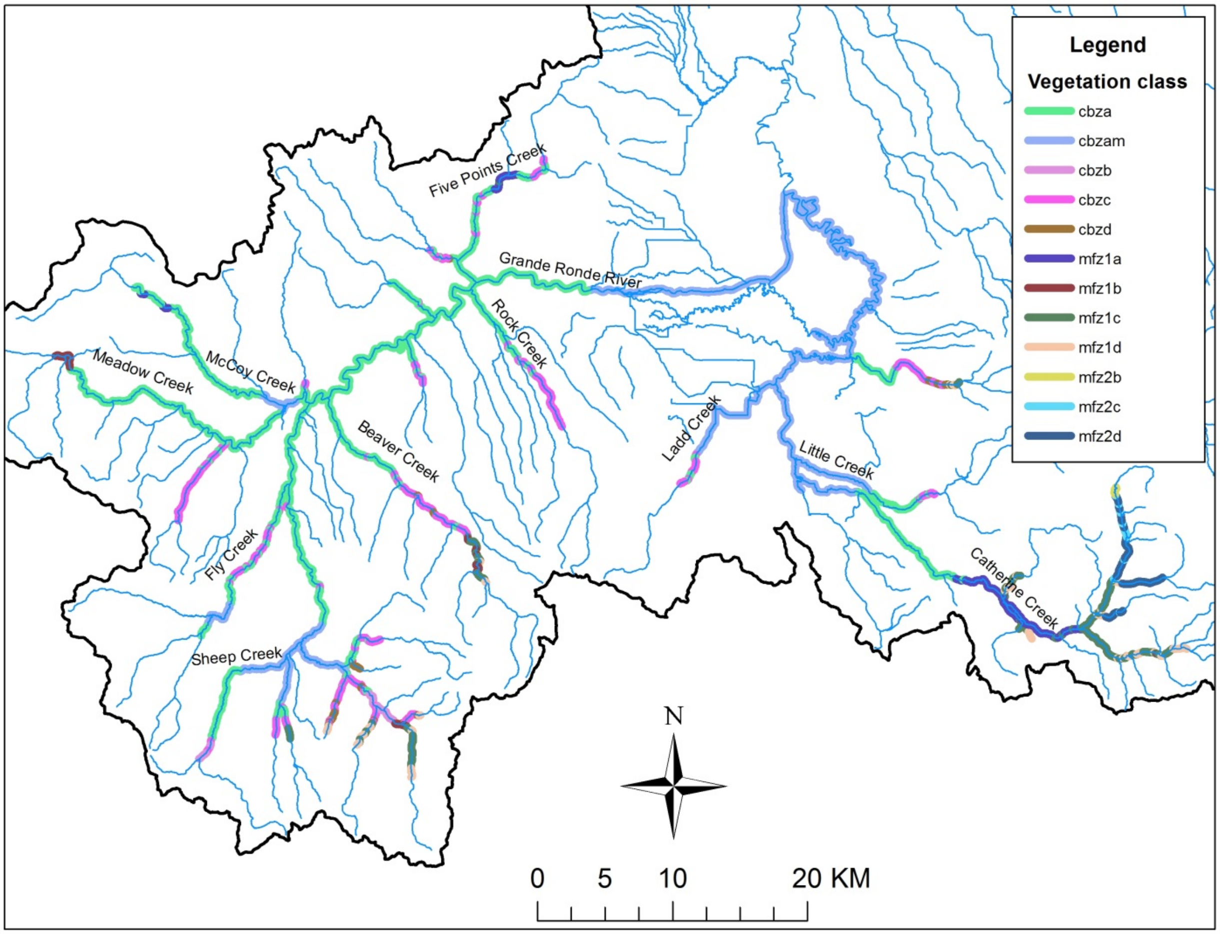


Figure 2. Vegetation classes based on the landform key described in Crowe and Clausnitzer (1997).

These primary vegetation classes were further subdivided into 1 of 3 fluvial surface types (alluvial bars, streambanks and floodplains, and terraces) based on the elevation difference between the stream surface and the land surface at each of the Heat Source model nodes. We used TTools, a GIS application which provides inputs to the Heat Source model, to sample LiDAR data at points (primary model nodes) spaced every 50 m along the center of the stream channel. At each primary model node, a series of radial transects are extended in each of 7 directions (S, SW, W, etc.). The elevation of the bare earth and vegetation from the LiDAR data is measured at 4 points (radial model nodes) spaced 10-15 m along each transect (Figure 3). We calculated the difference in elevation between the bare earth at each of these radial nodes and the stream surface at the associated primary node. We used the following rule set to assign each radial model node to a particular fluvial surface type:

1) If the elevation of the radial node was less than the estimated bankfull elevation, then the node was classified as alluvial bar.
2) If the elevation of the radial node was greater than or equal to the bankfull elevation and less than 1 meter above the bankfull elevation, then the node was classified as streambank and floodplain.

3) If the elevation of the radial node was greater than 1 meter above the bankfull elevation, then the node was classified at terrace.

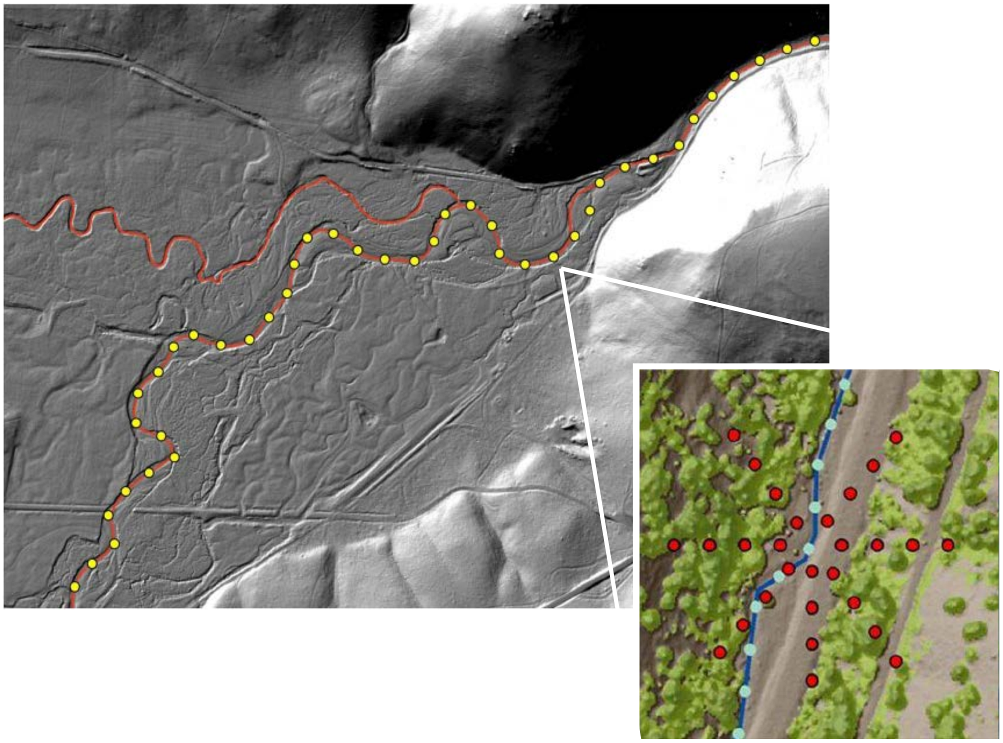


Figure 3. Example of radial sampling nodes used to estimate bare earth and vegetation height in Heat Source.

Bankfull elevation at each model node was estimated using a power function developed from CHaMP topographic data collected at 60 unique sites across the Upper Grande Ronde basin: $y = 0.06x^{0.4961}$ ($R^2 = 0.33$), where y = bankfull height (m) above the water surface, and x = bankfull width (m). This function was used to account for the fact that bankfull height above the water surface increases with increasing channel width.

A cutoff elevation of 1 meter above bankfull, which was used to define terrace surfaces, was based loosely on our field observations from habitat surveys conducted between 2010 and 2013. Although the elevation of terraces can vary widely according to stream size and location within the watershed, no data is currently available to estimate the relative elevation of terraces across the entire basin. As such, we assumed that a relative rise of 1 meter above the bankfull elevation is a good general cutoff point to represent the transition from floodplain to terrace or other upland vegetation types.

Potential canopy cover and vegetation height were estimated from data provided in Crowe and Clausnitzer (1997), Butcher *et al.* (2010), and other online sources (Table 3). Crowe and Clausnitzer (1997) provided extensive field measurements of average cover (percent canopy cover for a species averaged over all sample stands where the species was present) and constancy (the percentage of sample stands that contained a particular species) for each principal plant species found within a plant association group. Plant associate groups that were identified as early or mid-seral communities that have been caused by over-grazing or other ground disturbance and/or a drop in the water table were

excluded from this analysis because we sought to estimate vegetation potential under natural conditions with relatively little human impact. We used this information to calculate canopy cover and height for each unique combination of vegetation class and fluvial surface as described in the following steps:

1) We combined all shade-contributing plant species in each plant association group into one of two vegetation types: 1) overstory trees, and 2) tall shrubs. Low shrubs, forbs, and grasses were assumed to provide an insignificant amount of shade and were therefore ignored for modeling purposes. More specifically, dominant overstory trees and subdominant overstory trees were combined into one type called overstory trees. Understory trees and tall shrubs were combined into one type called tall shrubs.
2) Total canopy cover for each combination of plant association group, vegetation type, and plant species was calculated by multiplying average cover by percent constancy and dividing by 100.
3) Vegetation height for each species was based on values reported in Butcher *et al.* (2010) and various online sources (Table 4). Heights for each species were reported as a range, an average, or a maximum, depending on the source. The potential natural vegetation (PNV) height, which was ultimately used in temperature modeling, was defined as either the average height for a given species or 75% of the max height, whichever was greater. A value of 75% of the max is based on the assumption that the average stand height under natural potential conditions would be somewhat less than the maximum height achievable for a single specimen, and is consistent with methods used by the Oregon Department of Environmental Quality (ODEQ) in their TMDL analysis of the John Day and Deschutes River basins (Butcher *et al.* 2010).
4) Weighted height (height X total cover) was calculated for each unique combination of vegetation class, fluvial surface, plant association group, vegetation type, and species.
5) Total canopy cover and weighted height were summed for each unique combination of vegetation class, fluvial surface, plant association group, and vegetation type. Weighted average height was then calculated by dividing the sum of weighted height by the sum of total canopy cover. Thus, the average vegetation height for a given group is weighted by the percent cover for each species.
6) Total canopy cover and weighted average height was then averaged across all potential plant association groups to provide a single cover and height value for each unique combination of vegetation class and fluvial surface.
7) Finally, the total cover for tall shrubs was adjusted to ensure that the combined canopy cover for overstory trees and tall shrubs did not exceed 100%. Specifically, if the sum of overstory tree cover and tall shrub cover exceeded 100%, the tall shrub cover was calculated as 100 – overstory tree cover.

With estimates of canopy cover and vegetation height for each vegetation class and fluvial surface type, we then assigned a cover value and height to each radial sampling node in Heat Source. As described above, the Heat Source model nodes were first assigned to a vegetation class by overlaying the model nodes with the vegetation class layer in ArcGIS. The model nodes were then assigned to a fluvial surface type based on the relative elevation of the model node above the water surface. Finally, the information in Table 3 was assigned to each model node based on its vegetation class and fluvial surface type.

The Heat Source model uses vegetation height at each model node to calculate the amount of solar radiation reaching the stream channel. Canopy cover is not a direct input to the model. To account for canopy cover, we randomly selected a subset of model nodes for inclusion in the Heat Source

calculations in proportion to the cover value for each node. For example, if a model node was assigned a cover value of 50% for overstory trees with a height of 40 meters, and 30% for tall shrubs with a height of 3 meters, there would be a 50% probability that the model node would be assigned a height of 40 meters, a 30% probability that the model node would be assigned a height of 3 meters, and a 20% probability that the model node would be assigned a height of 0 meters (i.e., no vegetation cover).

Table 3. Total percent cover and height (m) for each combination of vegetation class and fluvial surface.

		Overstory Trees		Tall shrubs	
Class	Fluvial surface	Total Cover (%)	Avg Height (m)	Total Cover (%)	Avg Height (m)
cbza	Alluvial bars	47.0	44.3	44.0	6.9
cbza	Streambanks and Floodplains	51.9	30.6	45.3	3.7
cbza	Terraces	50.0	39.3	50.0	2.2
cbzb	Alluvial bars	0.0	0.0	0.0	0.0
cbzb	Streambanks and Floodplains	22.0	22.9	62.1	3.2
cbzb	Terraces	57.3	25.9	15.7	0.9
cbzc	Alluvial bars	0.0	0.0	0.0	0.0
cbzc	Streambanks and Floodplains	0.0	0.0	95.7	3.1
cbzc	Terraces	59.6	48.5	40.4	1.6
cbzd	Alluvial bars	0.0	0.0	0.0	0.0
cbzd	Streambanks and Floodplains	0.0	0.0	91.9	3.3
cbzd	Terraces	0.0	0.0	91.9	3.3
mfz1a	Alluvial bars	47.0	44.3	44.0	6.9
mfz1a	Streambanks and Floodplains	55.3	27.6	44.7	3.1
mfz1a	Terraces	57.5	41.9	42.5	2.1
mfz1b	Alluvial bars	0.0	0.0	0.0	0.0
mfz1b	Streambanks and Floodplains	22.0	22.9	40.1	3.3
mfz1b	Terraces	55.0	29.6	14.4	1.3
mfz1c	Alluvial bars	0.0	0.0	0.0	0.0
mfz1c	Streambanks and Floodplains	31.5	51.5	68.5	3.2
mfz1c	Terraces	73.0	52.3	26.9	4.1
mfz1d	Alluvial bars	0.0	0.0	0.0	0.0
mfz1d	Streambanks and Floodplains	25.2	25.9	70.5	2.4
mfz1d	Terraces	25.2	25.9	70.5	2.4
mfz2b	Alluvial bars	0.0	0.0	0.0	0.0
mfz2b	Streambanks and Floodplains	25.2	22.9	32.4	3.0
mfz2b	Terraces	50.8	25.0	13.4	1.5
mfz2c	Alluvial bars	0.0	0.0	0.0	0.0
mfz2c	Streambanks and Floodplains	35.6	42.6	64.4	3.1
mfz2c	Terraces	67.2	52.0	32.8	3.7
mfz2d	Alluvial bars	0.0	0.0	0.0	0.0

mfz2d	Streambanks and Floodplains	22.7	25.9	65.4	2.5
mfz2d	Terraces	22.7	25.9	65.4	2.5
cbzam	Alluvial bars	47.0	44.3	44.0	6.9
cbzam	Streambanks and Floodplains	0.0	0.0	41.2	4.3
cbzam	Terraces	47.1	44.1	52.9	2.3

Table 4. Vegetation heights used to simulate restoration of riparian vegetation. The potential natural vegetation (PNV) height was defined as either the average height for a given species or 75% of the max height, whichever was greater.

Veg Type	Species name	Min height (m)	Max height (m)	Avg Height (m)	75% Max	PNV Height (m)	Source
Overstory Trees	Grand fir		76.0		57.0	57.0	Butcher *et al.* (2010)
Overstory Trees	Subalpine fir		30.5		22.9	22.9	Butcher *et al.* (2010)
Overstory Trees	Western juniper	4.0	10.0	7.0	7.5	7.5	http://www.na.fs.fed.us/pubs/silvics_manual/Volume_1/juniperus/occidentalis.htm
Overstory Trees	Western larch	30.0	55.0	42.5	41.3	42.5	http://www.fs.fed.us/database/feis/plants/tree/larocc/all.html
Overstory Trees	Lodgepole pine		30.5		22.9	22.9	Butcher *et al.* (2010)
Overstory Trees	Engelmann spruce		36.5		27.4	27.4	Butcher *et al.* (2010)
Overstory Trees	Western white pine		55.0		41.3	41.3	http://www.fpl.fs.fed.us/documnts/usda/amwood/258wwhpi.pdf
Overstory Trees	Ponderosa pine		55.0		41.3	41.3	Butcher *et al.* (2010)
Overstory Trees	Quaking aspen		24.0		18.0	18.0	Butcher *et al.* (2010)
Overstory Trees	Black cottonwood	30.0	60.0	45.0	45.0	45.0	https://plants.usda.gov/plantguide/pdf/cs_pobat.pdf
Overstory Trees	Douglas-fir		76.0		57.0	57.0	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Grand fir		5.0		3.8	3.8	Assumed based on CHaMP definition of understory
Tall Shrubs and Understory Trees	Subalpine fir		5.0		3.8	3.8	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Rocky mountain maple			5.0	0.0	5.0	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Mountain alder			4.0	0.0	4.0	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Sitka alder	2.0	3.5	2.8	2.6	2.8	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Western serviceberry		3.7		2.8	2.8	http://www.pnwplants.wsu.edu/PlantDisplay.aspx?PlantID=345
Tall Shrubs and Understory Trees	Mountain big sagebrush	1.0	2.0	1.5	1.5	1.5	http://www.fs.fed.us/database/feis/plants/shrub/arttrit/all.html
Tall Shrubs and Understory Trees	Bog birch	3.4	5.5	4.5	4.1	4.5	Butcher *et al.* (2010)

Veg Type	Species name	Min height (m)	Max height (m)	Avg Height (m)	75% Max	PNV Height (m)	Source
Tall Shrubs and Understory Trees	Red-osier dogwood			2.5	0.0	2.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Black hawthorn			4.7	0.0	4.7	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Oceanspray		4.6		3.5	3.5	https://green.kingcounty.gov/gonative/Plant.aspx?Act=view&PlantID=24
Tall Shrubs and Understory Trees	Western juniper		5.0		3.8	3.8	Assumed based on CHaMP definition of understory
Tall Shrubs and Understory Trees	Black twinberry		3.7		2.8	2.8	http://plants.usda.gov/factsheet/pdf/fs_loin5.pdf
Tall Shrubs and Understory Trees	Utah honeysuckle	1.0	2.0	1.5	1.5	1.5	http://montana.plant-life.org/species/loni_utah.htm
Tall Shrubs and Understory Trees	Lewis's mock-orange	0.9	3.0	2.0	2.3	2.3	http://plants.usda.gov/plantguide/pdf/pg_phle4.pdf
Tall Shrubs and Understory Trees	Mallow ninebark	1.0	2.0	1.5	1.5	1.5	http://www.fs.fed.us/global/iitf/pdf/shrubs/Physocarpus%20malvaceus.pdf
Tall Shrubs and Understory Trees	Lodgepole pine		6.0		4.5	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Engelmann spruce		6.0		4.5	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Ponderosa pine		5.0		3.8	3.8	Assumed based on CHaMP definition of understory
Tall Shrubs and Understory Trees	Quaking aspen		6.0		4.5	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Black cottonwood		5.0		3.8	3.8	Assumed based on CHaMP definition of understory
Tall Shrubs and Understory Trees	Douglas-fir		5.0		3.8	3.8	Assumed based on CHaMP definition of understory
Tall Shrubs and Understory Trees	Golden currant	1.0	3.0	2.0	2.3	2.3	http://plants.usda.gov/plantguide/pdf/cs_riaua.pdf
Tall Shrubs and Understory Trees	Wax currant	0.5	1.5	1.0	1.1	1.1	http://www.fs.fed.us/database/feis/plants/shrub/ribcer/all.html

Veg Type	Species name	Min height (m)	Max height (m)	Avg Height (m)	75% Max	PNV Height (m)	Source
Tall Shrubs and Understory Trees	Stinking currant	0.5	2.0	1.3	1.5	1.5	http://nativeplants.evergreen.ca/search/view-plant.php?ID=00574
Tall Shrubs and Understory Trees	Whitestem gooseberry		3.0		2.3	2.3	http://en.wikipedia.org/wiki/Ribes_inerme
Tall Shrubs and Understory Trees	Idaho gooseberry	0.8	1.5	1.1	1.1	1.1	http://www1.dnr.wa.gov/nhp/refdesk/fguide/pdf/rioxi2.pdf
Tall Shrubs and Understory Trees	Prickly currant	0.5	2.0	1.3	1.5	1.5	http://en.wikipedia.org/wiki/Ribes_lacustre
Tall Shrubs and Understory Trees	Wolf's currant	1.0	5.0	3.0	3.8	3.8	http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=250065809
Tall Shrubs and Understory Trees	Bald-hip rose		1.5		1.1	1.1	http://www.wnps.org/landscaping/herbarium/pages/rosa-gymnocarpa.html
Tall Shrubs and Understory Trees	Nootka rose	0.3	2.7	1.5	2.0	2.0	https://plants.usda.gov/plantguide/pdf/pg_ronu.pdf
Tall Shrubs and Understory Trees	Roses			1.5	0.0	1.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Wood's rose	0.6	3.0	1.8	2.3	2.3	http://plants.usda.gov/plantguide/pdf/pg_rowo.pdf
Tall Shrubs and Understory Trees	Thimbleberry		2.4		1.8	1.8	http://www.pnwplants.wsu.edu/PlantDisplay.aspx?PlantID=257
Tall Shrubs and Understory Trees	Bebb willow	3.4	5.5	4.5	4.1	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Booth willow	3.4	5.5	4.5	4.1	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Coyote willow		7.0		5.3	5.3	https://plants.usda.gov/plantguide/pdf/cs_saex.pdf
Tall Shrubs and Understory Trees	Geyer willow	3.4	5.5	4.5	4.1	4.5	Butcher *et al.* (2010)
Tall Shrubs and Understory Trees	Pacific willow	4.6	13.8	9.2	10.4	10.4	http://plants.usda.gov/plantguide/pdf/cs_salul.pdf
Tall Shrubs and Understory Trees	Lemmon willow	3.4	5.5	4.5	4.1	4.5	Butcher *et al.* (2010)

Veg Type	Species name	Min height (m)	Max height (m)	Avg Height (m)	75% Max	PNV Height (m)	Source
Tall Shrubs and Understory Trees	Rigid willow	0.9	3.7	2.3	2.8	2.8	http://www.illinoiswildflowers.info/trees/plants/hl_willow.html
Tall Shrubs and Understory Trees	Buffaloberry	1.0	4.0	2.5	3.0	3.0	http://en.wikipedia.org/wiki/Shepherdia_canadensis
Tall Shrubs and Understory Trees	Mountain-ash	1.2	2.4	1.8	1.8	1.8	http://www.fs.fed.us/database/feis/plants/shrub/sorsit/all.html
Tall Shrubs and Understory Trees	Birch-leaf spirea	0.6	0.9	0.8	0.7	0.8	https://www.hoerrnursery.com/plant-o-pedia/birchleaf-spirea-white-frost-tor/
Tall Shrubs and Understory Trees	Common snowberry	0.6	1.5	1.1	1.1	1.1	http://www.pnwplants.wsu.edu/PlantDisplay.aspx?PlantID=298
Tall Shrubs and Understory Trees	Pacific yew		15.0		11.3	11.3	http://www.na.fs.fed.us/pubs/silvics_manual/Volume_1/taxus/brevifolia.htm
Tall Shrubs and Understory Trees	Big huckleberry	0.3	1.2	0.8	0.9	0.9	http://www.fs.fed.us/database/feis/plants/shrub/vacmem/all.html

Results and Discussion

Source model simulations demonstrated considerable potential for riparian restoration actions to improve stream temperatures and significantly increase the quantity of usable habitat for rearing Chinook salmon. Under current climatic, streamflow, and riparian conditions (i.e., 2010 conditions), approximately 86% of the total stream length had a maximum weekly maximum temperature (MWMT) greater than 18°C (Figure 4, Table 18). In contrast, the estimated proportion of total stream length exceeding 18°C dropped to 47% under the fully restored potential natural vegetation model scenario (Figure 5, Table 5). Similarly, the proportion of total stream length with temperatures exceeding 20°C declined from about 80% under current conditions to 11% under restored conditions.

Simulated temperature declines resulting from vegetation restoration were less dramatic than those predicted using the PNV map developed by ODEQ as part of the Grande Ronde TMDL analysis (ODEQ 1999) (Figure 6). Water temperatures predicted using our PNV map were higher than the ODEQ predictions by 1.7°C on average (range = -.7 – 7.3), although the differences were much greater during the warmest hours of the day when vegetation shading had the largest influence on water temperature. These differences likely resulted from the fact that ODEQ PNV map was based on a much more simplified classification system that assumed an essentially uniform stand of trees with 100% canopy cover and 80% foliage density within each class. The more conservative approach used in this analysis accounted for broad variability in canopy cover among different vegetation classes, and is more reflective of actual field measurements of vegetation composition (Crowe and Clausnitzer 1997). In addition, this analysis accounts for the potential shade provided by tall shrub species, which were not included in the ODEQ analysis.

The MWMT across the entire modeled area in the Upper Grande Ronde basin averaged 23.2°C (Standard Deviation = 3.9) under current conditions (model run 1; Table 16). For restoration scenarios (model runs 2-14), average MWMT ranged from 17.5 to 22.9°C, with the full PNV scenario (Model run 13) producing the greatest decline in average water temperature. Model runs that included restoration of riparian vegetation within isolated components of the watershed (e.g., runs 2-7) had a relatively small effect on downstream temperatures (Figure 7). For example, restoration of all areas upstream of Vey Meadows (model run 2) resulted in a basin-wide average MWMT of 22.7°C, a decrease of only 0.5°C. Model runs 3-7 produced similar results, with differences in mean MWMT from current conditions ranging from -1.2 to -.4°C.

Not surprisingly, the most dramatic declines in basin-wide temperatures occurred with model scenarios that simulated vegetation restoration across multiple contiguous segments of the stream network. Notable improvements in stream temperature were achieved beginning with model run 9 (i.e., restoration of all areas upstream of the Meadow Creek confluence; Figure 7). The median MWMT declined from 24.4°C under current conditions to 20.6°C under restored conditions (model run 9) (Table 6). Temperatures declined even more markedly with the addition of Meadow Creek (model run 10), which produced a basin-wide median MWMT of 18.9°C. Additional restoration downstream to the mouth of Five Points Creek (i.e., model run 11) resulted in a relatively small decline in the median MWMT compared with model run 10 (median MWMT = 18.2°C), but did produce a notable constriction in the distribution of temperatures across the basin. That is, the majority of stream length across the basin spanned a much narrower range of water temperatures compared with model runs 1-10 as evidenced by the smaller boxes (i.e., interquartile range) shown in Figure 7. Minimal benefits in terms of basin-wide reductions in water temperature were gained by restoring riparian vegetation in Five Points

Creek (model run 12) or the mainstem Grande Ronde River downstream of Five Points Creek (model run 13). In addition, the exploratory model run which included restoration of areas above Vey Meadows and the segment below Vey Meadows to the mouth of Meadow Creek (model run 14) produced minimal declines in basin-wide water temperatures.

The distribution of MWMT within each assessment unit is shown in Figures 9 and 10. Due to the large number of assessment units, we chose to focus on three units UGC2, UGC4, and UGC5, which contain the largest amount of potential Chinook habitat according to the ICTRT intrinsic potential analysis. Assessment unit UGC2, which includes the stretch of the Grande Ronde River between Meadow Creek and Five Points Creek, contains roughly 32% of the potential Chinook habitat area within the Upper Grande Ronde basin. This area has very warm water temperatures, with a median MWMT of 26.2°C under current conditions. Model run 6, which included restoration within the UGC2 boundaries as well as Beaver Creek, produced substantial declines in water temperature (median MWMT = 20.9°C; Table 6). However, these temperatures are still well above the preferred temperature limits for juvenile Chinook rearing. Suitable rearing temperatures, albeit somewhat warmer than preferable, were not achieved until all areas upstream of and including UGC2 were restored (i.e., model runs 11-13). The median water temperature for these model runs was 18.7°C.

Assessment unit UGC4 (i.e., Meadow Creek), which contains approximately 14% of the potential Chinook habitat, has a current median MWMT of 25°C. Restoration of riparian vegetation within this assessment unit reduced the median MWMT to 18.5°C (Figure 9). Assessment unit UGC5 (i.e., Grande Ronde River from Sheep Creek to Meadow Creek) also includes about 14% of the potential Chinook habitat and has a current median MWMT of 24°C. Simulated temperatures in this assessment unit declined substantially to a median MWMT of 18.8°C under model run 4, which included restoration of the Grande Ronde River from below Vey Meadows to Meadow Creek as well as Fly Creek. Extending the scope of restoration to include all areas upstream of Meadow Creek (i.e., model runs 9-13) produced the most substantial declines in water temperature (median MWMT = 17.1°C) and narrowed the range of observed temperatures considerably (Figure 9).

The same general patterns among model runs were observed for the proportion of hours where water temperature exceeded 18°C. The average proportion hours > 18°C ranged from a low of 0.04 for model run 13 to a high of 0.31 for model run 1 (Table 6). Minimal reductions in proportion hours > 18°C were achieved for model runs 2 through 8, with the difference in mean proportion hours > 18°C from the current model ranging from -0.06 to -0.01. Similar to the pattern in MWMT, the proportion hours > 18°C started to decline considerably beginning with model run 9 and generally leveled off after model run 11 (Figure 8).

The percentage of total Chinook habitat area (as estimated by the ICTRT intrinsic potential analysis) with water temperature exceeding 18°C MWMT was 96% under current conditions compared with 61% under PNV conditions (Table 7; Figure 11). Similarly, the estimated percentage of Chinook habitat area with MWMT greater than 20°C declined dramatically from 93% under current conditions to 7% under PNV conditions. As with the other temperature metrics that we examined, the basin-wide benefits of vegetation restoration were minimal when restoration actions were limited to isolated segments of the watershed. The greatest increases in usable Chinook habitat area were achieved when vegetation restoration occurred across multiple contiguous segments of the stream network. The largest relative decline in habitat area with MWMT > 20°C occurred between model run 10 and 11. Specifically, the percentage of habitat area with MWMT > 20°C declined from 55% under model run 10 to 21% under model run 11. The addition of Five Points Creek (model run 12) and the mainstem below Five Points

Creek (model run 13) yielded additional declines in the proportion of habitat with MWMT > 20, but the relative magnitude of declines were smaller.

The results from this analysis should be considered preliminary. Temperature modeling results are likely to change in the near future as a result of refinements to the potential natural vegetation (PNV) information for the Upper Grande Ronde River basin following completion of an ongoing riparian vegetation mapping project (to be completed in Spring 2015). In addition, we acknowledge that several other factors may contribute significantly to changes in stream temperature that were not included in this analysis such as climate change and changes in channel morphology (e.g., channel narrowing). These factors will be included in future modeling of stream temperatures. We also intend to refine the modeling scenarios to include a more realistic representation of the magnitude and spatial distribution of riparian restoration that is likely to be achieved over the next 25-50 years based on consultation with restoration planners in the basin. Finally, we intend to expand this modeling effort to include Catherine Creek.

These results provide useful information for restoration planners, managers, and stakeholders to better understand the potential benefits of riparian vegetation restoration for reducing water temperature and improving habitat conditions for ESA-listed salmonid species. These preliminary results suggest that water temperatures across the entire salmon-bearing portion of the Upper Grande Ronde basin could be reduced from an average MWMT of 23.2°C under current conditions to 17.5°C under fully restored conditions. In terms of usable habitat area for Chinook salmon, we estimated that the percentage of potential habitat area with MWMT greater than 18°C could be reduced from approximately 96% under current conditions to 61% under fully restored conditions. These findings demonstrate substantial potential for riparian restoration actions to improve stream temperatures and significantly increase the quantity of usable habitat for rearing Chinook salmon.

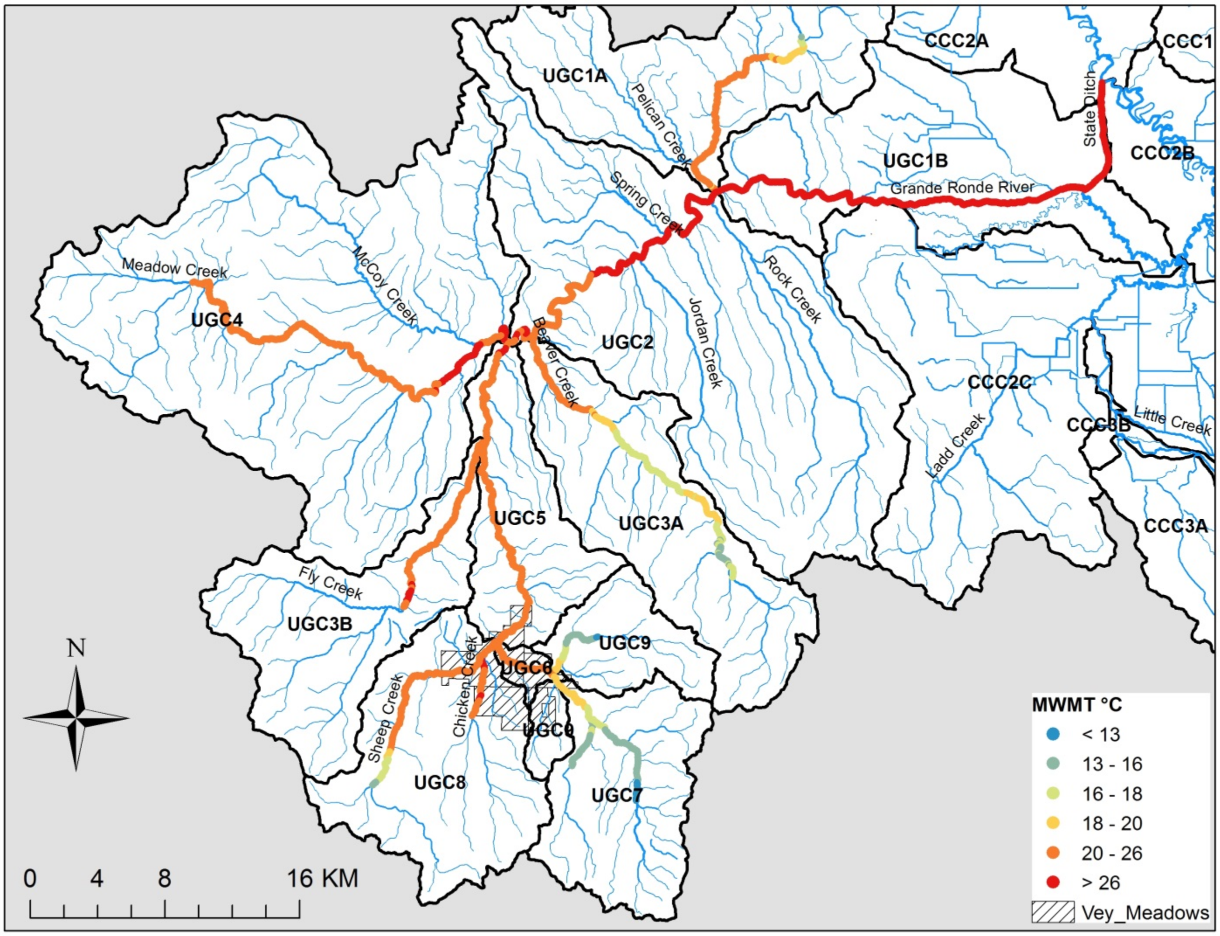


Figure 4. Map of maximum weekly maximum temperature (MWMT °C) at points spaced every 100 meters in the Grande Ronde River basin as predicted by the Heat Source model under current (2010) conditions.

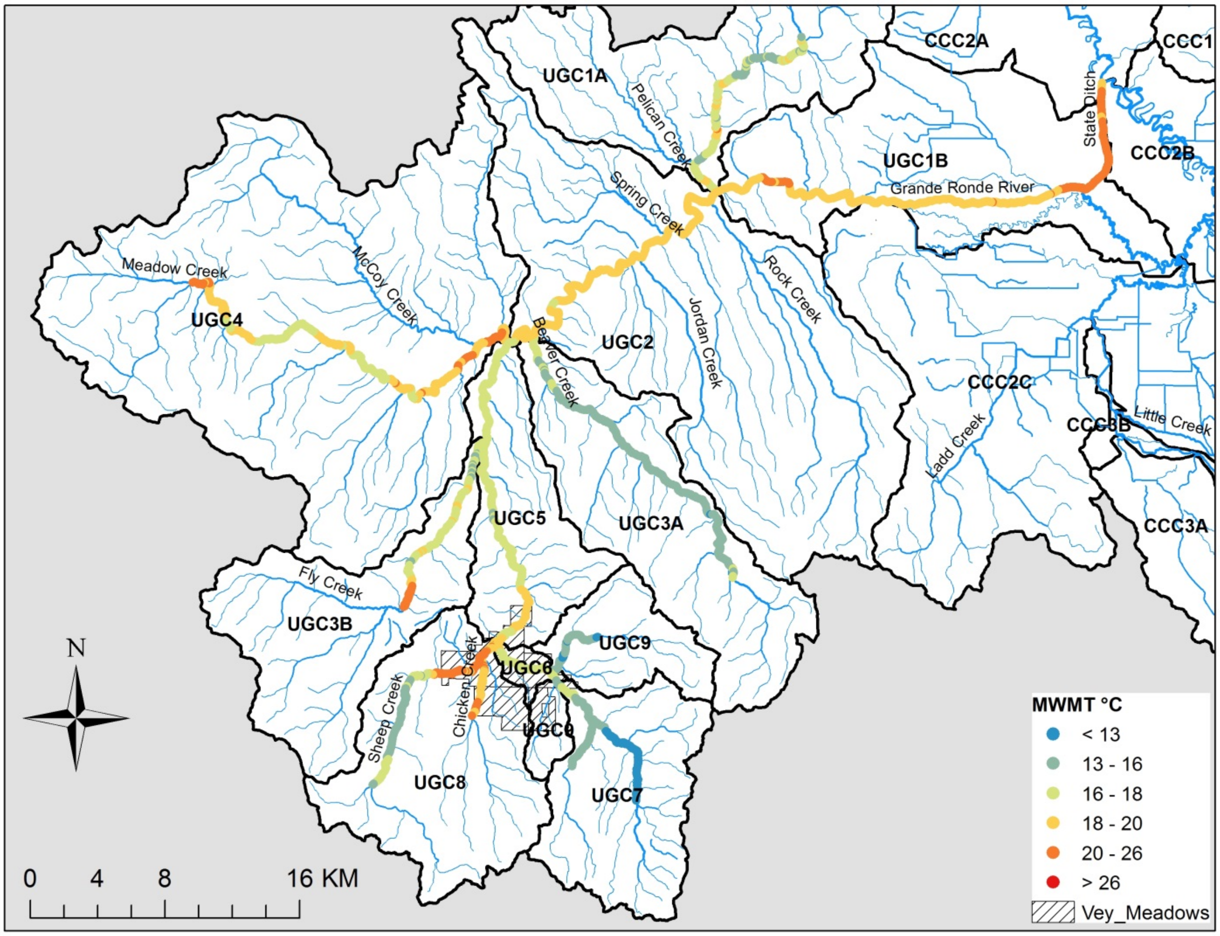


Figure 5. Map of maximum weekly maximum temperature (MWMT °C) at points spaced every 100 meters in the Grande Ronde River basin as predicted by the Heat Source model under restored potential natural vegetation (PNV) conditions.

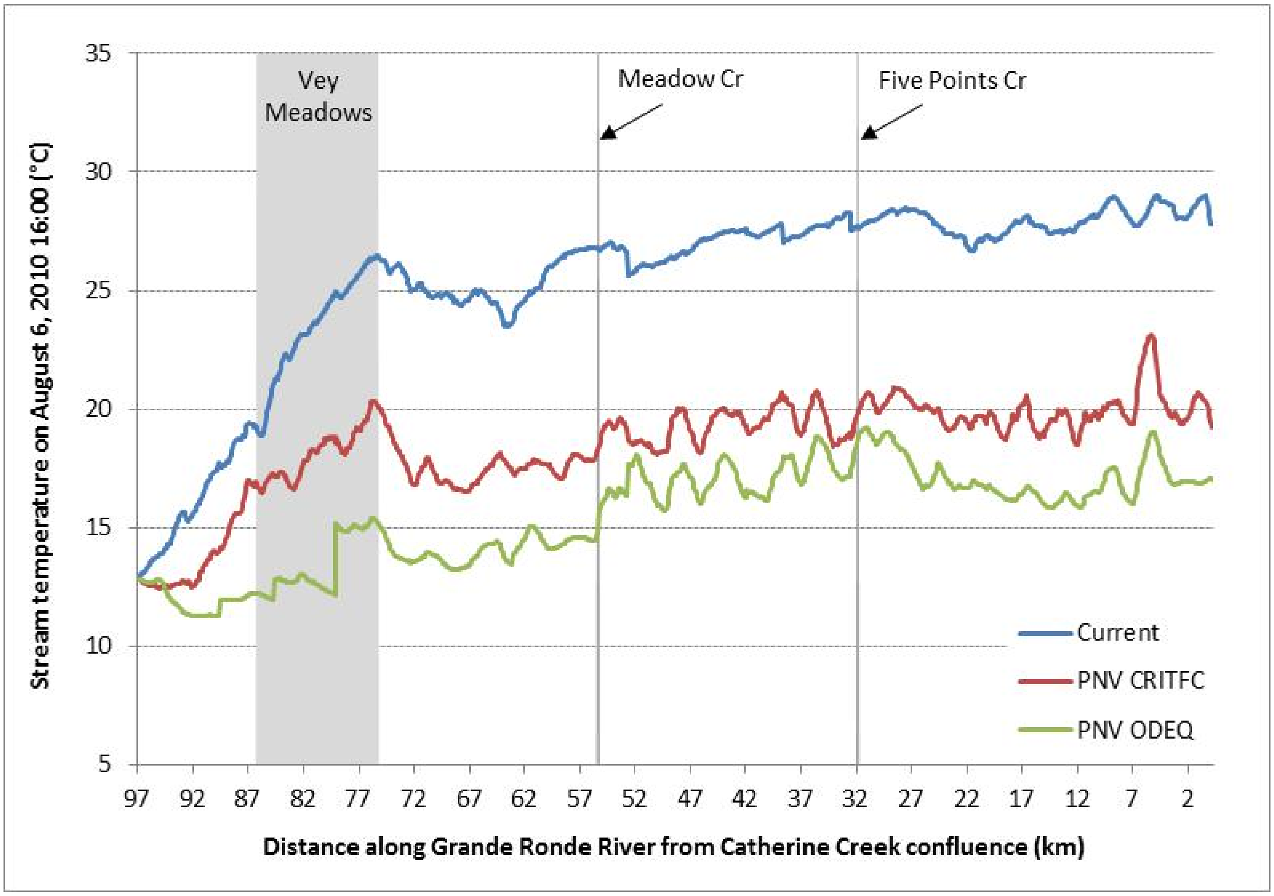


Figure 6. Stream temperature (°C) in the Grande Ronde River on August 6, 2012 16:00, at points spaced every 100 meters from the headwaters (rkm 97) to the confluence of Catherine Creek (rkm 0) as predicted by the Heat Source model. Longitudinal temperature profiles are shown for three model scenarios including 1) current conditions, 2) potential natural vegetation (PNV) conditions as estimated by the Columbia River Inter-Tribal Fish Commission (CRITFC), and 3) PNV conditions as estimated by the Oregon Department of Environmental Quality (ODEQ).

Table 5. Summary statistics for MWMT (°C) and the proportion of hours where stream temperature exceeded 18°C at all model nodes in the Upper Grande Ronde River basin for 14 different model runs.

	Model run													
Statistic	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
	MWMT (°C)													
Min	12.4	12.2	12.4	12.4	12.4	12.4	12.4	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Max	28.9	28.9	28.9	28.7	28.8	28.5	28.8	28.9	28.8	28.8	28.4	28.3	25.8	28.8
Mean	23.2	22.7	22.4	22.2	22.4	22.0	22.9	21.9	20.8	20.0	18.7	18.3	17.5	21.7
Median	24.4	24.0	22.7	23.3	23.3	23.4	24.3	22.4	20.6	18.9	18.2	17.6	17.6	22.9
Std Dev	3.9	4.4	4.0	4.0	4.1	4.0	4.2	4.5	4.6	4.3	3.8	3.6	2.3	4.5
	Proportion hours > 18°C													
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	0.76	0.76	0.76	0.76	0.76	0.75	0.76	0.76	0.76	0.76	0.75	0.75	0.37	0.76
Mean	0.31	0.30	0.27	0.26	0.27	0.25	0.30	0.26	0.22	0.17	0.11	0.09	0.04	0.25
Median	0.31	0.28	0.23	0.26	0.25	0.26	0.30	0.22	0.10	0.03	0.01	0.00	0.00	0.23
Std Dev	0.23	0.23	0.24	0.23	0.24	0.19	0.24	0.24	0.25	0.25	0.20	0.20	0.05	0.24

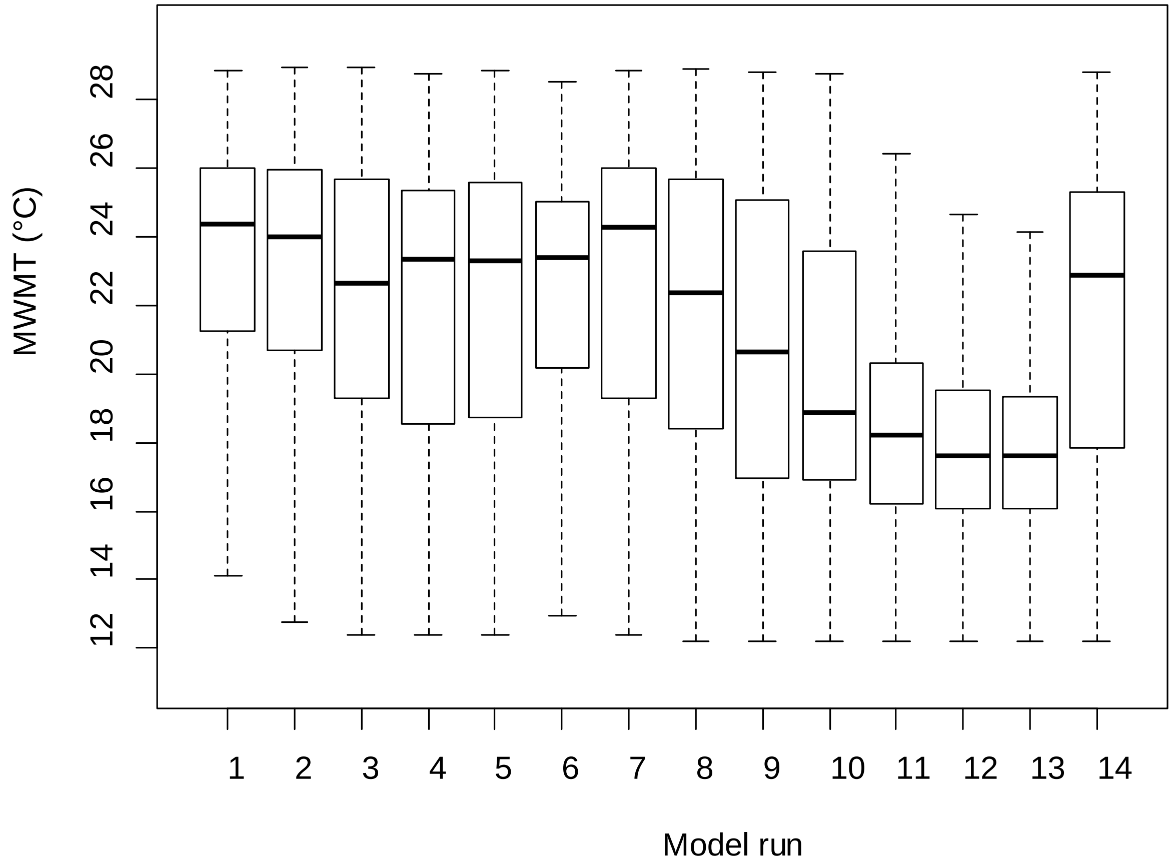


Figure 7. Boxplot showing the frequency distribution of MWMT (°C) at all model nodes in the Upper Grande Ronde River basin for 14 different model runs.

Table 6. Median MWMT (°C) and median proportion of hours where water temperature exceeded 18°C for each assessment unit and model run.

Assessment	Model run													
unit	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
	Median MWMT (°C)													
UGC1A	21.6	21.6	21.6	21.6	21.6	21.6	16.7	21.6	21.6	21.6	21.6	16.7	16.7	21.6
UGC1B	27.6	27.6	27.6	27.3	27.6	25.8	27.5	27.6	27.2	27.2	25.6	25.5	19.8	27.3
UGC2	26.2	26.2	26.1	24.9	26.1	20.9	26.2	26.0	24.7	24.7	18.7	18.7	18.7	25.0
UGC3A	18.4	18.4	18.4	18.4	18.4	14.9	18.4	18.4	18.4	18.4	14.9	14.9	14.9	18.4
UGC3B	23.2	23.2	23.2	17.3	23.2	23.2	23.2	23.2	17.3	17.3	17.3	17.3	17.3	17.3
UGC4	25.0	25.0	25.0	25.0	18.5	25.0	25.0	25.0	25.0	18.5	18.5	18.5	18.5	25.0
UGC5	24.0	23.7	22.2	18.8	24.0	24.0	24.0	21.8	17.1	17.1	17.1	17.1	17.1	18.3
UGC6	22.1	20.5	18.9	22.1	22.1	22.1	22.1	17.0	17.0	17.0	17.0	17.0	17.0	20.5
UGC7	15.2	13.7	15.2	15.2	15.2	15.2	15.2	13.7	13.7	13.7	13.7	13.7	13.7	13.7
UGC8	24.7	24.1	20.2	24.7	24.7	24.7	24.7	19.3	19.3	19.3	19.3	19.3	19.3	24.1
UGC9	16.2	13.5	16.2	16.2	16.2	16.2	16.2	13.5	13.5	13.5	13.5	13.5	13.5	13.5
	Median proportion hours > 18° C													
UGC1A	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.00	0.00	0.25
UGC1B	0.72	0.71	0.71	0.71	0.71	0.63	0.72	0.71	0.70	0.70	0.58	0.58	0.10	0.70
UGC2	0.55	0.54	0.52	0.42	0.53	0.16	0.55	0.51	0.39	0.38	0.03	0.03	0.03	0.42
UGC3A	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.02
UGC3B	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
UGC4	0.32	0.32	0.32	0.32	0.02	0.32	0.32	0.32	0.32	0.02	0.02	0.02	0.02	0.32
UGC5	0.31	0.27	0.17	0.03	0.31	0.31	0.31	0.15	0.00	0.00	0.00	0.00	0.00	0.01
UGC6	0.13	0.06	0.02	0.13	0.13	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.06
UGC7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UGC8	0.29	0.26	0.10	0.29	0.29	0.29	0.29	0.06	0.06	0.06	0.06	0.06	0.06	0.26
UGC9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

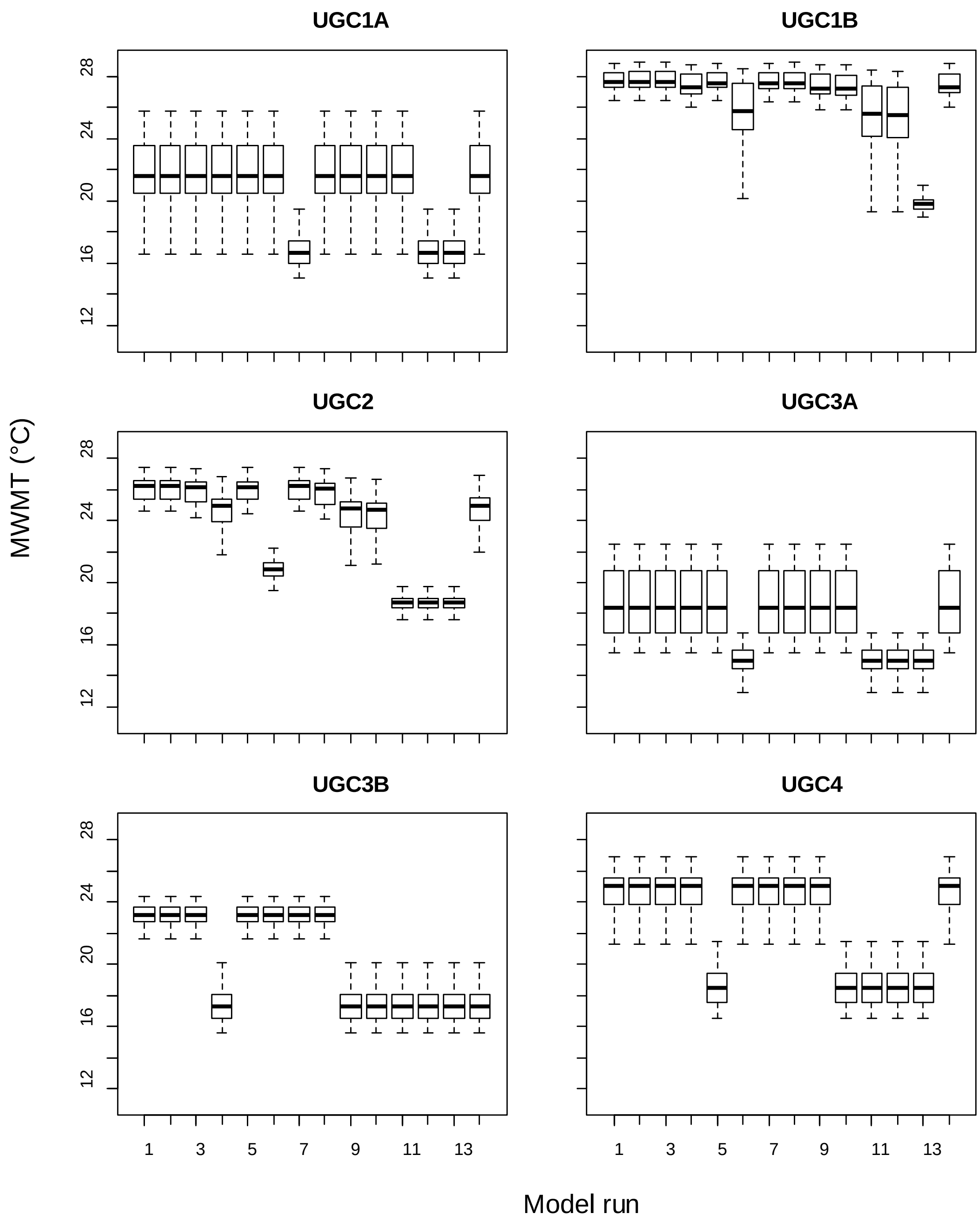


Figure 8. Boxplots showing the frequency distribution of MWMT (°C) at all model nodes within the Grande Ronde Atlas assessment units (UGC1A-UCG4) in the Upper Grande Ronde River basin for 14 different model runs.

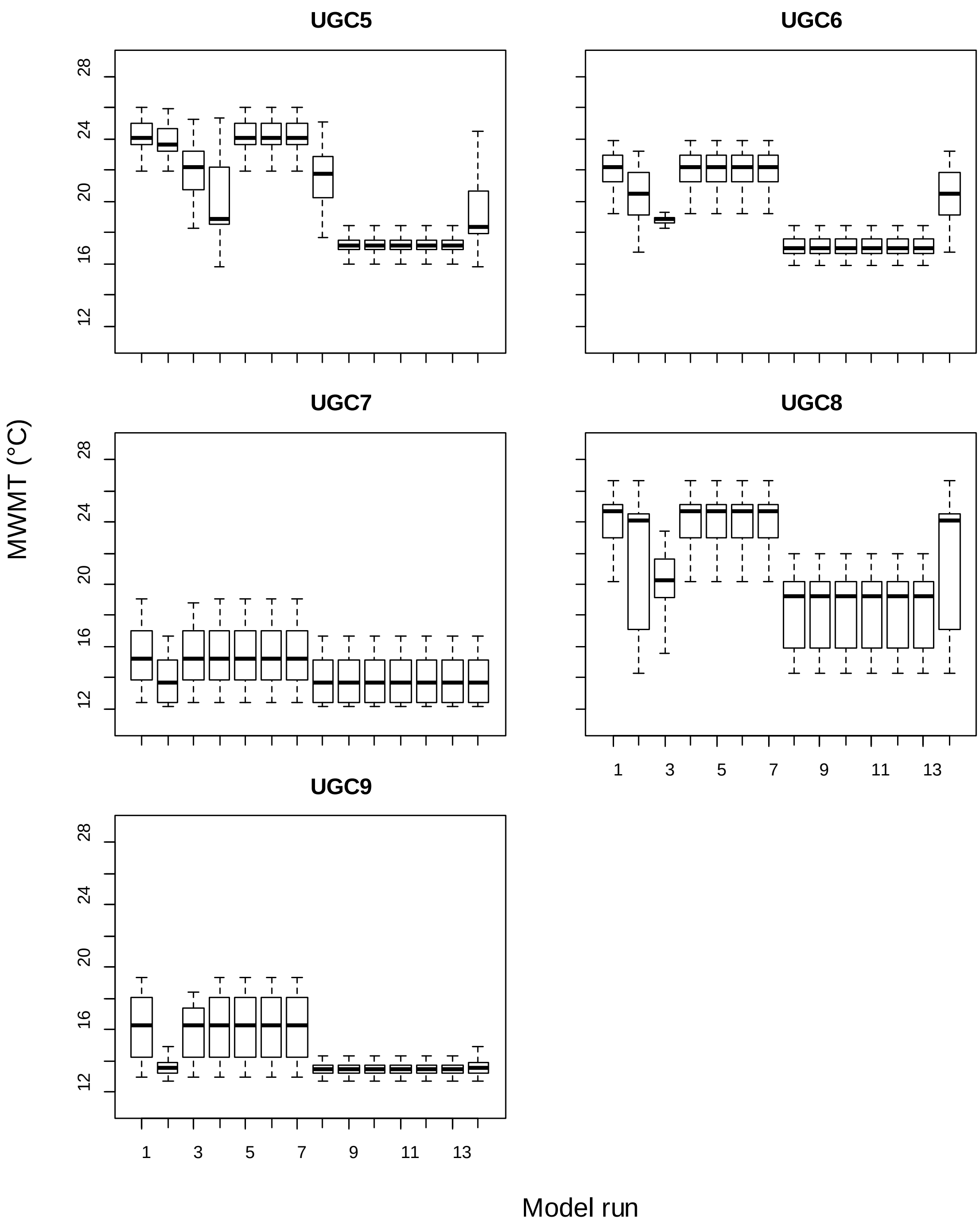


Figure 9. Boxplots showing the frequency distribution of MWMT (°C) at all model nodes within the Grande Ronde Atlas assessment units (UGC5-UGC9) in the Upper Grande Ronde River basin for 14 different model runs.

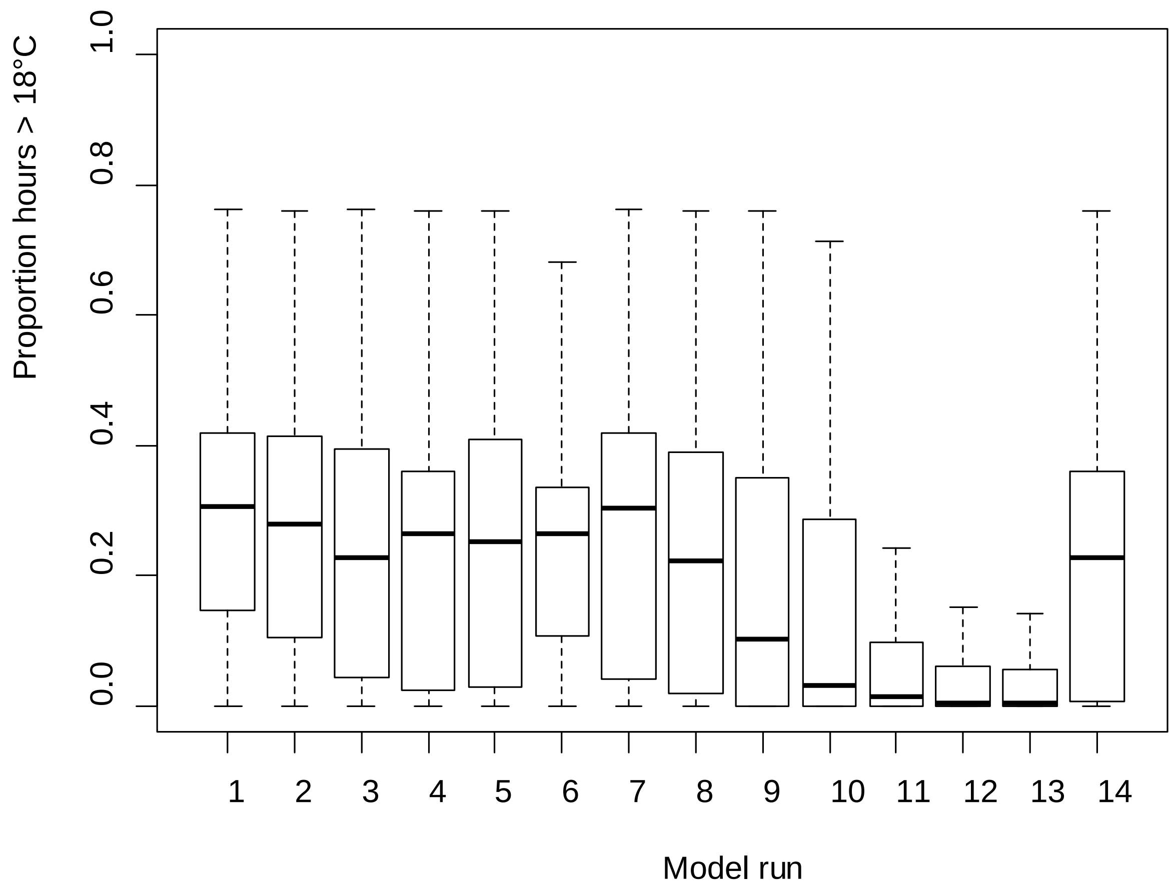


Figure 10. Boxplot showing the frequency distribution of the proportion of hours where stream temperature exceeded 18 °C at all model nodes in the Upper Grande Ronde River basin for 14 different model runs.

Table 7. Proportion of total model nodes and proportion of total Chinook habitat area where MWMT exceeded 16, 18, and 20°C.

	Proportion of total model nodes where MWMT exceeded threshold			Proportion of total habitat area where MWMT exceeded threshold		
Model run	16°C	18°C	20°C	16°C	18°C	20°C
R1 (Current)	0.93	0.86	0.80	0.98	0.96	0.93
R2	0.88	0.81	0.76	0.96	0.93	0.90
R3	0.93	0.85	0.71	0.98	0.95	0.83
R4	0.93	0.82	0.68	0.98	0.94	0.81
R5	0.93	0.82	0.68	0.98	0.92	0.81
R6	0.85	0.81	0.76	0.94	0.92	0.88
R7	0.91	0.80	0.74	0.97	0.91	0.88
R8	0.87	0.77	0.67	0.94	0.87	0.81
R9	0.86	0.64	0.53	0.94	0.75	0.67
R10	0.86	0.59	0.41	0.94	0.70	0.55
R11	0.77	0.53	0.27	0.90	0.65	0.21
R12	0.76	0.47	0.21	0.89	0.61	0.16
R13 (PNV)	0.76	0.47	0.11	0.89	0.61	0.07
R14	0.88	0.74	0.63	0.95	0.87	0.78

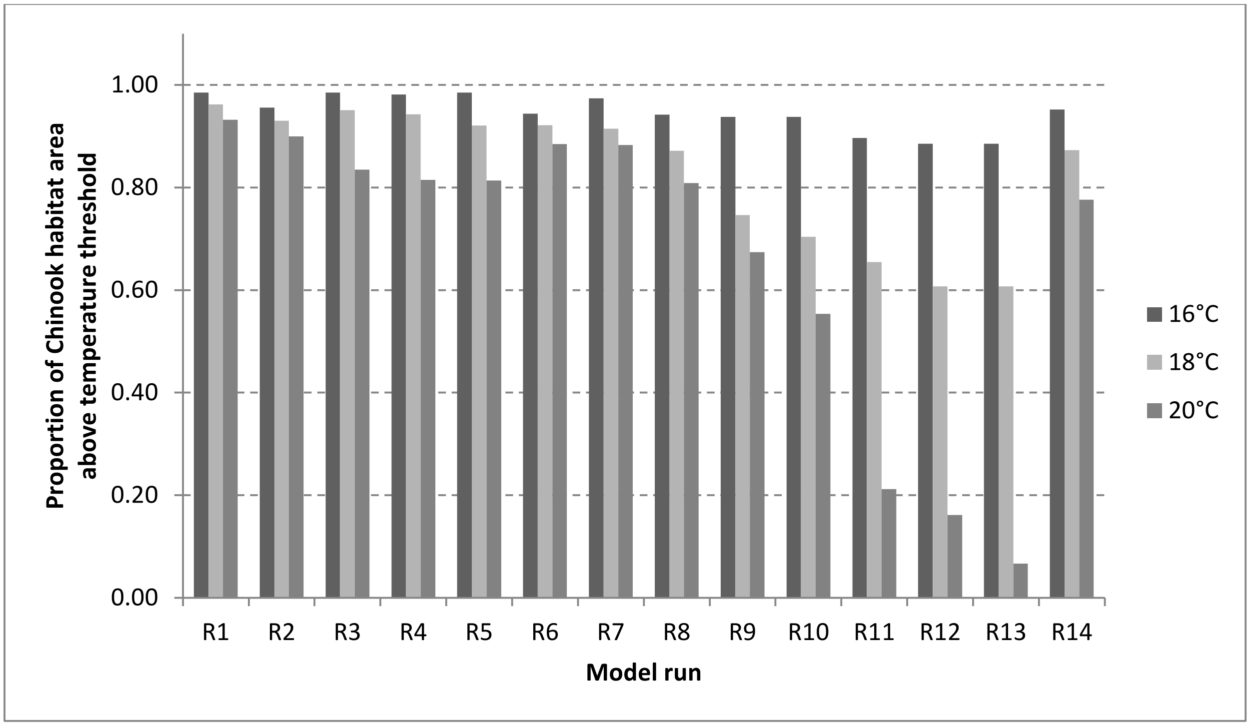


Figure 11. Proportion of total Chinook habitat area where MWMT exceeded 16, 18, and 20°C.

Table 8. Proportion of total Chinook habitat area within each Grande Ronde assessment unit where MWMT exceeded 16, 18 and 20°C.

Assessment	Model run													
unit	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
	Proportion of total Chinook habitat area													
UGC1A	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
UGC1B	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
UGC2	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
UGC3A	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
UGC3B	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
UGC4	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
UGC5	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
UGC6	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
UGC7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
UGC8	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
UGC9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Proportion of total Chinook habitat area with MWMT > 16°C													

UGC1A	1.00	1.00	1.00	1.00	1.00	1.00	0.80	1.00	1.00	1.00	1.00	0.80	0.80	1.00
UGC1B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
UGC2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
UGC3A	0.96	0.96	0.96	0.96	0.96	0.23	0.96	0.96	0.96	0.96	0.23	0.23	0.23	0.96
UGC3B	1.00	1.00	1.00	0.88	1.00	1.00	1.00	1.00	0.88	0.88	0.88	0.88	0.88	0.88
UGC4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
UGC5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	1.00
UGC6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98	1.00
UGC7	0.56	0.15	0.56	0.56	0.56	0.56	0.56	0.10	0.10	0.10	0.10	0.10	0.10	0.15
UGC8	1.00	0.83	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.83
UGC9	1.00	0.26	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
Total	0.98	0.96	0.98	0.98	0.98	0.94	0.97	0.94	0.94	0.94	0.90	0.89	0.89	0.95
	Proportion of total Chinook habitat area with MWMT > 18°C													
UGC1A	0.97	0.97	0.97	0.97	0.97	0.97	0.14	0.97	0.97	0.97	0.97	0.14	0.14	0.97
UGC1B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
UGC2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.97	0.97	1.00
UGC3A	0.72	0.72	0.72	0.72	0.72	0.00	0.72	0.72	0.72	0.72	0.00	0.00	0.00	0.72
UGC3B	1.00	1.00	1.00	0.31	1.00	1.00	1.00	1.00	0.31	0.31	0.31	0.31	0.31	0.31
UGC4	1.00	1.00	1.00	1.00	0.71	1.00	1.00	1.00	1.00	0.71	0.71	0.71	0.71	1.00
UGC5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.16	0.16	0.16	0.16	0.16	0.73
UGC6	1.00	0.90	0.99	1.00	1.00	1.00	1.00	0.16	0.16	0.16	0.16	0.16	0.16	0.90
UGC7	0.28	0.00	0.26	0.28	0.28	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UGC8	1.00	0.80	0.91	1.00	1.00	1.00	1.00	0.59	0.59	0.59	0.59	0.59	0.59	0.80
UGC9	1.00	0.00	0.23	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.96	0.93	0.95	0.94	0.92	0.92	0.91	0.87	0.75	0.70	0.65	0.61	0.61	0.87
	Proportion of total Chinook habitat area with MWMT > 20°C													
UGC1A	0.87	0.87	0.87	0.87	0.87	0.87	0.00	0.87	0.87	0.87	0.87	0.00	0.00	0.87
UGC1B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.96	0.01	1.00
UGC2	1.00	1.00	1.00	0.99	1.00	0.94	1.00	1.00	0.97	0.97	0.00	0.00	0.00	1.00
UGC3A	0.52	0.52	0.52	0.52	0.52	0.00	0.52	0.52	0.52	0.52	0.00	0.00	0.00	0.52
UGC3B	1.00	1.00	1.00	0.23	1.00	1.00	1.00	1.00	0.23	0.23	0.23	0.23	0.23	0.23
UGC4	1.00	1.00	1.00	1.00	0.17	1.00	1.00	1.00	1.00	0.17	0.17	0.17	0.17	1.00
UGC5	1.00	1.00	0.76	0.33	1.00	1.00	1.00	0.75	0.00	0.00	0.00	0.00	0.00	0.28
UGC6	0.95	0.60	0.00	0.95	0.95	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.60

UGC7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UGC8	1.00	0.78	0.69	1.00	1.00	1.00	1.00	0.41	0.41	0.41	0.41	0.41	0.41	0.78
UGC9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.93	0.90	0.83	0.81	0.81	0.88	0.88	0.81	0.67	0.55	0.21	0.16	0.07	0.78

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Butcher, D., J. Crown, K. Brannan, K. Kishida, and S. Hubler. 2010. John Day River Basin total maximum daily load (TMDL) and water quality management plan (WQMP). Oregon Department of Environmental Quality, Portland, OR

Clarke, S.E., and S.A. Bryce. 1997. Hierarchical subdivisions of the Columbia Plateau and Blue Mountains Ecoregions, Oregon and Washington. General Technical Report. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

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Crowe, E.A., and R.R. Clausnitzer. 1997. Mid-montane wetland plant associations of the Malheur, Umatilla and Wallowa-Whitman National Forests. Technical Paper. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

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Watershed Sciences, Inc. 2012a. Upper Grande Ronde River Basin stream temperature modeling. Prepared for the Columbia River Inter-Tribal Fish Commission. Watershed Sciences, LLC, Portland, Oregon.

Watershed Sciences. 2012b. Upper Grande Ronde River Basin stream temperature model expansion. Prepared for the Columbia River Inter-Tribal Fish Commission. Watershed Sciences, LLC, Portland, Oregon.

Appendix M. Examples from the scientific literature showing the relationship between observed salmonid juvenile abundance relative to water temperature. This illustrates potential habitat capacity determinants.

The figures below illustrate the relationship found in the literature between juvenile salmonid density and water temperature. These relationships appear to be relatively consistent and indicate that salmonid density tends to decline from approximately 12°C, where density is a maximum value at optimum water temperatures to 22°C, where juvenile density reaches extinction. Given that these relationships appear to be consistent among salmonids, there appears to be a means to scale the abundances expected during the summer period from the optimum temperature zone to the lower limit of occurrence. In last year's annual report (McCullough et al. 2013), we reported on progress in using water temperature history to predict the stream reach in a longitudinal continuum where Chinook mortality would reach 100%. Between that location and the optimum thermal zone upstream, mortalities in the intervening stream zone would account for some of the reduction in abundance. The remainder would be accounted for by increasing probabilities of disease, predation from warm-water adapted species, reduced growth, inability to feed, behavioral avoidance, and other sublethal effects leading to eventual density reduction.

Lessard, J.L. and D.B. Hayes. 2003. Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. River Research and Application 19(7):721-732.

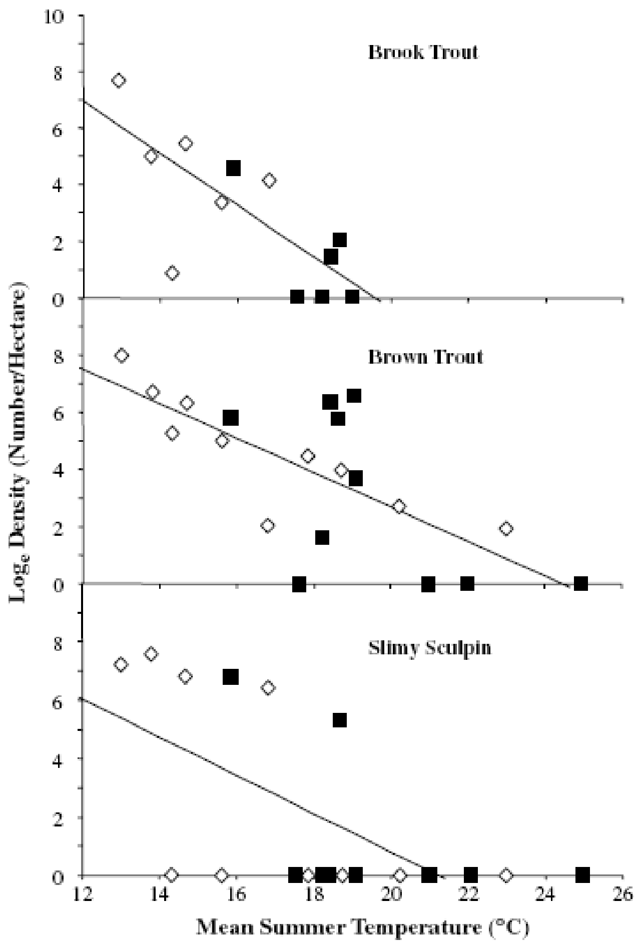


Figure 3. Mixed modelling analysis relating the log$_e$ transformed brook trout, brown trout and slimy sculpin population densities to mean summer temperature (°C). Upstream (open diamonds) and downstream (closed squares) samples are indicated, but position was not significant. Brook trout model is based on the six streams that contained brook trout and the brown trout and slimy sculpin models are based on all ten study streams

Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. Trans. Am. Fish. Soc. 123:627-640.

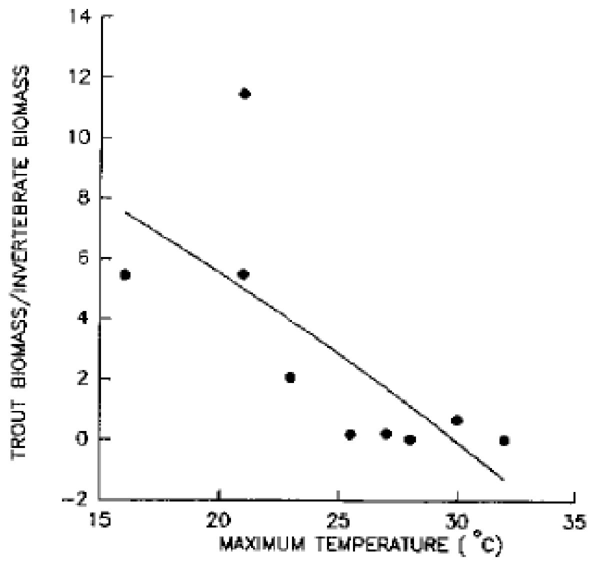


FIGURE 7.—Regression of trout biomass : invertebrate biomass ratio on maximum daily temperature for all reaches combined; $r = -0.71$, $P < 0.05$.

Madriñán, L.F. 2008. Biophysical Factors Driving the Distribution and Abundance of Redband/Steelhead Trout (Oncorhynchus mykiss gairdneri) in the South Fork John Day River Basin, Oregon, USA. Ph.D. Thesis. Department of Fish and Wildlife, Oregon State University, Corvallis, Oregon. 113 p.

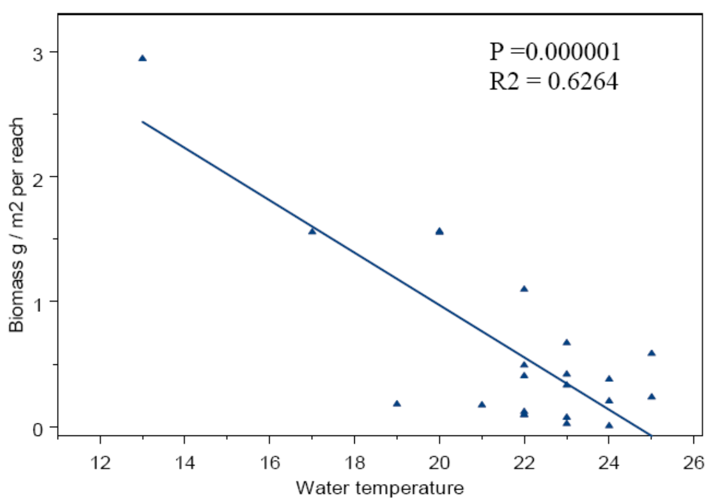


Figure 4.6 (B): Regression analysis between maximum temperature and trout biomass by stream reach

Several studies have shown that maximum stream temperature is negatively associated with trout density (Li et al. 1994, Ebersole et al. 2003); however, most of them did not use biomass because they were unable to identify fish size segregation between patches and assumed that all trout were of equal

size. The classification of juvenile salmonids in different size classes is particularly important when their response to water temperature is being considered.

Ebersole, J.L, Liss, W.J, and Frissell, C.A. 2003. Thermal heterogeneity, channel morphology, and salmonid abundance in northeastern Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 60: 1266 – 1280.

Ebersole et al.

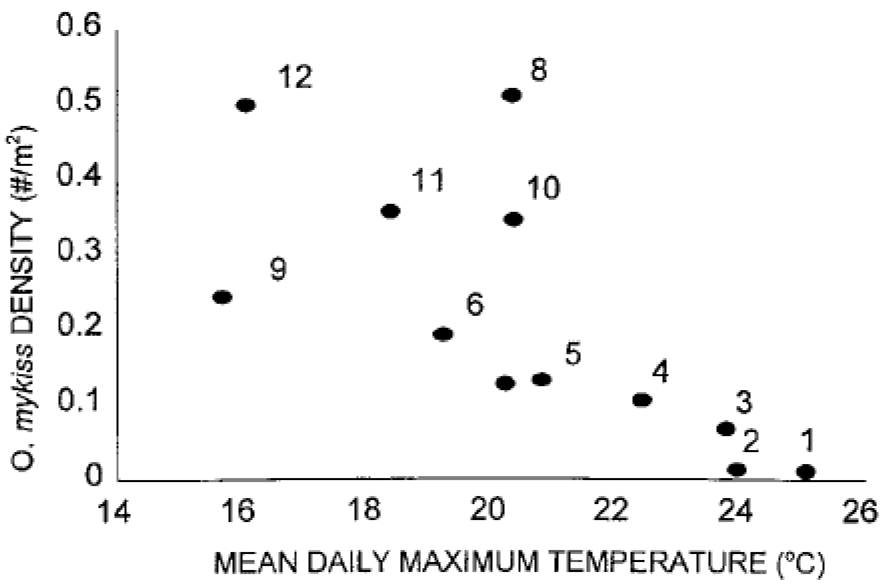
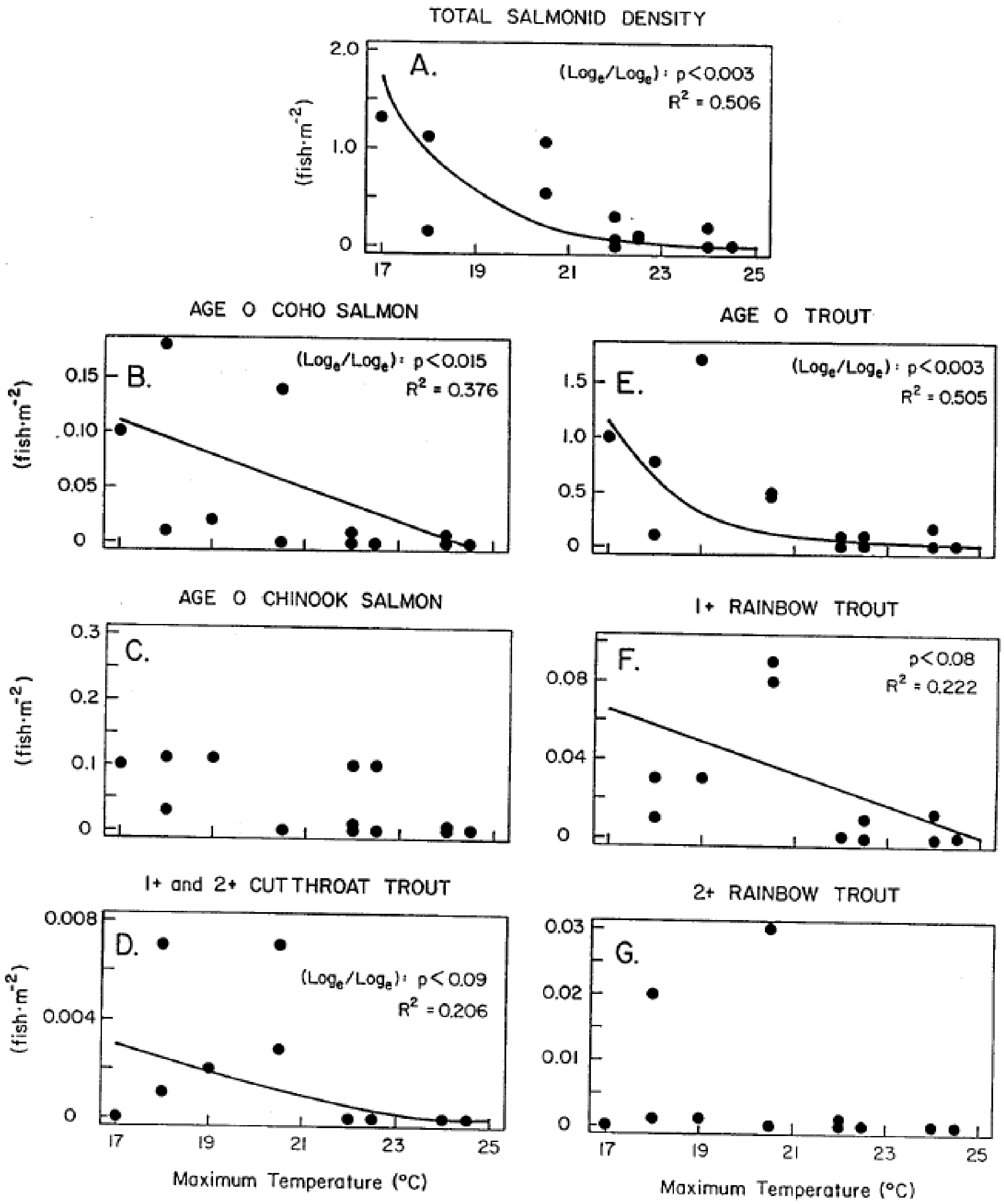


Fig. 3. Relationship between mean rainbow trout density and mean daily maximum water temperatures of 12 study reaches. The numbers refer to map codes for study reaches listed in Table 1.

Frissell, C.A. 1992. Cumulative effects of land use on salmon habitat in southwest Oregon coastal streams. PhD. Thesis. Oregon State University, Corvallis, Oregon. 227 p.



Drake, D. 2012. **Multivariate Analysis of Fish and Environmental Factors in the Grande Ronde Basin of Northeastern Oregon. Oregon Department of Environmental Quality, Portland, Oregon.**

File: ODEQ-Grande Ronde-multivariate analysis-fish-environmental factors-Bio012.pdf

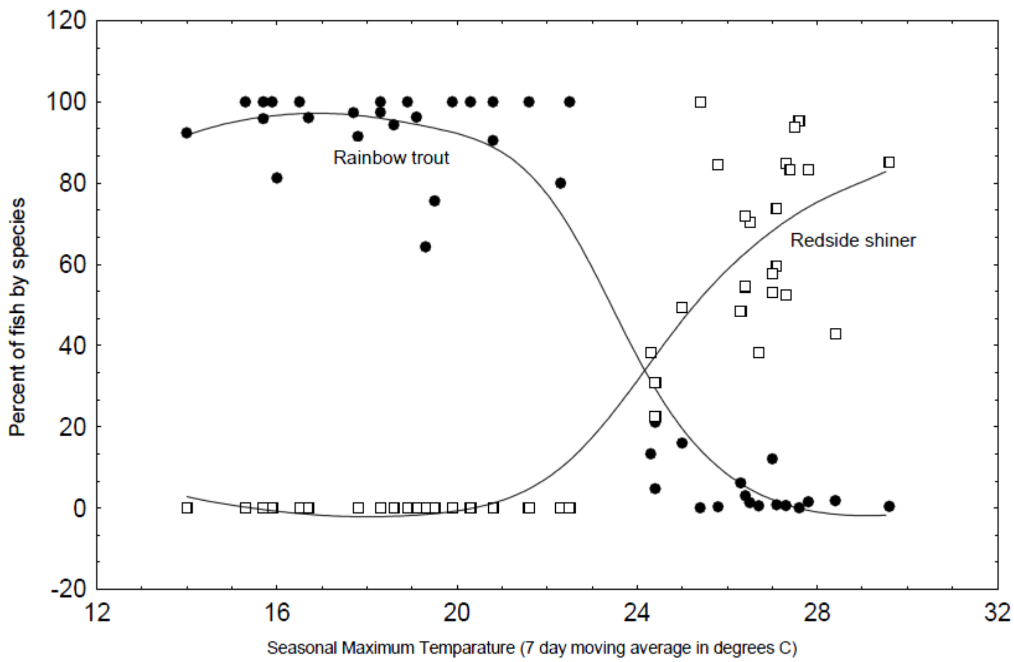


Figure 7. Relationship between percent of Rainbow trout (Oncorhynchus mykiss) and Redside shiner (Richardsonius balteatus) versus the seasonal maximum temperature. A distance weighted least squares line was used as a best fit model.

Thompson, L.C., J.L. Voss, R.E. Larsen, W.D. Tietje, R.A. Cooper, and P.B. Moyle. 2012. Southern Steelhead, Hard Woody Debris, and Temperature in a California Central Coast Watershed. Transactions of the American Fisheries Society 141(2):275-284.

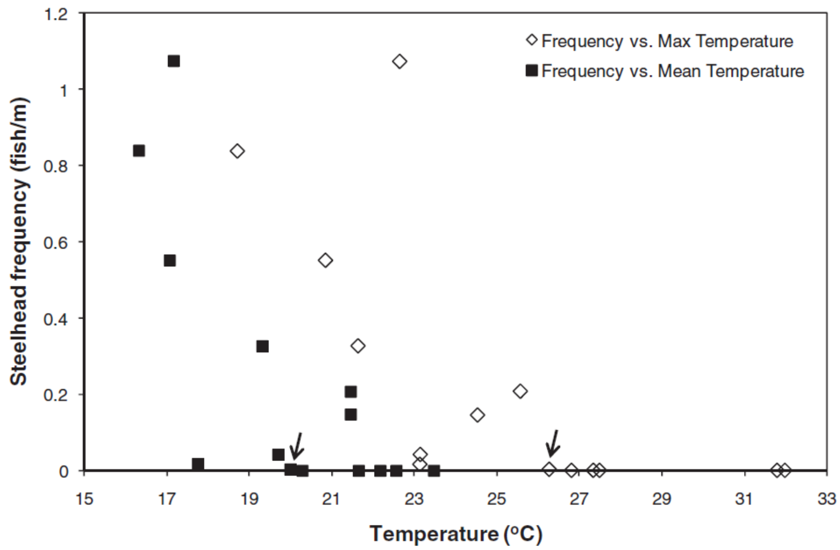


FIGURE 2. Steelhead density plotted against mean water temperature and maximum water temperature. The value producing D_{KBS} (the maximum difference between the observed and theoretical bivariate distribution) for each predictive variable is denoted by an arrow.

Dunham, J., B. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23(3):894-904.

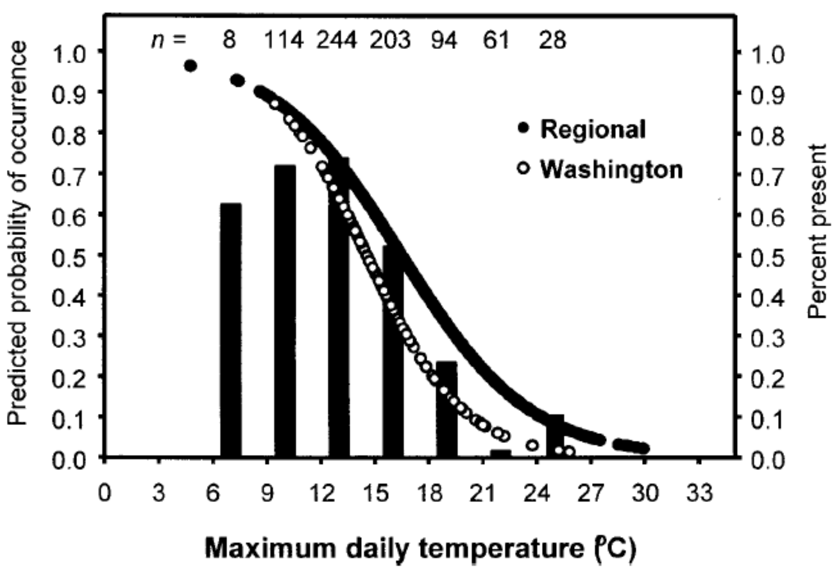


FIGURE 2.—Occurrence of small bull trout in relation to temperature. The left y-axis shows the predicted probability of occurrence in relation to maximum daily temperature for the regional and Washington 2000 data sets (indicated by circles). The right y-axis shows the percentage of sites (both data sets; $n = 752$ sites) where small bull trout were observed (indicated by bars). Bars are centered on 3°C bins with sample sizes indicated above each.

Beauchene, M., M. Becker , C.J. Bellucci , N. Hagstrom, and Y. Kanno. 2014. Summer Thermal Thresholds of Fish Community Transitions in Connecticut Streams. North American Journal of Fisheries Management 34(1):119-131.

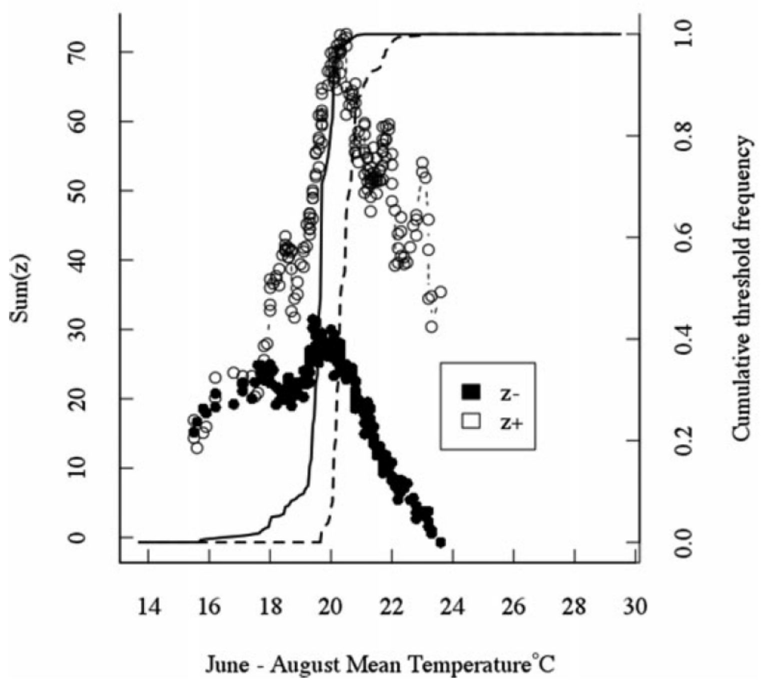


Figure. Threshold Indicator Taxa ANalysis (TITAN) outputs. (**A**) sum(*z*) scores for decreasers (filled circles) and increasers (open circles) across the summer temperature gradient. Vertical lines are cumulative frequency distributions of change points for negative (solid) and positive (dashed) indicator species across 500 replicate runs.

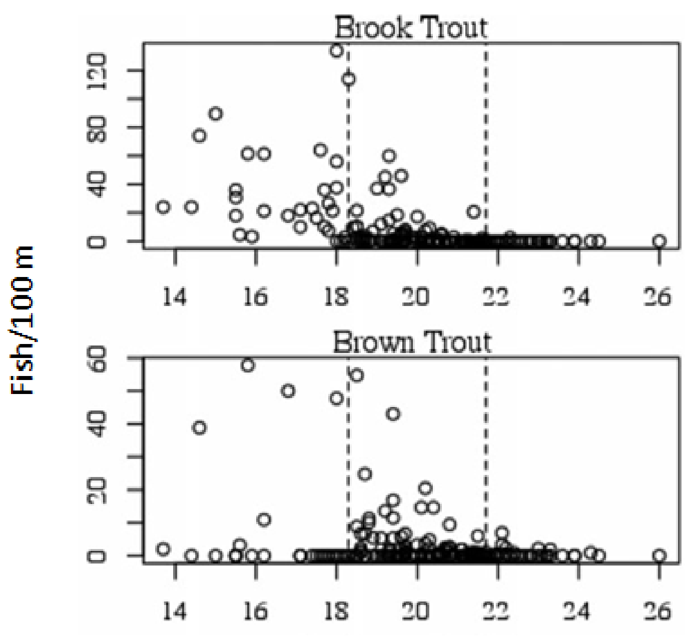


Figure. Standardized abundance (fish count per 100 m) in response to June–August mean water temperature.

Note: In the Beauchene et al. (2014) study above, brook trout and brown trout are the salmonid members of the decreaser group (i.e., those species whose z-scores decrease with increases in summer mean temperatures. These species were members of the "cold" group, found at maximum daily mean temperatures of 22.4°C for the 3-month summer period.

Appendix N. Riparian Vegetation Mapping in the Grande Ronde Watershed, Oregon: Monitoring and Validation of Spring Chinook Habitat Recovery and Population Viability

PHASE 2 PROGRESS REPORT

RIPARIAN VEGETATION MAPPING IN THE GRANDE RONDE WATERSHED, OREGON: MONITORING AND VALIDATION OF SPRING CHINOOK HABITAT RECOVERY AND POPULATION VIABILITY

PREPARED FOR

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
PORTLAND, OREGON

PREPARED BY

ABR, INC.—ENVIRONMENTAL RESEARCH & SERVICES
FAIRBANKS, ALASKA

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FORT COLLINS, COLORADO

RIPARIAN VEGETATION MAPPING IN THE GRANDE RONDE WATERSHED, OREGON: MONITORING AND VALIDATION OF SPRING CHINOOK HABITAT RECOVERY AND POPULATION VIABILITY

PHASE 2 PROGRESS REPORT

Prepared for

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INTRODUCTION

The Columbia River Inter-Tribal Fish Commission (CRITFC) seeks to develop a spatially-based system for modeling abundance, productivity, and growth rate for spring Chinook salmon in the upper Grande Ronde watershed in northeastern Oregon (Figure 1). This watershed has experienced various levels of anthropogenic disturbance, which has compromised the quality of Chinook spawning and rearing habitat. To assess the extent to which current conditions are affecting fish population dynamics, a model of watershed health will be developed based on water temperature, fine sediment (surface and depth), stream flow, and riparian condition. CRITFC is particularly interested in determining the potential to restore the water temperature regime in the watershed, which will require developing a water temperature model. Maps of the current vegetation and potential natural vegetation (PNV) communities are critical to supporting this model.

ABR, Inc.—Environmental Research & Services (ABR) and Elizabeth Crowe are working collaboratively to develop a map of existing and potential natural vegetation throughout the extent of the spring Chinook spawning and rearing zone in the upper Grande Ronde watershed. This progress report outlines the work conducted during Phase 2 (1 April 2013 – 31 March 2014) of this multi-phased project.

OBJECTIVES

Phase 2 objectives included:

1. Develop a species-structure vegetation classification for northeastern Oregon similar to the Alaska Vegetation Classification (Viereck et al. 1992) and create a cross-reference between the species-structure classes and existing plant association classifications for the study area.
2. Aggregate soil series classes from the Union County and Wallowa-Whitman National Forest soil surveys into fewer soil classes that represent functionally similar soils based on morphology, parent material, soil depth, texture, and coarse fragments.
3. Complete draft Integrated Terrain Unit (ITU) mapping of the upper reaches of the Study Area, including the Grande Ronde River and tributaries upstream of LaGrande, Oregon and Catherine Creek and associated tributaries upstream of the confluence with Ladd Creek. Mapping of the remainder of the Study Area will be completed during Phase 3 of the study.

STUDY AREA

The study area encompasses approximate 7,300 hectares (ha) of the Grande Ronde River watershed in northeast Oregon (Figure 1). The study area is defined by a 100 meter buffer along each side of the center of active river channels, including the mainstem and major tributaries of the Grande Ronde River and Catherine Creek from the convergence of Catherine Creek with the Grande Ronde upstream to the headwaters.

METHODS

CLASSIFICATION OF ECOLOGICAL COMPONENTS

We classified and mapped several ecosystem components in the study area using standardized classification and coding systems originally developed for Alaska and modified where appropriate for northeastern Oregon (Tables 1–3).

PHYSIOGRAPHY

Physiography characterizes the dominant tectonic and geomorphic processes controlling the landscape and was classified following Jorgenson et al. (2008) with modifications for northeastern Oregon when appropriate (Table 1).

SOILS

The base map for delineating ITUs is a merger of soil mapping layers produced by the Union County Soil Survey (Dyksterhuis and High 1985) and the Wallowa-Whitman National Forest Soils Database (Soil Survey Staff). This layer contains 111 soil series. As an additional mapping reference, data from unpublished riparian soil mapping on the Wallowa-Whitman National Forest were used when available. These riparian soil map units contain an additional 12 soil series. Many of

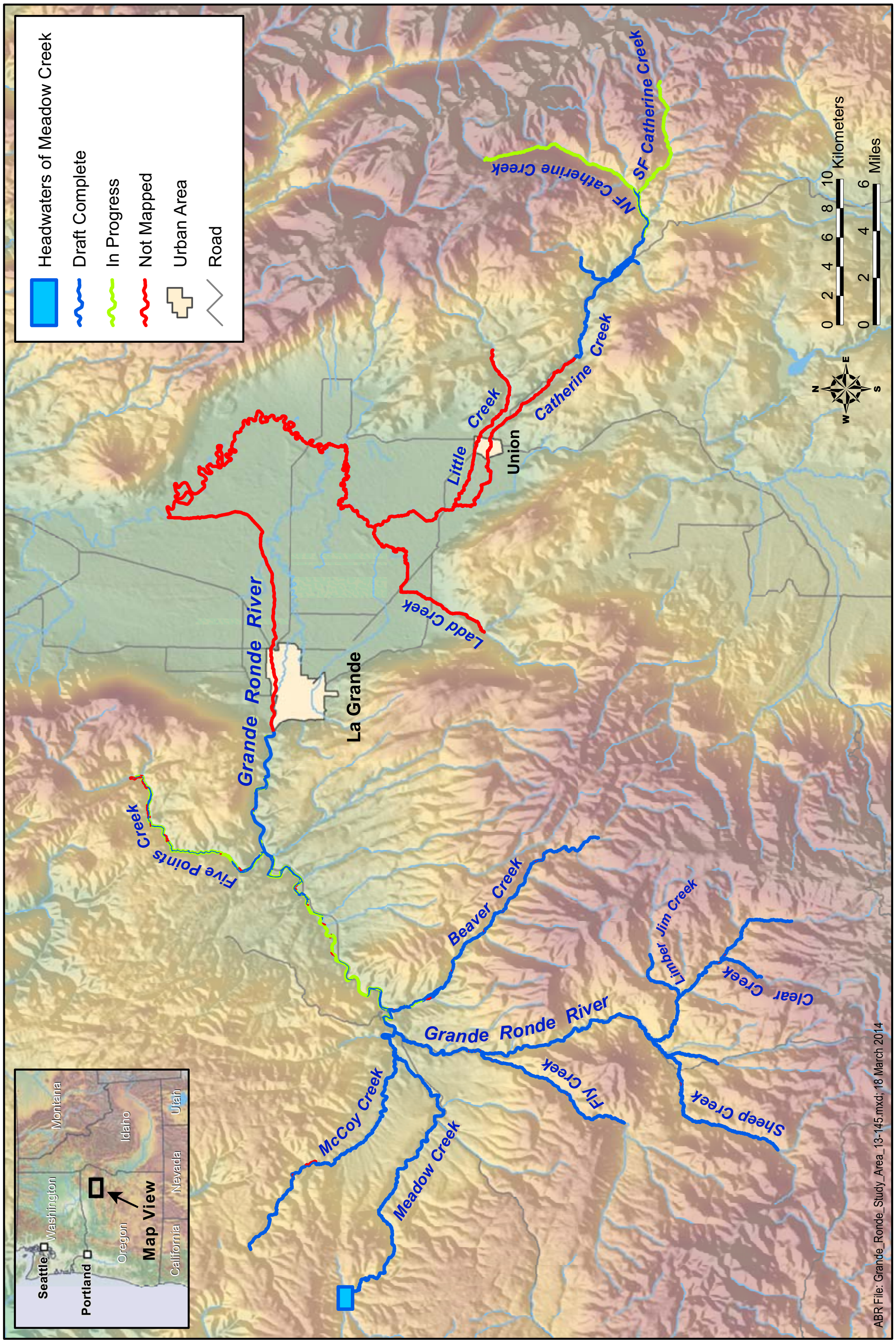

Figure 1. Overview of riparian vegetation mapping study area, including the status of draft Integrated Terrain Unit (ITU) mapping and the detailed study area at the headwaters of Meadow Creek depicted in subsequent figures, Grande Ronde River watershed, northeastern Oregon.

Table 1. Standard classification system developed for classifying and mapping physiography and generalized soils in the Grande Ronde River watershed, northeastern Oregon.

Code	Title
PHYSIOGRAPHY CODING	
L	Lowland
R	Riverine
U	Upland
SOIL CODING	
AsilovCF	Ashy silt loam over coarse frags
AsilovL	Ashy silt loam over loam
AsilovSk	Ashy silt loam over skeletal
DpSiCL	Deep–silt to clay loam
DpCF	Deep w/coarse fragments
LiShC	Lithic/Shallow to Clay
LovSk	Loam over skeletal
LSil	Loam/Silt Loam
LSilbr	Loam/Silt Loam–brackish
LSilor	Loam/Silt Loam–organic-rich
LGr	Loamy-gravelly
MDpCF	Mod. deep w/coarse frags
Roads	Roads
Rock	Rock Outcrop
SSkEnt	Sandy-skeletal Entisols
StmBkHG	Streambanks–high gradient
Urban	Urban Complex
Water	Water

the soil series were similar enough to support nearly identical existing and/or PNVs. Consequently, the soil series were aggregated into generalized soil units to simplify ITU mapping. The soil series were aggregated by reviewing profile descriptions and typical pedon for each series from the three data sources discussed above (U.S. Department of Agriculture, Natural Resources Conservation Service Soils). Soil cross sectional diagrams (Appendix 1) were created for all series and compared to determine which could be combined. The criteria used as the basis for combining series included horizon textural classes; horizon coarse fragment content (gravels, cobbles, stones); depth to root restricting layers (e.g. bedrock, duripans, clay) and/or perched water tables; strong chemical characteristics; and soil temperature and soil moisture classes. Horizon texture, coarse fragment content, profile depth, and chemical composition strongly influence Levels I through III of the vegetation classification. Soil temperature and moisture classes are also very important influences on plant species occurrence, density, and structure and will be considered when polygons are attributed with Level IV classes; Level III vegetation classes were used for the Phase 2 draft mapping (see Vegetation below). Ultimately, 14 generalized soil units were developed (Table 1) from the original 123 soil series (Appendix 2). Four additional non-soil classes were added to the soil classification for mapping purposes, including Roads, Rock Outcrop, Urban Complex, and Water.

VEGETATION AND DISTURBANCE

Plant associations and plant community types from Crowe and Clausnitzer (1997) and Wells (2006) were organized into a 5-level hierarchical classification scheme (Appendix 3) similar to Viereck et al (1992). The plant associations and community types are equivalent to Level V vegetation types, but cannot be mapped with a high degree of accuracy since they are plant species-level associations. Many Level V types occur in more than one Level IV type because they can have a range of total tree or shrub overstory canopy cover (i.e., open vs. closed) and shrub heights (i.e., low vs. tall). Level III vegetation classes were used for the Phase 2 draft mapping (Table 2), but will be mapped to Level IV when the map is complete. This lower-level mapping is a more efficient scale to use for preliminary mapping and will provide the information needed for field survey preparation. Disturbance characterizes recent (< 5 years) or ongoing landscape disturbance, and includes both natural (e.g., forest fire) and anthropogenic (e.g., agricultural) field classes (Table 3).

MAPPING OF ECOLOGICAL COMPONENTS

Individual ecological components were mapped simultaneously as compound codes called Integrated Terrain Units (ITUs). For the draft

Table 2. Standard classification system developed for classifying and mapping existing vegetation (level III classes) in the Grande Ronde River watershed, northeastern Oregon.

Code	Title
Bbg	Barren
Bpv	Partially Vegetated
DC	Disturbance Complex
Fbc	Closed Broadleaf Forest
Fbo	Open Broadleaf Forest
Fnc	Closed Needleleaf Forest
Fno	Open Needleleaf Forest
Fnw	Needleleaf Woodland
Hgd	Dry Graminoid Meadow
Hgm	Moist Graminoid Meadow
Hgw	Wet Graminoid Meadow
RD	Roads
RO	Rock Outcrop
Slc	Closed Low Shrub
Slo	Open Low Shrub
Stc	Closed Tall Shrub
Sto	Open Tall Shrub
Xd	Urban Complex
Wf	Fresh Water
Xr	Riverine Complex
Xu	Upland Complex
Ub	Buildings and Other Structures

mapping, ITUs were mapped by assigning four parameters to each polygon describing physiography, existing vegetation, soils, and disturbance (e.g., Riverine/Moist Graminoid Meadow/Loam-Silt Loam/Absent). The mapping parameters were attributed using a standardized coding scheme (Tables 1–3); following from the above example, e.g., R/Hgm/LSil/A.

Polygon delineation was done on-screen in a Geographic Information System (GIS) by aerial photo-interpretation of 4-band (including near-infrared [NIR]) 1.0-meter pixel resolution imagery acquired July-August 2012 (Figure 2). The imagery was obtained from the National Aerial Imagery Program (NAIP). The NIR band provided additional information that assisted in differentiating between vegetation classes (e.g., needleleaf vs. broadleaf). Secondarily, mapping was conducted on a CRITFC-supplied NAIP natural color orthophotography mosaic acquired in 2009 with 1.0-m pixel resolution.

A LiDAR dataset (1.0-m resolution), provided by CRITFC and generated by Watershed Sciences, Inc. (LiDAR Remote Sensing Data: Grande Ronde River Basin, Oregon, Watershed Sciences, Inc. December 23, 2009) was also used to assist the mapping effort. The BareEarth_mosaic raster dataset was further processed by ABR into an elevation-independent hillshade, using the ESRI Spatial Analyst toolset in ArcMap 10.2 (Figure 2). This was used to delineate valley bottom and channel location, physiography, and landscape features and disturbances, particularly under forest canopy. The Canopy2009_mosaic was used to assess tree and shrub height and density (e.g., Open vs. Closed Needleleaf Forest) (Figure 2).

Map polygons were delineated at a mapping scale of 1:2,000 to 1:3,000 for a final map scale (the scale at which the mapping is valid for landscape analysis) of 1:5,000. The minimum mapping size for polygons (a 'polygon' is defined here as an area delineated on the map as a single unit) was 0.10 ha for waterbodies, 0.81 ha for complexes, and 0.20 ha for all other classes. Minimum width for mapping the active riverbed was set at 5 m, below which the stream bed was not mapped but was instead aggregated with the surrounding floodplain. Several complex vegetation classes were used to map highly heterogeneous areas associated with dynamic geomorphic processes and anthropogenic disturbance. The complexes were used for polygons where at least 3 vegetation classes were present, the dominant cover type occupied <65% of the polygon, and inclusions were below the minimum size for mapping. Draft maps were produced for each of the individual ecological components used to create the ITUs (physiography, vegetation, soils, and disturbance).

Table 3. Standard classification system developed for classifying and mapping disturbance in the Grande Ronde River watershed, northeastern Oregon.

Code	Title
A	Absent, None (mature vegetation)
DC	Disturbance complex
Ha	Agricultural Field
Hag	Livestock Grazing
Hc	Clearings (Non-agricultural or undifferentiated)
Hcl	Logged
Hd	Human Developed Sites (urban complex)
Hdr	Residential Development
He	Excavation/Pits (undifferentiated)
Hf	Fill
Hfgr	Gravel Road
Hfgrp	Paved Road
Hft	Mine Tailings
Hsb	Building
Hwc	Canal
Hwd	Ditch
Hwe	Water-filled excavation
Hwi	Drainage Impoundment
Nf	Fire
Ngfd	Fluvial Deposition
Ngfe	Fluvial Erosion/channel migration

RESULTS AND DISCUSSION

The ITU map is in draft form and is presently in progress (Figure 1). Of the total study area (7,300 ha), approximately 3,756 ha (52% of the total study area) has been mapped in Draft form; 1,103 ha (15%) is In Progress; and 2,425 ha (33%) is Not Mapped. As the draft mapping is not complete for the entire study area, the Results and Discussion are limited to a small area of Draft Complete mapping in the headwaters of Meadow Creek to illustrate the ITU classification and mapping methods, and the preliminary map products to be prepared in this study. Note that in many cases, ecosystem component classes appear in the description tables but do not appear in the map legends. This is because the Results and Discussion section is limited to the headwaters of Meadow Creek, while the ITU mapping will eventually encompass the entire study area and will include the additional ecological components not present in the headwaters of Meadow Creek.

MEADOW CREEK

PHYSIOGRAPHY

Three physiography classes were mapped in the headwaters of the Meadow Creek mapping area (Figure 3, Table 4). The most common physiography class was upland (51.8% of the mapping area, Table 5), followed by riverine (36.5%), and lowland (11.7%). Physiographic units are broad areas on the landscape that are characterized by similar geomorphic processes,

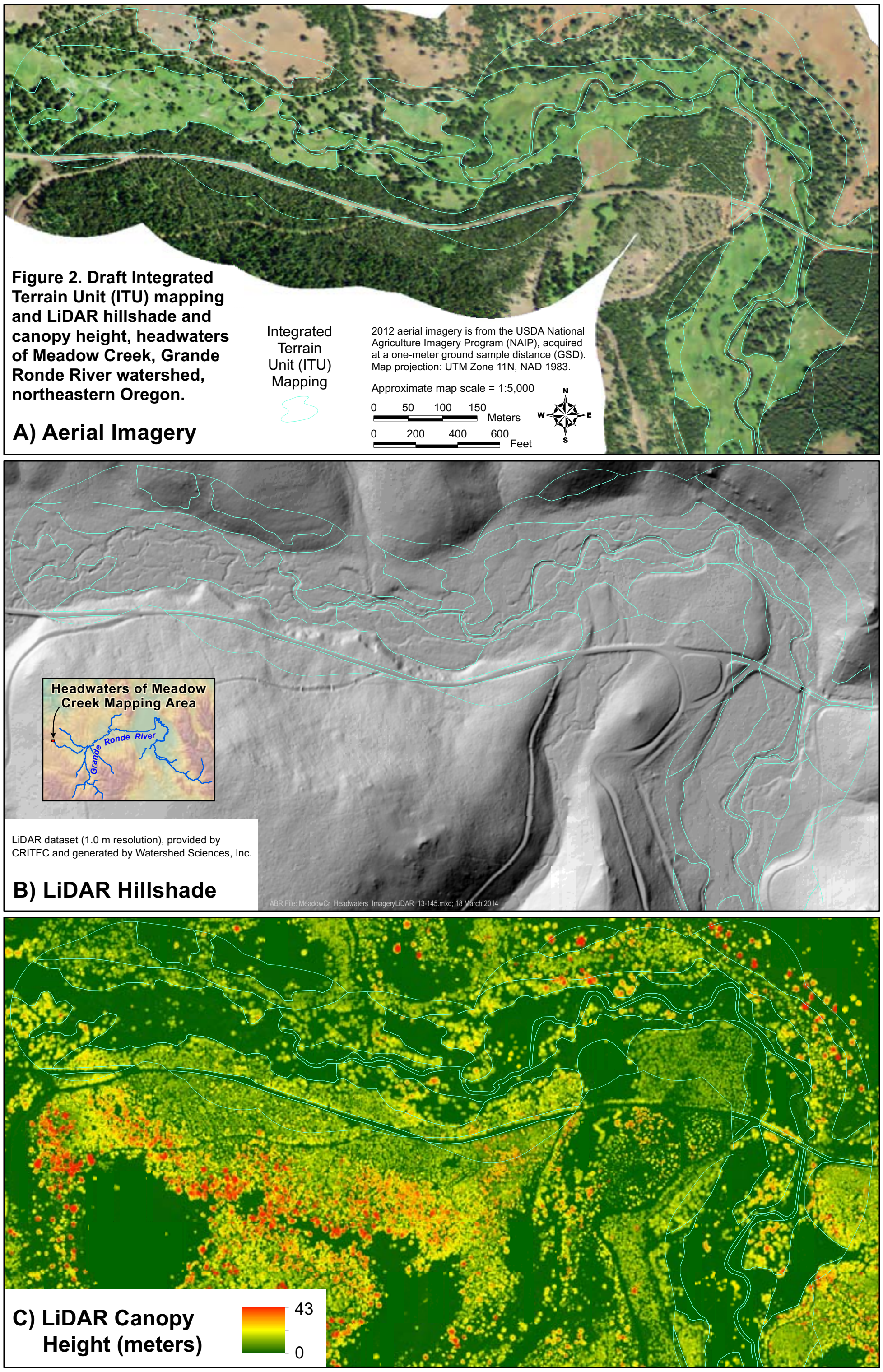

Figure 2. Draft Integrated Terrain Unit (ITU) mapping depicting A) the aerial imagery over which polygons were delineated, B) the LiDAR hillshade used for delineating topographic features, and C) the LiDAR canopy height data used for determining vegetation height and structure classes (e.g., closed tall vs. open low shrub), headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

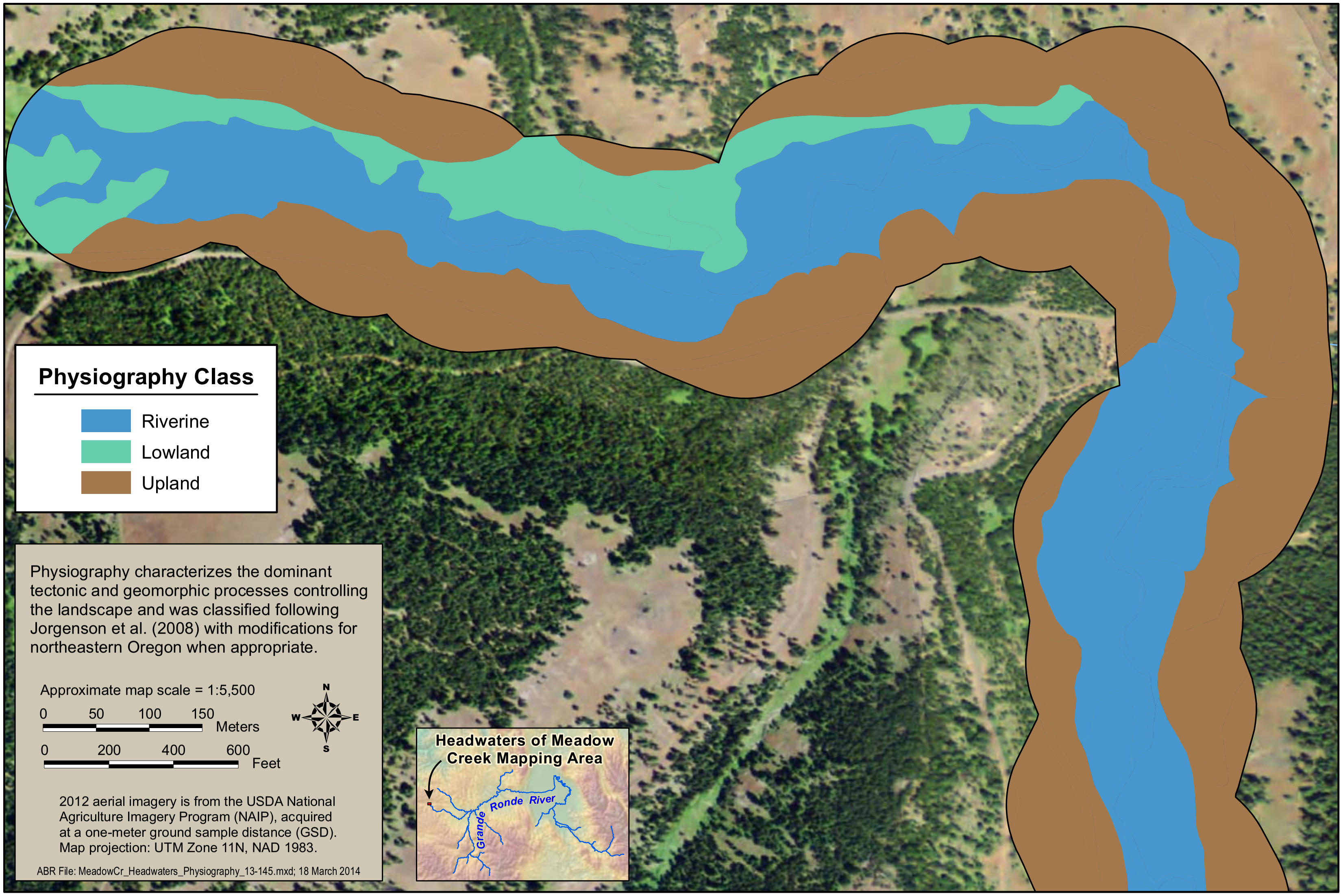

Figure 3. Draft Integrated Terrain Unit (ITU) mapping depicting physiography for the headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

Table 4. Classification and description of physiography classes mapped in the headwaters of Meadow Creek mapping area, Grande Ronde River watershed, northeastern Oregon.

Physiography Class	Description
Lowland (L)	Flat to gently sloping and concave areas of the landscape at elevations lower than adjacent uplands. Typically zones of water accumulation.
Riverine (R)	Areas of the landscape subject to regular (<5–25 yrs) to irregular (25–100 yrs) channel and overbank flooding by rivers or streams
Upland (U)	Moderate to steeply sloping and convex areas of the landscape at elevations above adjacent lowland and riverine areas. Typically water shedding.

topographic relief, and geologic substrate. For instance, by mapping physiography we can differentiate areas on the landscape that are subject to frequent flooding and associated sedimentation and erosion (i.e., riverine), areas that rarely flood and have poorly drained soils (i.e., lowlands), and areas characterized by dry, well-drained soils on moderately to steeply sloping topography (i.e., uplands). Physiography will be used 1) in the 2014 field study design to direct our sampling towards riparian areas, and 2) in the final map to inform the mapping of Level IV PNV classes.

SOILS

Six generalized soil classes and two non-soil classes were mapped in the headwaters of Meadow Creek mapping area (Figure 4, Table 6). The most common generalized soil classes included Ashy silt loam over skeletal (33.8% of the mapping area, Table 5), Ashy Silt Loam over Loam (31.1%), and Loam/Silt Loam–organic-rich (15.3%). The generalized soil classes assist in predicting the structural characteristics of both existing and potential vegetation, i.e., whether a site may support herbaceous, shrubby or forested vegetation. When combined with the soil temperature and moisture classes, these soil classes will help predict the specific dominant overstory plant species (e.g., subalpine fir vs. grand fir), particularly when mapping potential vegetation. Correlating generalized soil classes with specific fluvial geomorphic surfaces and stream channel types (e.g., plane bed vs. pool-riffle) in lowland and riverine physiography are likely to be more accurate than upland areas. Field verification data collecting in summer 2014 will be used to assess the generalized soil classification and mapping.

EXISTING VEGETATION

Eleven Level III vegetation classes were mapped in the headwaters of Meadow Creek mapping area (Figure 5, Table 7). The most common Level III vegetation class was Needleleaf Woodland (25.6% of the mapping area, Table 5), followed by Closed Needleleaf Forest (19.3%), and Wet Graminoid Meadow (17.4%). We mapped existing Level III vegetation classes in the draft mapping because the classification is based on vegetation structure and life form rather than individual species, which allowed for rapid mapping progress. For the draft mapping, Level III vegetation classes are sufficient for developing our 2014 field sampling scheme. For Riverine and Lowland areas in the final map, the Level III classes will be refined and replaced with Level IV vegetation classes. PNV also will be classified to Level IV for each existing vegetation polygon. Since the focus of this mapping effort is on riparian areas, the delineation of existing Level III vegetation classes in Upland areas will be refined but will represent the final vegetation map classes.

DISTURBANCE

Three disturbance classes were mapped in the headwaters of the Meadow Creek mapping area (Figure 6, Table 8). The most common disturbance class was No Disturbance (58.0% of the mapping area, Table 5), followed by Livestock Grazing (39.6%), and Gravel Road (2.4%). Disturbance characterizes recent (< 5 years) or ongoing landscape disturbance, and includes both natural (e.g., forest fire), and anthropogenic (e.g., agricultural field) classes. Mapping recent landscape disturbances is important because it allows us to identify areas on the landscape where

Table 5. Areal extent of individual components of Integrated Terrain Units (ITUs) in the headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

ITU Components	Acres	Hectares	%
PHYSIOGRAPHY CLASSES			
Lowland	11.2	4.5	11.7
Riverine	34.9	14.1	36.5
Upland	49.5	20.0	51.8
TOTAL	95.7	38.7	100.0
GENERALIZED SOIL CLASSES			
Ashy silt loam over loam	14.7	5.9	15.3
Ashy silt loam over skeletal	32.3	13.1	33.8
Loamy-gravelly	1.0	0.4	1.1
Lithic/Shallow to Clay	10.9	4.4	11.4
Loam/Silt Loam - organic-rich	29.8	12.0	31.1
Mod. deep w/coarse frags	2.2	0.9	2.3
Roads	2.3	0.9	2.4
Streambanks - high gradient	2.5	1.0	2.6
TOTAL	95.7	38.7	100.0
LEVEL III VEGETATION CLASSES			
Partially Vegetated	1.0	0.4	1.1
Closed Needleleaf Forest	18.5	7.5	19.3
Open Needleleaf Forest	11.1	4.5	11.6
Needleleaf Woodland	24.5	9.9	25.6
Dry Graminoid Meadow	6.0	2.4	6.3
Moist Graminoid Meadow	2.3	0.9	2.4
Wet Graminoid Meadow	16.6	6.7	17.4
Roads	2.3	0.9	2.4
Open Low Shrub	1.5	0.6	1.6
Closed Tall Shrub	2.1	0.8	2.2
Riverine Complex	9.7	3.9	10.1
TOTAL	95.7	38.7	100.0
DISTURBANCE CLASSES			
No Disturbance	55.5	22.5	58.0
Gravel Road	2.3	0.9	2.4
Livestock Grazing	37.9	15.3	39.6
TOTAL	95.7	38.7	100.0

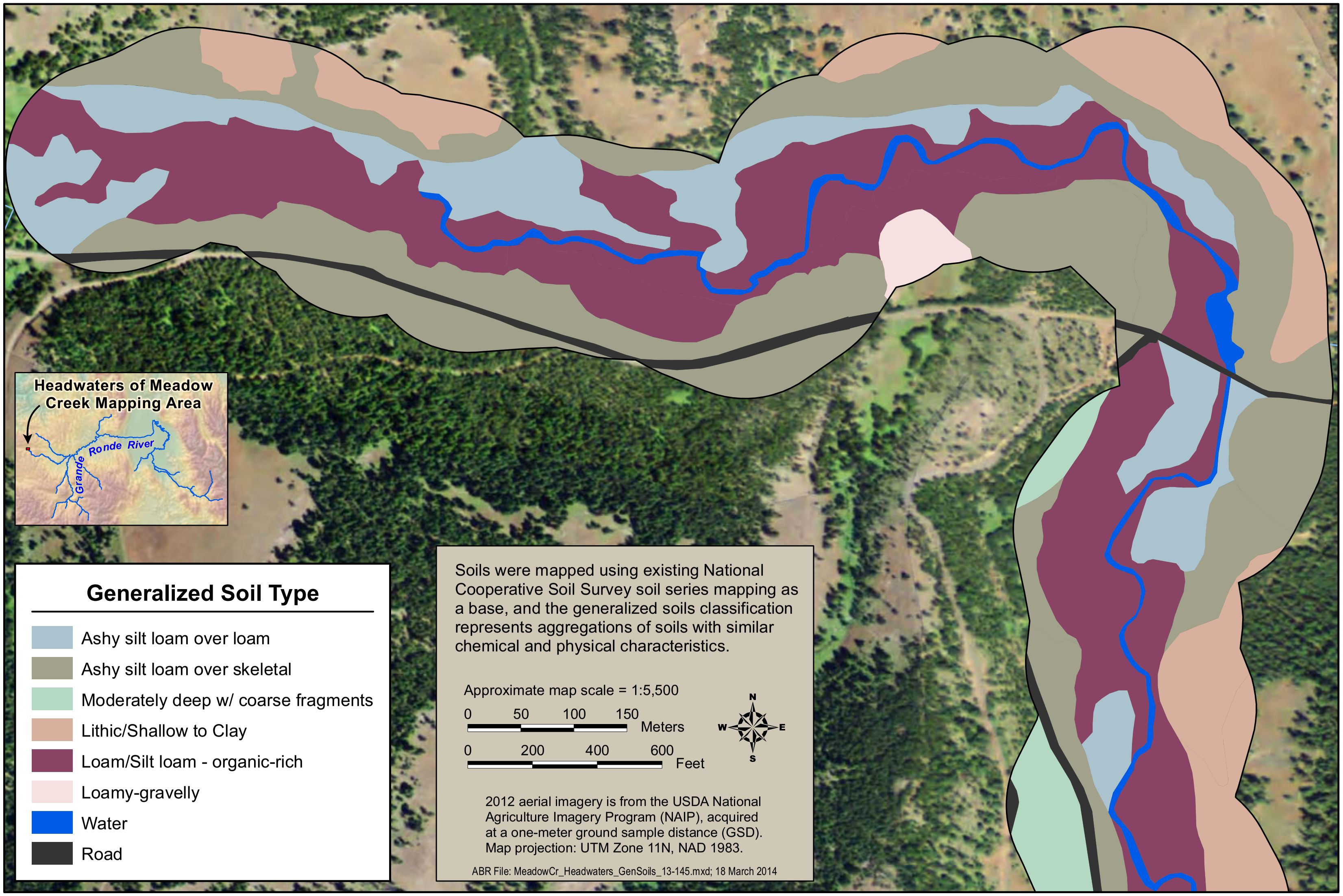

Figure 4. Draft Integrated Terrain Unit (ITU) mapping depicting generalized soils for the headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

Table 6. Classification and description of generalized soils in the Grande Ronde River watershed, northeastern Oregon. Generalized soil classes that were mapped in the headwaters of Meadow Creek mapping area are indicated with an asterisk.

Level III Vegetation Class	Description
Ashy silt loam over coarse frags (AsilovCF)	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with sandy loam to gravelly loam textures between 50 cm and 100 cm below soil surface
Ashy silt loam over loam (AsilovL)*	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with ashy silt loam or silt loam textures between 50 cm and 100 cm below soil surface
Ashy silt loam over skeletal (AsilovSk)*	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with at least 35% gravels, cobbles and/or stones between 50 cm and 100 cm below soil surface
Deep–silt to clay loam (DpSiCL)	Soils without bedrock or clay horizon within 100 cm below soil surface; horizon textures within 50 cm below soil surface are silt loam to clay loam
Deep w/coarse fragments (DpCF)	Soils without bedrock or clay horizon within 100 cm below soil surface; at least one horizon within 50 cm below soils surface contain at least 15% gravels, cobbles or stones
Lithic/Shallow to Clay (LiShC)*	Soils with bedrock or clay horizon within upper 50 cm below soil surface
Loam over skeletal (LovSk)	Soils with at least one horizon with loam or sandy loam texture above a horizon with at least 35% gravels, cobbles or stones all within 50 cm below soil surface
Loam/Silt Loam–brackish (LSilbr)	Soils occurring in contemporary or prehistoric lake basins with at least one horizon with silt loam texture within 50 cm below soil surface
Loam/Silt Loam–organic-rich (LSilor)*	Mollisols and Histosols (organic soils) occurring in valley bottom meadows
Loam/Silt Loam (LSil)	Mollisols and soils in which all horizons within 50 cm below soil surface have textures of silt loam or loam and less than 15% gravels, cobbles or stones
Loamy-gravelly (LGr)*	Soils occurring on alluvial fans with silt loam, loam, sandy loam or gravelly silt loam textures within 50 cm below soil surface
Mod. deep w/coarse frags (MDpCF)*	Soils with bedrock or clay horizon within 100 cm below soil surface; at least one horizon within 50 cm below soils surface contain at least 15% gravels, cobbles or stones
Roads (Roads)*	Soil, gravel or paved road surface
Rock Outcrop (Rock)	Rock outcrop
Sandy-skeletal Entisols (SSkEnt)	Entisols (poorly developed soils) with sandy textures and at least 35% by volume gravels, cobbles and/or stones within 50cm below soil surface
Streambanks–high gradient (StmBkHG)	Soils with high ash content and high water tables occurring along streambanks of narrow, high elevation streams
Urban Complex (Urban)	Mix of structures and other human-modified surfaces that are too small to map individually
Water (Water)*	River, stream, lake or pond

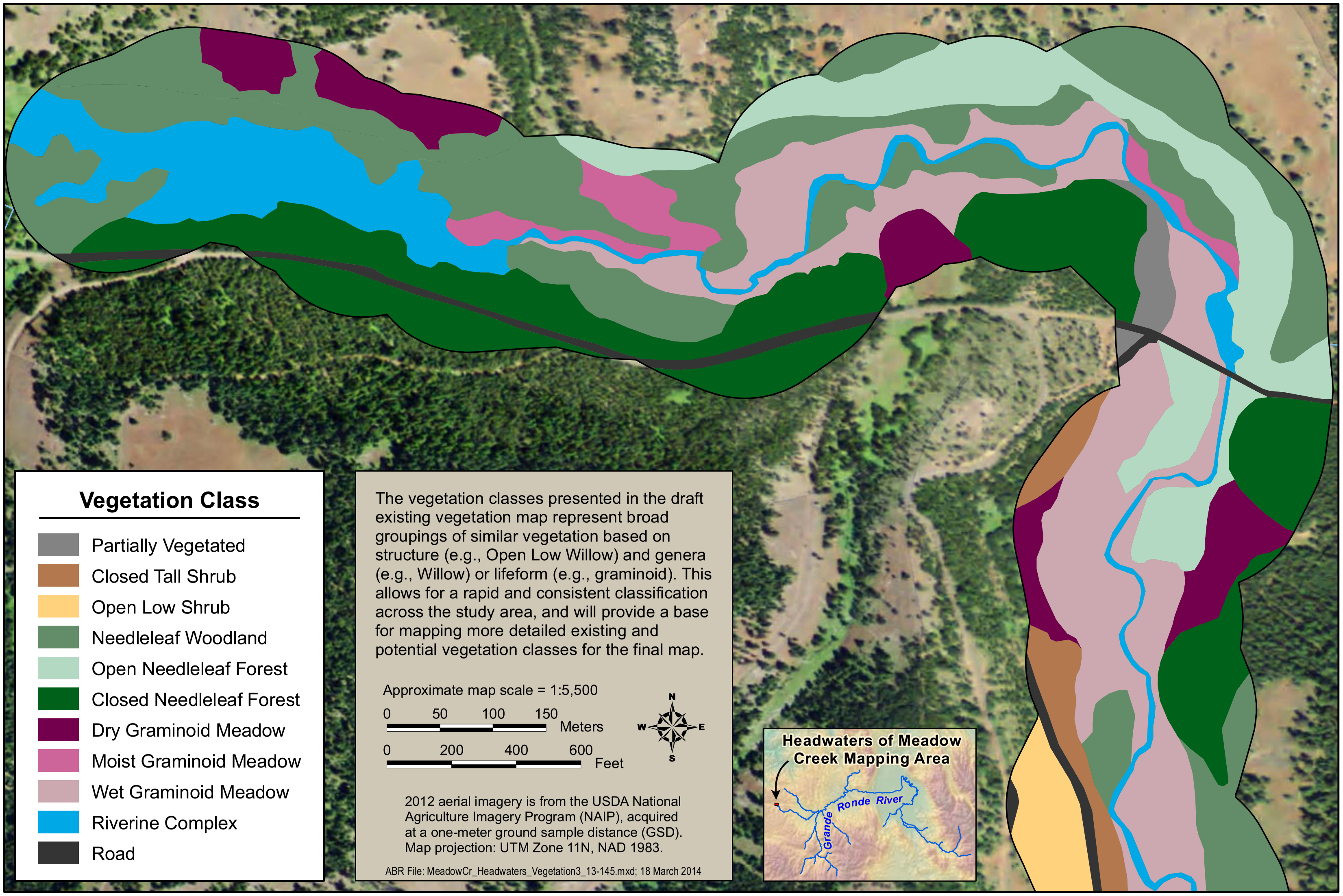

Figure 5. Draft Integrated Terrain Unit (ITU) mapping depicting existing vegetation (level III classes) for the headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

Table 7. Classification and description of existing vegetation (level III classes) in the Grande Ronde River watershed, northeastern Oregon. Existing vegetation classes that were mapped in the headwaters of Meadow Creek mapping area are indicated with an asterisk.

Level III Vegetation Class	Description
Barren (Bbg)	Areas on the landscape with 0–5% vegetated cover
Buildings and Other Structures (Ub)	Discrete buildings or structures that are at least the area of the minimum map unit size
Closed Broadleaf Forest (Fbc)	Areas on the landscape with > 60% broadleaf tree cover
Closed Low Shrub (Slc)	Areas on the landscape with >7 5% low (< 1.5 m) shrubs.
Closed Needleleaf Forest (Fnc)*	Areas on the landscape with > 60% needleleaf tree cover
Closed Tall Shrub (Stc)*	Areas on the landscape with > 75% tall (> 1.5 m) shrubs
Disturbance Complex (DC)	Areas on the landscape with > 25% vegetated cover and 3 disturbed vegetation types that co–occur spatially and cannot be split into individual vegetation classes given the minimum map unit size, and no single vegetation type is dominant (>2/3 of the area)
Dry Graminoid Meadow (Hgd)*	Areas on the landscape with < 25% shrubs and >25% graminoid cover, dry sites
Fresh Water (Wf)	Areas of the landscape with ≤ 25% vegetated cover and characterized by persistent fresh water, including rivers, ponds, and reservoirs
Moist Graminoid Meadow (Hgm)*	Areas on the landscape with < 25% shrubs and >25% graminoid cover, moist sites
Needleleaf Woodland (Fnw)*	Areas on the landscape with 10–25% needleleaf tree cover
Open Broadleaf Forest (Fbo)	Areas on the landscape with 25–60% broadleaf tree cove.
Open Low Shrub (Slo)*	Areas on the landscape with 25–75% low (< 1.5 m) shrubs
Open Needleleaf Forest (Fno)*	Areas on the landscape with 25–60% needleleaf tree cover
Open Tall Shrub (Sto)	Areas on the landscape with 25–75% tall (> 1.5 m) shrubs
Partially Vegetated (Bpv)*	Areas on the landscape with 5–25% vegetated cover
Riverine Complex (Xr)*	Riverine areas with 3 or more riparian vegetation types that co-occur spatially and cannot be split into individual vegetation types given the minimum map unit size, and no single vegetation type is dominant (> 2/3 of the area)
Road (RD)*	Paved and gravel roads
Rock Outcrop (RO)	Areas of the landscape with ≤ 25% vegetated cover and > 25% exposed rock outcrop
Upland Complex (Xu)	Upland areas with 3 or more upland vegetation types that co-occur spatially and cannot be split into individual vegetation types given the minimum map unit size, and no single vegetation type is dominant (> 2/3 of the area)
Urban Complex (Xd)	Urban areas that include roads, buildings, and other urban development
Wet Graminoid Meadow (Hgw)*	Areas of the landscape with < 25% shrubs and > 25% graminoid cover, wet sites

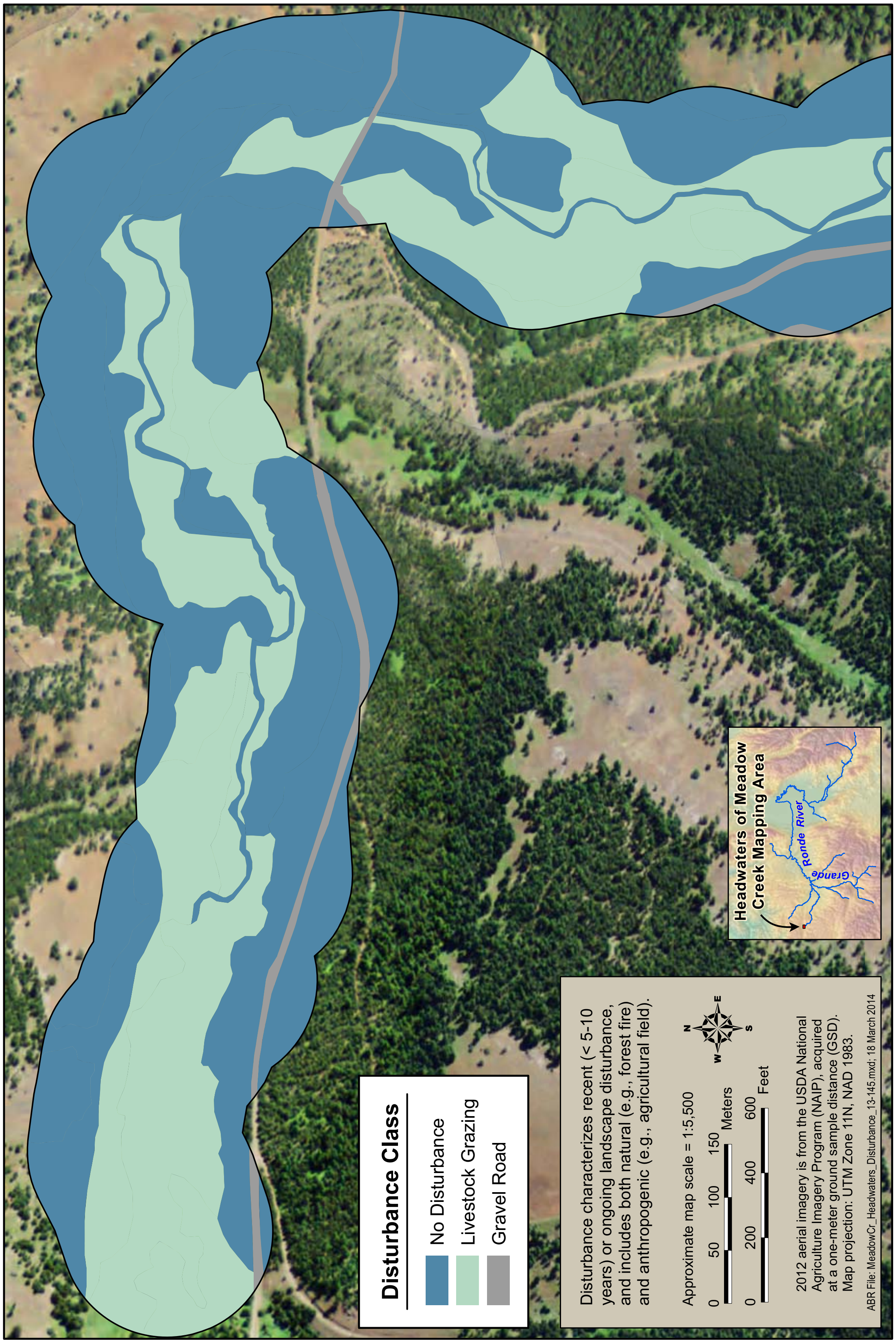

Figure 6. Draft Integrated Terrain Unit (ITU) mapping depicting disturbance for the headwaters of Meadow Creek, Grande Ronde River watershed, northeastern Oregon.

Table 8. Classification and description of disturbance in the Grande Ronde River watershed, northeastern Oregon. Disturbance classes that were mapped in the headwaters of Meadow Creek mapping area are indicated with an asterisk.

Disturbance Class	Description
No Disturbance (A)*	No recent (i.e., post-2007) disturbance
Disturbance complex (DC)	Areas on the landscape with 3 or more disturbance types that co-occur spatially and cannot be split into individual disturbance types given the minimum map unit size, and no single disturbance type is dominant (>2/3 of the area)
Agricultural Field (Ha)	Active or abandoned agricultural fields
Livestock Grazing (Hag)*	Areas of the landscape affected by regular (annual or bi-annual) livestock grazing
Clearings (Non-agricultural or undifferentiated) (Hc)	Areas cleared of vegetation unrelated to agriculture
Logged (Hcl)	Areas of the landscape that have experienced recent logging.
Human Developed Sites (Hd)	Urban areas. Typically mapped with the vegetation class “Urban Complex”
Residential Development (Hdr)	Areas of residential development, including ranches and homesteads
Excavation/Pits (undifferentiated) (He)	Areas characterized by undifferentiated excavations and/or pits; often related to past or present mining activity
Fill (Hf)	Areas of the landscape characterized by gravel or other fill material
Gravel Road (Hfgr)*	Unpaved roads
Paved Road (Hfgrp)	Paved roads
Mine Tailings (Hft)	Areas of the landscape characterized by mine tailings
Building (Hsb)	Areas of the landscape affected by buildings and other structures. Typically mapped with the vegetation class “Buildings and Other Structures”
Canal (Hwc)	Canals and areas of the landscape otherwise affected by canals
Ditch (Hwd)	Ditches and areas of the landscape otherwise affected by ditches
Water-filled excavation (Hwe)	Small waterbodies created by soil excavation and subsequent infilling by water
Drainage Impoundment (Hwi)	Reservoirs or other waterbodies created by the impoundment of water
Fire (Nf)	Areas of the landscape affected by recent wildfire
Fluvial Deposition (Ngfd)	Riverine areas affected by recent fluvial sediment deposition
Fluvial Erosion/channel migration (Ngfe)	Riverine areas affected by recent fluvial erosion or channel migration

the soils and vegetation have been modified, which may result in a different vegetation potential for a given site.

SUMMARY

The classification and mapping we have completed during Phase 2 has provided a solid foundation for our upcoming field verification work and the subsequent final existing and potential vegetation maps. The LiDAR bare earth data has proven invaluable for delineating the extent of valley bottoms and for delineating primary and secondary stream channels and actively used and decommissioned roadbeds. These features were often very difficult to impossible to delineate using only the NAIP imagery. The upcoming field verification phase will provide the opportunity to test and refine our draft mapping and lay the groundwork for final mapping during Phase 3.

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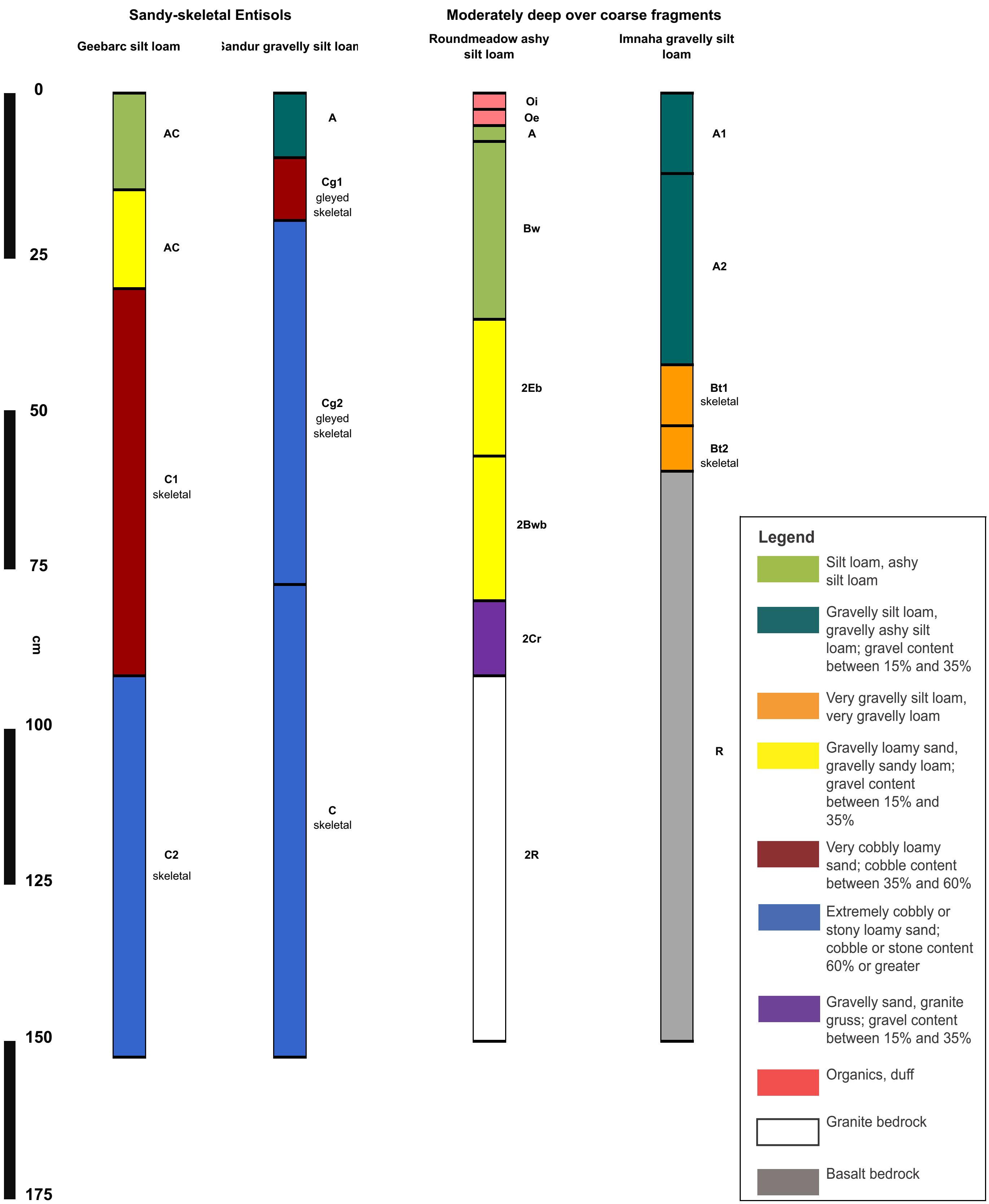

Appendix 1. Block diagrams depicting typical soil texture, rock fragments, and soil horizons for soil series within generalized soil classes, Grande Ronde River watershed, northeastern Oregon..

Appendix 2. Cross-reference table showing relationship between generalized soil classes, soil series, physiography, landforms, and soil taxonomic classes, Grande Ronde River watershed, northeastern Oregon.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Ashy silt loam over coarse frags	Upland or Lowland	Terraces	Bigwall ashy silt loam	Ashy Typic Vitrixerands
			Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			Digit ashy silt loam	Ashy over loamy Typic Vitricryands
			Tamara ashy silt loam	Ashy over loamy Alfic Udivitrands
Ashy silt loam over loam	Upland or Lowland	Terraces	Bigbouldercreek ashy silt loam	Ashy Typic Udivitrands
			Tolo ashy silt loam	Ashy over loamy Alfic Vitrixerands
			Wolot silt loam	Ashy over loamy Alfic Vitrixerands
		Toeslopes/Footslopes	Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			Peaviner gravelly ashy sandy clay loam	Fine, smectitic Vertic Palexerolls
Ashy silt loam over skeletal	Upland or Lowland	Ridgetops and sideslopes	Syrupcreek ashy silt loam	Ashy over loamy-skeletal Alfic Udivitrands
		Sideslopes/Terraces	Limberjim ashy silt loam	Ashy over loamy-skeletal Alfic Udivitrands
		Terraces	Bucketlake stony ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Bullroar ashy silt loam	Ashy over loamy-skeletal Typic Udivitrands
			Icedee ashy silt loam	Ashy over loamy Alfic Vitricryands
			Rebarrow ashy silt loam	Ashy over loamy Alfic Udivitrands
			Tertoo cobbly, ashy silt loam	Ashy over loamy-skeletal Typic Vitrixerands
Deep–silt to clay loam	Upland	hillslopes	McMurdie silt loam, bedrock substratum	fine, smectitic Calcic Pachic Argixerolls
			Palouse silt loam	fine-silty Pachic Ultic Haploxerolls
		mountain slopes	Geisercreek ashy silt loam	Ashy over clayey Alfic Udivitrands
			Gorhamgulch ashy silt loam	Ashy over loamy Typic Udivitrands
		mountain slopes; plateaus	Nibolob ashy silt loam	Fine-loamy Vitrandic Argixerolls

Appendix 2. Continued.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Deep w/coarse fragments	Upland	back slopes; toeslopes; footslopes	Emily ashy silt loam	Loamy-skeletal Vitrandic Haploxerolls
		mountain slopes	Bulgar cobbly ashy silt loam	Ashy over loamy-skeletal Typic Udivitrands
			Dunstan ashy silt loam	Clayey-skeletal, smectitic Vitrandic Haploxeralfs
			Fourthcreek ashy silt loam	Ashy over loamy Typic Vitrixerands
			Gutridge gravelly ashy silt loam	Ashy over loamy-skeletal Typic Udivitrands
			Lakefork gravelly ashy silt loam	Ashy-skeletal Typic Udivitrands
			Marblepoint stony ashy silt loam	Loamy-skeletal Andic Haplocryepts
			Pasturecreek gravelly ashy silt loam	Loamy-skeletal Andic Eutrudepts
			Warfield gravelly ashy sandy loam	Loamy-skeletal Vitrandic Haploxerepts
		mountain slopes; plateaus	Bigcow gravelly ashy silt loam	Loamy-skeletal Andic Haploxerepts
			Getaway stony ashy silt loam	Loamy-skeletal Vitrandic Argixerolls
			Harl very gravelly ashy silt loam	Ashy-skeletal Typic Udivitrands
			Klickson ashy silt loam	Loamy-skeletal Vitrandic Argixerolls
			MountEmily ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Pinuscreek ashy silt loam	Loamy-skeletal Andic Haploxeralfs
Lithic/Shallow to Clay	Upland	hillslopes	Gwinly very cobbly silt loam	Clayey-skeletal, smectitic Lithic Argixerolls
			Ramo silty clay loam	Fine, smectitic Typic Argixerolls
			Rockly very gravelly loam	Loamy-skeletal Lithic Haploxerolls
			Starkey very stony silt loam	Clayey-skeletal, smectitic Typic Argixerolls
			Ukiah silty clay loam	Fine, smectitic Vertic Argixerolls
		mountain slopes	Btree ashy slit loam	Ashy over clayey-skeletal Alfic Udivitrands
			Cowsley very stony silt loam	fine, smectitic Xeric Argialbolls
			Flyvalley ashy silt loam	Ashy Lithic Udivitrands
			Powderriver gravelly ashy sandy loam	Loamy-skeletal Lithic Haploxerepts
			Unitylake ashy silt	Fine, smectitic Vertic Palexeralfs
		mountain slopes; plateaus	Anatone very cobbly silt loam	Loamy-skeletal Lithic Haploxerolls
			Bocker very cobbly silt loam	Loamy-skeletal Lithic Haploxerolls

Appendix 2. Continued.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Lithic/Shallow to Clay (continued)			Burgerbutte extremely cobbly ashy sandy loam	Loamy-skeletal Lithic Humicryepts
			Fivebeaver gravelly ashy silt loam	Loamy-skeletal Lithic Ultic Haploxerolls
			Fivebit extremely stony loam	Loamy-skeletal Lithic Ultic Haploxerolls
			Harlow very stony clay loam	Clayey-skeletal Lithic Argixerolls
			Lowerbluff ashy silt loam	Ashy Lithic Vitrixerands
			Roostercomb extremely gravelly clay loam	Clayey-skeletal Typic Argixerolls
			Thirstygulch very stony ashy loam	Loamy-skeletal Lithic Ultic Haploxerolls
Loam over skeletal	Riverine	Low Floodplains	Dardry loam	Loamy-skeletal Cumulic Ultic Haploxerolls
			Melloe loam	Loamy-skeletal Typic Endoaquolls
			Mugwump sandy loam	Loamy-skeletal Cumulic Hapludolls
			Terlough gravelly silt loam	Loamy-skeletal Aquic Hapludolls
			Voats fine sandy loam	Sandy-skeletal Fluventic Haploxerolls
Loam/Silt Loam	Riverine or Lowland	Higher Floodplains	Bandarrow silt loam	Coarse-loamy Typic Cryaquolls
			Broady	Loamy Aquic Haplocryolls
			Catherine silt	Fine-silty Cumulic Endoaquolls
			Catherine silty clay loam	Fine-silty Cumulic Endoaquolls
			Terrodd silt loam	Fine-loamy Aquic Cumulic Hapludolls
			Typic Cryaquolls	Typic Cryaquolls
			Veazie loam	Coarse-loamy over sandy or sandy-skeletal Cumulic Haploxerolls
	Upland or Lowland	Terraces	Alicel fine sandy loam/loam/silt loam	fine-loamy Pachic Haploxerolls
			Bodale loam	Coarse-loamy Cumulic Haplocryolls
			Hutchinson variant silt loam	fine, smectitic Argic Durixerolls
			Imbler fine sandy loam	coarse-loamy Pachic Haploxerolls
			Jett silt loam	fine-silty Cumulic Haploxerolls
			La Grande silt/silty clay loam	fine-silty Pachic Haploxerolls
			Tovame silt loam	Coarse-loamy Cumulic Hapludolls

Appendix 2. Continued.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Loam/Silt Loam (continued)			Ultic Haploxerolls	Sandy-skeletal Ultic Haploxerolls
			Verdeplane	Fine-loamy Pachic Hapludolls
			Witknee very fine sandy loam	Coarse-loamy Aquic Hapludolls
Loam/Silt Loam–brackish	Lowland	Lake Basins/Salty Soils	Hooly ash silt loam	medial over loamy Typic Endoaquands
			Hoopal fine sandy loam	coarse-loamy Typic Duraquolls
			Hot Lake ashy silt loam	medial over loamy Aquic Haploxerands
			Umapine silt loam	coarse-silty Typic Halaquepts
Loam/Silt Loam–organic-rich	Riverine or Lowland	Meadows	Bandarrow silt loam	Coarse-loamy Typic Cryaquolls
			Melloe loam	Loamy-skeletal Typic Cryaquolls
			Tovame silt loam	Coarse-loamy Pachic Hapludolls
			Typic Cryaquolls	Typic Cryaquolls
			Typic Haplosaprists	Coarse-loamy Typic Haplosaprists
			Peaviner gravelly ashy sandy clay loam	Fine, smectitic Vertic Palexerolls
Loamy-gravelly	Upland	Alluvial Fans	Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			La Grande silt/silty clay loam	fine-silty Pachic Haploxerolls
			Phys (gravelly) silt loam	loamy-skeletal Typic Argixerolls
			Riceton	Coarse-loamy Ultic Haploxerolls
Mod. deep w/coarse frags	Upland	glacial valley floors; cirque basins	Mudlakebasin ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
		hillslopes	Klicker stony silt loam (40-65% slopes)- north/south slopes	Loamy-skeletal Vitrandic Argixerolls
			Lookingglass silt loam/very stony silt loam	fine, smectitic Xeric Argialbolls
			Royst very stony silt loam	Clayey-skeletal, smectitic Pachic Argixerolls
			Watama silt loam	fine-loamy Pachic Haploxerolls
		mountain slopes	Angelbasin ashy silt loam	Loamy-skeletal Andic Dystrocryepts
			Bler ashy silt loam	Clayey-skeletal, smectitic Vitrandic Palexerolls

Appendix 2. Continued.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Mod. deep w/coarse frags (continued)			Endcreek ashy silt loam	Ashy over loamy-skeletal Typic Vitrixerands
			Flycreek ashy silt loam	Ashy over clayey Alfic Udivitrands
			Hall Ranch stony loam	Fine-loamy Ultic Haploxerolls
			Olot silt loam	Ashy over loamy-skeletal Typic Vitrixerands
			Peaviner gravelly ashy sandy clay loam	Loamy-skeletal Vitrandic Argixerolls
			Roundmeadow ashy silt loam	Coarse-loamy Andic Haploxerepts
			Threecent ashy silt loam	Ashy over clayey Alfic Udivitrands
		mountain slopes; plateaus	Bennettcreek ashy silt loam	Loamy-skeletal Vitrandic Haploxeralfs
			Bolony ashy silt loam	Fine-loamy Vitrandic Argixerolls
			Bunchpoint ashy silt loam	Coarse-loamy Vitrandic Haploxerolls
			Deardorf stony ashy loam	Ashy over loamy-skeletal Typic Udivitrands
			Downeygulch gravelly ashy silt loam	Coarse-loamy Vitrandic Haploxerepts
			Kamela stony ashy silt loam	Loamy-skeletal Vitrandic Haploxerepts
			Klicker stony (ashy) silt loam	Loamy-skeletal Vitrandic Argixerolls
			Larabee ashy loam	Loamy-skeletal Vitrandic Argixerolls
			McCartycreek cobbly ashy silt loam	Loamy-skeletal Vitrandic Haploxerolls
			Snell very stony loam	Clayey-skeletal Pachic Argixerolls
			Troutmeadows ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Webbgulch very gravelly ashy loam	Loamy-skeletal Vitrandic Haploxerepts
			Wonder stony ashy silt loam	Loamy-skeletal Andic Haploxerepts
Roads	various	Human modified	not applicable	not applicable
Rock Outcrop	Upland	cliffs and rock outcrops	not applicable	not applicable

Appendix 2. Continued.

Generalized Soil Series	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Sandy-skeletal Entisols	Riverine	Gravel bars/Incipient floodplains	Caulditch	Sandy-skeletal Typic Cryaquents
			Geebarc silt loam	Sandy-skeletal Oxyaquic Cryorthents
			Gulliford very gravelly loamy sand	Sandy-skeletal Oxyaquic Udorthents
			Sandur gravelly silt loam	Sandy-skeletal Aeric Endoaquents
Streambanks–high gradient	Riverine	Streambanks	Aquic Vitricryands	Ashy over loamy Aquic Vitricryands
Urban Complex	various	Human modified	not applicable	not applicable

Appendix 3. Cross-reference table showing relationship between Level I through IV vegetation classes and plant associations, Grande Ronde River watershed, northeastern Oregon.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Forest	Conifer	Closed conifer forest	ABLA2–Dry	Abies lasiocarpa–dry	Abies lasiocarpa/Vaccinium scoparium
					Abies lasiocarpa/Polemonium pulcherrimum Pinus contorta/Vaccinium scoparium (Blues) Pinus contorta/Vaccinium scoparium (Wallowas)
			ABLA2-PIEN	Abies lasiocarpa-Picea engelmannii	Abies lasiocarpa-Picea engelmannii (closed forest)
					Abies lasiocarpa/Linnaea borealis Abies lasiocarpa/Senecio triangularis Abies lasiocarpa/Vaccinium membranaceum
			ABGR–Cool-Mesic	Abies grandis–Cool-Mesic	Abies grandis/Clintonia uniflora
					Abies grandis/Linnaea borealis Abies grandis/Linnaea borealis (Blue Mountains) Pinus contorta (Abies grandis)/Linnaea borealis
			ABGR–Warm-Dry	Abies grandis–Warm-Dry	Abies grandis/Carex geyeri
			ABGR-PIEN	Abies grandis-Picea engelmannii	Abies grandis/Acer glabrum
			PSME–Dry	Pseudotsuga menziesii–Dry	Pseudotsuga menziesii/Calamagrostis rubescens
					Pseudotsuga menziesii/Carex geyeri
			PSME–Mesic	Pseudotsuga menziesii–Mesic	Pseudotsuga menziesii/Symphoricarpos albus
					Pseudotsuga menziesii/Symphoricarpos albus-Floodplain
			PIPO–Mesic	Pinus ponderosa–Mesic	Pinus ponderosa/Poa pratensis
		Open conifer forest	ABLA2–Dry	Abies lasiocarpa–Dry	Abies lasiocarpa/Vaccinium scoparium

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Forest (continued)					Abies lasiocarpa/Polemonium pulcherrimum
					Pinus contorta/Vaccinium scoparium (Blues)
					Pinus contorta/Vaccinium scoparium (Wallowas)
			ABLA2-PIEN	Abies lasiocarpa-Picea engelmannii	Abies lasiocarpa-Picea engelmannii (closed forest)
					Abies lasiocarpa/Athyrium filix-femina
					Abies lasiocarpa/Carex disperma
					Abies lasiocarpa/Linnaea borealis
					Abies lasiocarpa/Senecio triangularis
					Abies lasiocarpa/Vaccineum membranaceum
			ABLA2-PIEN–Meadow	Abies lasiocarpa-Picea engelmannii–Meadow	Abies lasiocarpa/Calamagrostis canadensis
					Abies lasiocarpa/Carex aquatilis
					Abies lasiocarpa/Vaccinium uliginosum/Carex scopulorum
					Picea engelmannii-Abies lasiocarpa/Carex scopulorum
			PICO–Dry	Pinus contorta–Dry	Pinus contorta/Calamagrostis rubescens
					Pinus contorta/Calamagrostis rubescens-Vaccineum scoparium
					Pinus contorta/Vaccineum scoparium (cool xeric)
			PICO–Moist Meadow	Pinus contorta–Moist Meadow	Pinus contorta/Calamagrostis canadensis
					Pinus contorta/Carex lanuginosa
					Pinus contorta/Deschampsia cespitosa
					Pinus contorta/Poa pratensis
			PICO–Wet Meadow	Pinus contorta–Wet Meadow	Pinus contorta/Carex aquatilis
					Pinus contorta/Carex scopulorum
			PIEN	Picea engelmannii	Picea engelmannii/Athyrium filix-femina
					Picea engelmannii/Bromus vulgaris
					Picea engelmannii/Carex disperma
					Picea engelmannii/Cinna latifolia
					Picea engelmannii/Cornus stolonifera
					Picea engelmannii/Equisetum arvense
					Picea engelmannii/Senecio triangularis

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Forest (continued)			ABGR–Cold	Abies grandis–Cold	Abies grandis/Vaccinium scoparium
			ABGR-PIEN	Abies grandis-Picea engelmannii	Abies grandis/Acer glabrum
					Abies grandis/Acer glabrum-Floodplain Abies grandis/Acer glabrum-Physocarpus malvaceus Abies grandis/Athyrium filix-femina Abies grandis/Symphoricarpos albus-Floodplain
			ABGR–Cool-Mesic	Abies grandis–Cool-Mesic	Abies grandis/Clintonia uniflora
					Abies grandis/Linnaea borealis Abies grandis/Linnaea borealis (Blue Mountains) Abies grandis/Vaccineum membranaceum Abies grandis/Vaccineum membranaceum (Blue Mountains) Pinus contorta(Abies grandis)/Linnaea borealis Pinus contorta(Abies grandis)/Vaccineum membranaceum/Linnaea borealis Pinus contorta/Vaccineum membranaceum (Blue Mountains)
			ABGR–Warm-Dry	Abies grandis–Warm-Dry	Abies grandis/Calamagrostis rubescens Abies grandis/Carex geyeri Abies grandis/Spiraea betulifolia Abies grandis/Spiraea betulifolia (Blue Mountains) Abies grandis/Symphoricarpos albus/Fragaria virginiana
			ABGR-PSME–Warm-Mesic	Abies grandis-Pseudotsuga menziesii–Warm-Mesic	Pseudotsuga menziesii/Acer glabrum-Physocarpus malvaceus
					Pseudotsuga menziesii/Acer glabrum-Physocarpus malvaceus-Floodplain Pseudotsuga menziesii/Holodiscus discolor Pseudotsuga menziesii/Physocarpus malvaceus
			PSME–Mesic	Pseudotsuga menziesii–Mesic	Pseudotsuga menziesii/Spiraea betulifolia
					Pseudotsuga menziesii/Symphoricarpos albus Pseudotsuga menziesii/Symphoricarpos oreophilis (Wallowas)
			PSME–Dry	Pseudotsuga menziesii–Dry	Pseudotsuga menziesii/Calamagrostis rubescens

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Forest (continued)					Pseudotsuga menziesii/Carex geyeri
			PIPO–Mesic	Pinus ponderosa–Mesic	Pinus ponderosa/Poa pratensis Pinus ponderosa/Symphoricarpos albus Pinus ponderosa/Symphoricarpos albus-Floodplain
			PIPO–Dry	Pinus ponderosa–Dry	Pinus ponderosa/Calamagrostis rubescens Pinus ponderosa/Carex geyeri
		Conifer woodland	ABGR-PSME–Warm-Mesic	Abies grandis-Pseudotsuga menziesii–Warm-Mesic	Pseudotsuga menziesii/Acer glabrum-Physocarpus malvaceus
			PSME–Mesic	Pseudotsuga menziesii–Mesic	Pseudotsuga menziesii/Symphoricarpos oreophilis (Wallowas)
			PIPO–Steppe	Pinus ponderosa–Steppe	Pinus ponderosa/Agropyron spicatum Pinus ponderosa/Agropyron spicatum (Wallowas) Pinus ponderosa/Festuca idahoensis
	Deciduous/Broadleaf	Closed deciduous forest	POTR–Wet	Populus tremuloides–Wet	Populus tremuloides/Carex aquatilis
			POTR–Mesic	Populus tremuloides–Mesic	Populus tremuloides/Poa pratensis
			POTR–Dry	Populus tremuloides–Dry	Populus tremuloides/Symphoricarpos albus
			POTR2–Terrace	Populus trichocarpa–Terrace	Populus trichocarpa/Symphoricarpos albus
		Open deciduous forest	POTR–Wet	Populus tremuloides–Wet	Populus tremuloides/Carex aquatilis
			POTR–Mesic	Populus tremuloides–Mesic	Populus tremuloides/Calamagrostis canadensis Populus tremuloides/Carex lanuginosa Populus tremuloides/Mesic Forb

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Forest (continued)					Populus tremuloides/Poa pratensis
			POTR–Dry	Populus tremuloides–Dry	Populus tremuloides/Symphoricarpos albus
			POTR–Floodplain	Populus tremuloides–Floodplain	Populus tremuloides/Alnus incana-Cornus stolonifera
			POTR2–Floodplain	Populus trichocarpa–Floodplain	Populus trichocarpa/Acer glabrum
					Populus trichocarpa/Alnus incana-Cornus stolonifera
			POTR2–Terrace	Populus trichocarpa–Terrace	Populus trichocarpa/Symphoricarpos albus
Shrub	Tall shrub	Closed tall shrub	ALSI–Floodplain	Alnus sinuata -Floodplain	Alnus sinuata/Athyrium filix-femina
					Alnus sinuata/Cinna latifolia Alnus sinuata/Mesic Forb
			ALIN–Floodplain	Alnus incana–Floodplain	Alnus incana-Cornus stolonifera/Mesic Forb Alnus incana-Ribes spp./Mesic Forb Alnus incana-Symphoricarpos albus Alnus incana/Athyrium filix-femina Alnus incana/Calamagrostis canadensis Alnus incana/Carex deweyana Alnus incana/Carex lenticularis var. lenticularis Alnus incana/Glyceria elata Alnus incana/Heracleum lanatum Alnus incana/Poa pratensis
			ALIN–Wet Meadow	Alnus incana– Wet Meadow	Alnus incana/Carex lanuginosa
					Alnus incana/Scirpus microcarpus
			COST	Cornus stolonifera	Cornus stolonifera
			SALIX–Mesic Meadow	Tall Willow Meadow–Mesic	Wetland Shrub (this is a map unit from the W-W existing veg GIS layer) [code is WETSH]

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Shrub (continued)			SALIX–Gravel Bar	Salix–Gravel Bar	Salix exigua
					Salix rigida
		Open tall shrub	ALIN–Floodplain	Alnus incana–Floodplain	Alnus incana/Equisetum arvense
					Alnus incana/Poa pratensis
			ALIN–Wet Meadow	Alnus incana–Wet meadow	Alnus incana/Carex amplifolia
					Alnus incana/Carex aquatilis Alnus incana/Carex utriculata
			SALIX–Mesic Meadow	Tall Willow Meadow–Mesic	Salix spp./Carex lanuginosa
					Salix spp./Poa pratensis Wetland Shrubs (less than 16 ft. tall) [code is WETSH]
			SALIX–Wet Meadow	Tall Willow Meadow–Wet	Salix spp./Carex aquatilis
					Salix spp./Carex utriculata
			Upland Shrub–Dry	Upland Shrub–Dry	Cercocarpus ledifolius
	Low shrub	Closed low shrub	RIBES–Floodplain	Ribes–Floodplain	Ribes spp./Glyceria elata
					Ribes spp./Mesic Forb
			Shrub–Cold Meadow	Shrub Meadow–Cold	Salix commutata/Carex scopulorum
					Salix spp./Calamagrostis canadensis (SACO2-SABO2) Salix spp./Mesic Forb
			Upland Shrub–Mesic	Upland Shrub–Mesic	Symphoricarpos albus
		Open low shrub	Shrub–Cold Meadow	Shrub Meadow–Cold	Potentilla fruticosa-Betula glandulosa

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Shrub (continued)			Shrub–Mesic Meadow	Shrub Meadow–Mesic	Potentilla fruticosa/Deschampsia cespitosa
					Potentilla fruticosa/Poa pratensis
			Upland Shrub–Mesic	Upland Shrub–Mesic	Physocarpus malvaceus
					Symphoricarpos albus
			Upland Shrub–Scabland	Upland Shrub–Scabland	Artemisia rigida/Poa sandbergii (scabland)
Herbaceous	Graminoid	Dry graminoid herbaceous	AGSP-FEID	Agropyron spicatum-Festuca idahoensis	Agropyron spicatum-Eriogonum heracleoides
					Agropyron spicatum-Festuca idahoensis (deep soil, gentle slopes) Agropyron spicatum-Festuca idahoensis (deep soil, steep slopes) Agropyron spicatum-Poa sandbergii (shallow soil, deep slopes) Agropyron spicatum-Poa sandbergii-Danthonia unispicata Festuca idahoensis-Carex hoodii Festuca idahoensis-Carex hoodii Festuca idahoensis-Koeleria cristata (ridge)
			Upland Steppe	Upland Steppe	Poa sandbergii-Danthonia unispicata
			Subalpine Steppe	Subalpine Steppe	Subalpine/alpine grassland dom. by bunchgrasses, sedges, other grasses
			Meadow–Dry	Meadow–Dry	Dry Meadow
		Mesic graminoid herbaceous	Meadow–Mesic	Meadow–Mesic	Alopecurus pratensis
					Calamagrostis canadensis Carex lanuginosa Carex microptera Carex nebrascensis Deschampsia cespitosa Elymus cinereus Juncus balticus

Appendix 3. Continued.

Level I	Level II	Level III	Level IV Code	Level IV	Plant Associations
Herbaceous (continued)					Poa pratensis
			Meadow–Mesic-Cold	Meadow–Mesic-Cold	Carex jonesii
					Carex nigricans
			Graminoid/Forb–Gravel Bar	Graminoid/Forb–Gravel Bar	Carex lenticularis var. lenticularis
					Cinna latifolia Glyceria elata Scirpus microcarpus
		Wet graminoid herbaceous	Graminoid–Riverine Swamp	Graminoid–Riverine Swamp	Puccinellia pauciflora
			Wet Meadow–Cold	Meadow–Wet-Cold	Carex canescens
					Carex scopulorum
			Wet Meadow	Meadow–Wet	Carex amplifolia Carex aquatilis Carex cusickii Carex stipata Carex utriculata Carex vesicaria var. vesicaria Eleocharis palustris Eleocharis pauciflora prob. CAUT, CAAQ or CACA