Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators: Annual Report 2009

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Columbia River Inter-Tribal Fish Commission
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Project Number	2009-004-00
Proposer	CRITFC
Short Description	Monitoring recovery trends in key spring Chinook habitat
Province(s)	Blue Mountain
Subbasin(s)	Grande Ronde
Contact Name	Dale A. McCullough
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A: 119. Manage and Administer Projects

Title: Produce next year's SOW

A. Funding Package - Conduct internal review (e.g., Supervisor or Interagency).

Submit next year's SOW and Budget for internal contractor review before submitting to BPA. Assuming this review takes 30 days, start this milestone 120 days before the end of the current contract.

Progress: Our statement of work and budget for contract year 2010 have been developed and approved by BPA.

C. Attend professional conferences for professional development
Attend AFS and/or JASA meetings for professional development.

Progress: On February 24-26 three habitat team staff attended Oregon AFS meeting in Eugene, OR. This meeting was very worthwhile for relevant presentations given and for the opportunity to coordinate

and share ideas with professionals from a variety of agencies and tribes, including USFS, OSU, ODFW, CTUIR, BOR, NOAA, and EPA.

Deliverable: D. Funding Package - Submit draft to COTR

B: 165. Produce Environmental Compliance Documentation

Title: Provide proof of all EC and permits to BPA

Description: Get approval for environmental compliance permits from BPA.

Deliverable Specification: Obtain environmental compliance permit for installation of flow monitoring equipment alongside the stream channel in a location in each of two study streams.

Progress: Letters have been submitted to both Garth Griffin (NOAA) and Gary Miller (USFWS) requesting approval to conduct research in the Upper Grande Ronde and Catherine Creek in 2010. These two agencies are responsible for ensuring that no harm is done to spring Chinook and steelhead (NOAA) and bull trout (USFWS), respectively, owing to research and monitoring activities. As of March 23, 2009 we have not received approval. However, verbal communication with NOAA indicates that restrictions on activities would be only slightly greater than those imposed in 2009 due to the greater level of substrate disturbance anticipated. Based upon maps of bull trout distribution available from ODEQ, it appears that we would not be sampling extensively in bull trout habitat because it is so limited and restricted to headwater areas and our substrate disturbing activities are confined to spring Chinook spawning areas that appear from the ODEQ bull trout distribution map not to overlap greatly with chinook. We are seeking guidance on appropriate work windows because our activity timing can be shaped to accommodate rules designed to provide no potential effect, except for measuring streamflow on cross-sections and installing water temperature data loggers in well-distributed locations. Taking samples of streambed gravels and macroinvertebrates would cause more substrate disturbance, but could be timed to coincide with work windows acceptable to these agencies.

C: 191. Watershed Coordination

Title: Coordinate with regional agencies, tribes, and landowners

Description: Coordination with other entities involved in M&E and data collection in the Grande Ronde and Upper Columbia under the ISEMP work. Agencies involved will be NMFS, ODFW, CTUIR, Yakama Nation, and Nez Perce Tribe. Coordination with the specified agencies in the Columbia needed to initiate and sustain work. Provide peer review of monitoring plans of other agencies and tribes and seek peer review of CRITFC plans and progress. Participate in appropriate regional forums (e.g. PNAMP), and individually with other agencies, to improve the comparability of results from tribal projects with similar efforts within the interior Columbia Basin. Share information, data, scientific literature, expertise in developing monitoring plans that have highly reliable methods and a spatially stratified and statistically sound sampling design. Host pre- and post-field-season workshops with habitat monitoring teams from member tribes. These workshops will be used to standardize sampling protocols, training material and methods, and sampling designs among our member tribes. This is essential as there are numerous BPA and NOAA projects doing similar work in other basins like the Upper Columbia, S.F. Salmon and the

John Day. This project is akin to the others and will give us a better cross-sectional coverage to make inferences for the Columbia River, i.e. is the habitat adequate for salmonind survival to specific lifecycle stages.

Deliverable Specification: Coordination with the specified agencies in the Columbia needed to initiate and sustain work. Provide peer review of monitoring plans of other agencies and tribes and seek peer review of CRITFC plans and progress. Participate in appropriate regional forums (e.g. PNAMP), and individually with other agencies, to improve the comparability of results from tribal projects with similar efforts within the interior Columbia Basin. Share information, data, scientific literature, expertise in developing monitoring plans that have highly reliable methods and a spatially stratified and statistically sound sampling design. Host pre- and post-field-season workshops with habitat monitoring teams from member tribes. These workshops will be used to standardize sampling protocols, training material and methods, and sampling designs among our member tribes.

Deliverable:

A. Coordination on Research, Monitoring and Evaluation

B. Coordinate with regional agencies, tribes, and landowners

Progress: Coordination with other entities involved in M&E and data collection in the Grande Ronde and Upper Columbia such as in ISEMP and PNAMP work. Agencies involved will be NMFS, ODFW, Grande Ronde Watershed Council, Umatilla Tribe (CTUIR), Yakama Nation, and Nez Perce Tribe.

Land owner co-ordination is essential as we will need to have owner permission to collect data in some areas. This will also require co-ordination with the USFS as it will be essential for data sharing. We also need to co-ordinate with NOAA as we need to provide more efficient use of field staff and to develop a more comprehensive monitoring program.

In late 2008 CRITFC hosted all four member tribal habitat staff for a meeting to discuss plans for tribal M&E. At this meeting CRITFC presented its proposed habitat monitoring and spring Chinook productivity modeling plan. The tribal staff presented their intended monitoring plans.

On June 9, 2009 we attended a large coordination meeting in La Grande, OR in which representatives from ODFW, CTUIR, CRITFC, GR Model Watershed, NOAA, and BOR were present. We discussed plans that each participating group had for monitoring in the Grande Ronde basin.

We visited CTUIR staff at several instances throughout 2009 to discuss our plans in the Grande Ronde, learn about the CTUIR monitoring plans, and coordinate activities. We learned about the CTUIR River Vision, a plan for viewing the ecosystems in the tribal ceded areas in light of native First Foods (deer, elk, huckleberries, roots, water). We also met the CTUIR's subcontractor (Stillwater Sciences) in Portland and discussed opportunities to share in the overall plans for monitoring salmon habitat quality/quantity. Stillwater Sciences has developed a modeling framework called Ripple that has many framework elements in common with those that we have proposed for modeling spring Chinook productivity on a life cycle basis.

We contacted on several occasions CTUIR habitat staff in Mission; hatchery production staff in La Grande; restoration planning and monitoring group in Island City, and RME staff at the EOU office in La Grande.

We participated with two of the CTUIR research teams plus ODFW staff in an annual Chinook redd monitoring effort in the Upper Grande and Catherine Creek. We initiated a plan to GPS the redds that had been flagged by the end date of spawning. This work was completed with the extensive help of the CTUIR survey teams.

We have conferred with the Grande Ronde Model Watershed group in matters concerning the available database on stream and watershed restoration and landowner permission. We mapped the locations of all watershed restoration activities in the two study basins. See **Appendix A.**

We met with the USFS habitat research staff in La Grande at the regional office; NOAA and USFWS field managers; ODFW field staff housed both at La Grande Fish Research Office at EOU (Badgley Hall) and also the Grande Ronde Watershed District Office (Regional Office).

We met with the Oregon State Highway Department to discuss access under various bridges in the area serviced by the department.

We met representatives of EPA in the Grande Ronde basin during one of their research field trips. This meeting led to learning about their developing theory relating cold water refugia to geological characteristics of the watersheds. Their mapping will assist us in development of hydrologically relevant stream classifications.

We have received water temperature and streamflow data from the USFS Regional Office in La Grande. These data in conjunction with USGS and OWRD data available online provide a good database from which to develop regional streamflow statistics.

We attended numerous PNAMP meetings held in Portland to discuss regional progress in monitoring. Several presentations of monitoring methods were made by USFS personnel representing AREMP and PIBO monitoring protocols; WDOE; USGS; ODFW. Among the PNAMP meetings were a series devoted to identification of IP (inherent potential) in classification of stream channels.

Coordination with other agencies and organizations has involved acquiring spatial data and GIS layers as baseline information about the watersheds and for integration with future analyses. This section describes coordination beyond sharing of stream temperature and flow data. We have acquired spatial data with researchers from the Environmental Protection Agency (EPA) in Corvallis (Jim Wigington and Joe Ebersole) regarding testing of their hydrological landscape region (HLR) classification. The HLRs incorporate information on climate class, seasonality of runoff, aquifer and soil permeability, and topography. This watershed classification system is expected to explain spatial variation in several watershed processes we are measuring (e.g., sediment dynamics and stream flow), and will therefore be important to account for when making inferences about potential habitat improvement. To date we have acquired spatial data in the form of GIS shapefiles and have included this in our master project mapping depository.

We are coordinating with Oregon Department of Environmental Quality (ODEQ) to expand the range of metrics describing habitat quality for Chinook salmon. Often the measurement of a few, simplistic metrics (such as stream flow, water temperature, and sediment) cannot adequately describe habitat quality for an organism in a holistic manner, so more integrated metrics (such as biotic indices based on aquatic invertebrates) are required. Our collaboration with ODEQ involves coordination of monitoring efforts so that collection of aquatic invertebrates at monitoring sites yields data that can be used in the river invertebrate classification and prediction system (RIVPACS) (Wright 1994), a biotic index that is gathering momentum among researchers in the western U.S. This collaboration involved attending a 2-day training in RIVPACS theory and application, and attending a meeting at ODEQ Hillsboro (with Shannon Hubler) to ensure data collection standardized with the method, and integration of aquatic monitoring into our field protocols.

Information about past and existing restoration activities funded through Oregon Watershed Enhancement Board (OWEB) and other sources are catalogued in a database managed by Grande Ronde Model Watershed (GRMW) (http://www.grmw.org/). We envision this data, which currently exists in a relatively unusable state because the magnitude of impact on habitat quality is not evaluated for individual projects, could potentially provide an index of restoration intensity by individual sub-watersheds. To date, we have acquired spatial data in GIS and associated attribute tables of GRMW projects and have included this in our master project mapping depository.

The Oregon Department of Fish & Wildlife's (ODFW) aquatic habitat inventory (AHI) is a comprehensive habitat survey conducted in contiguous channel units and summarized at the reach scale throughout the state (Moore et al. 2008). Because of the spatially-extensive nature of the AHI survey in the upper Grande Ronde and Catherine Creek watersheds, it seems strategic to capitalize on this existing data set, especially since there may be a new round of similar data collection in portions of the study area beginning 2010 (Kim Jones, ODFW, pers. comm.). We have acquired spatial data and related attributes for AHI channel unit and reach-scale surveys, performed quality control procedures on the data set, and have conducted preliminary analyses to elucidate the inter-related nature of habitat variables and demonstrate a proof-of-concept regarding future modeling strategies (see Develop RM&E Methods and Designs section).

C. Tribal coordination

Progress: We devoted considerable time in coordination with CRITFC member tribes that are seeking to develop sound RM&E plans. We anticipate that this project can serve as a model for other similar projects conducted by the CRITFC tribes in other areas. We will learn from these projects collectively, and share information about monitoring methods and study designs for different set objectives.

We have shared much of the data we collected in 2009 with the CTUIR monitoring team. These data included all water temperature, sediment, and streamflow data. In return we have received CTUIR water temperature data.

Proposal review for Burns Paiute Tribe

Beginning spring of 2010, the Burns Paiute Tribe is embarking on a Chinook salmon feasibility study in the adjacent Malheur River and its tributaries. The project employs oral histories of tribal elders and other ethnographic accounts to describe historic distribution of Chinook salmon, and implements water quality testing to compare with published tolerance values of Chinook salmon at important life history stages. Because of the similarities between our project and theirs—especially the emphasis on historic habitat not currently being used by Chinook salmon but having potential for restoration—we found it mutually beneficial to act as reviewers to their proposal (Maltz 2010) for first year's study. In reviewing and providing comments to Burns Paiute tribal staff, we have found several points of commonality and potential for future collaboration.

D: 148. Install Flow Measuring Device

Title: Install flow depth gages at two channel cross-sections

Description: Install a small pressure transducer and data logging system in one location in the Upper Grande Ronde River and one location in Catherine Creek. A small, secure instrument housing anchored at streamside will be needed to protect the equipment from weather and disturbance. The sensor will need to be secured to the stream bottom at a cross-section where it can accurately reflect stream stage heights for estimation of flow-stage height relationships.

Deliverable Specification: Two streamflow gaging stations in the Upper Grande Ronde and Catherine Creek for continuous recording of flow heights that will be related to manual streamflow measurements.

A. Environmental compliance requirements complete

On-the-ground work associated with this work element cannot proceed until this milestone is complete. Milestone is complete when final documentation is received from BPA environmental compliance staff (completion can be based on pre-existing environmental documentation from BPA).

Progress: We received permission from NOAA and BPA to install these devices in 2009, which are about the same size as temperature data loggers. Our installations will not be similar to the typical permanent USGS gauge houses but will be temporary.

B. Set up streamflow monitoring stations

Set up two flow monitoring stations (one each per study watershed) to continuously monitor streamflow depth at known cross sections. Gage sites will be located in the watersheds at points not subject to significant instream flow alterations.

Progress: Before we could install the two depth gauges (pressure transducers) at stream cross sections it was necessary for us to assess which streams already had streamflow gauges. It took considerable time to acquire USGS, OWRD, and USFS streamflow data. Currently, we do know the locations of all gauging sites in the two study basins. The existing gauge sites for streamflows were mapped (see **Appendix B**). On this basis we were able by approximately November 2009 to identify suitable cross sections on which to install depth gauges to establish stage-discharge relationships. However, by that time it was too late in the season and water levels were too high to install the gauges. At this point we have determined that the

SF Catherine Creek and upper Sheep Creek on USFS land would be suitable sites. These devices will be installed early in the field season during 2010.

Deliverable: C. Install one stream gauging station each in the Upper Grande Ronde and Catherine Creek

E: 98. Other

Title: Lab Set Up

Deliverable Specification: Install a venting fan to move moisture in air from a dryer oven to the outside for drying sediment samples. This will require installing a small metal hood; cutting a hole in the building wall; installing the fan. The lab will also be used for sieving and weighing sediment fractions to determine particle size distribution.

Progress: Our laboratory was set up in a basement room at CRITFC, 729 NE Oregon St., Suite 200, Portland, Oregon 97232. See **Appendix C** for views of the laboratory set up. Equipment provided for this laboratory for processing sediment samples and other field samples includes:

1. lab bench with storage drawers, shelves, electrical outlets on rear panel, and overhead light
2. Ohaus OBX-4101CA balance for weighing samples
3. Gilson OT-2 air drier for drying samples
4. Stainless steel, deep trays for containing entire 6 L sediment samples for drying
5. Tyler sieves for sieving gravel samples. Sieve mesh sizes used included 0.125, 0.355, 0.85, 2, 3.35, 4, 6.3, 8, 11.2, 16, 31.5, 63, and 90 mm.
6. Gilson SS-12R, 12" sieve shaker w/tapping
7. Omega HH42 handheld thermistor thermometer w/NIST calibration for calibrating Onset Hobo field water temperature data loggers

This same laboratory will be suitable for use in sorting macroinvertebrate samples that will be collected in 2010.

F: 157. Collect/Generate/Validate Field and Lab Data

Title: Collect preliminary water temperature and streamflow data

Deliverable Specification: Preliminary monitoring data on water temperature and streamflow taken at 70 locations to calibrate the temperature flow model to cover representative locations in the Upper Grande Ronde River and Catherine Creek. This has to be done so as to have adequate coverage of the basin and be distributed upstream and downstream of major tributaries. . Compile and summarize these data using a combination of Excel, database, and GIS applications. A summary will be uploaded to Pisces in Word or Excel.

A. Environmental compliance requirements complete

On-the-ground work associated with this work element cannot proceed until this milestone is complete. Milestone is complete when final documentation is received from BPA environmental compliance staff (completion can be based on pre-existing environmental documentation from BPA).

B. Assemble thermistor units

Assemble water temperature thermistor units with housings and attachment fittings for placing them in sampling locations.

C. Install water temperature monitoring devices.

Install approximately 75 water temperature thermistors (e.g., Hobo Temp thermistors) throughout the two study watersheds at stream nodes (i.e., where major tributaries enter the mainstem) to provide needed input data for water temperature modeling.

Progress: The Onset temperature loggers were calibrated at two temperatures in a water bath in the laboratory using an Omega NIST-traceable thermistor and according to ODEQ protocol. Loggers were launched individually in the field using a laptop computer attached to the docking station and with the Onset computer program. Loggers were predominantly housed in either black PVC tubing open on each end or in short sections of iron pipe tethered to a re-bar steel stake driven into the streambed. In cases where we attached loggers directly to re-bar steel stakes, the loggers were in positions in the channel where they were full shaded by large boulders or dense overhanging riparian vegetation.

D. Water temperature field data

Collect data on a monthly basis to create water temperature database using Thermistors such as HOBO device at approximately 70 locations scattered throughout the upper Grande Ronde and Catherine creek.

Progress: Water temperature data were collected from 25 sites in the Upper Grande Ronde and 9 sites in Catherine Creek watersheds. Dates of deployment and retrieval were approximately July 25, 2009 and October 8, 2009, respectively. We replaced loggers on approximately 15 sites to collect water temperature data throughout the winter. These loggers will be retrieved in June, 2010.

Samples were collected in sites recommended by Watershed Sciences, Inc. Recommendations were based on the physical needs in water temperature modeling. See **Appendix D** for maps of recommended sites.

E. Collect LiDAR data via Subcontract

LiDAR data will be collected via a subcontract. LiDAR data will provide high resolution data on terrain and vegetational elevations. This will permit creation of a topographic map focused on the stream and streamside zone, as well as the height and density or riparian canopy.

Progress: LiDAR data were collected for the Upper Grande Ronde and Catherine Creek by September 19, 2009. After data collection, point data were calibrated and processed. Watershed Sciences, Inc. delivered all LiDAR data to CRITFC in a report dated December 23, 2009. See **Appendix E** for this project summary. Currently, all LiDAR data, which includes the summary report, point data, raster data,

and vector data are stored on a server at CRITFC and on backup storage media. These data will be used to create high resolution hydrography layers, stream corridor topography that can be significant for computing topographic shading in the water temperature model, riparian cover height and foliage density.

F. Streamflow data

Monitor streamflow at approximately 70 locations in the upper Grande Ronde and Catherine Creek. These measurements will be collected in relation to TIR and LiDAR data collection program and measurements at the fixed gage sites. This data will be used to calibrate a temperature flow model that will be updated based on measurements of air temperature and cloud cover in subsequent years. The TIR data collection will be done in the second year of this project. Collect data monthly to ensure against lengthy periods of data collection failure. A data summary will be included in the annual progress report.

Progress: Streamflows were measured at 12 cross sections in the Upper Grande Ronde drainage and 6 in the Catherine Creek drain between August 31, 2009 and September 4, 2009. These data are summarized in **Appendix F**. Because of our late start in the season we were not able to collect streamflow at as many sites as we wished. We will attempt to collect streamflows at all sites where water temperature loggers are installed to facilitate water temperature modeling. The intent is to have at least two values at different stage heights spanning the spring-summer flow recession period measured for each cross section so that the flow on the day of the FLIR flight (probably to be scheduled in July-August period to capture high water temperatures) can be estimated. Some sites will be selected to act as higher intensity streamflow measurement sites, including those that will be selected for installation of a streamflow gauge (i.e., pressure transducer).

These sites hosted by the UW Climate Impacts Group provide numerous streamflow statistics for long-term gauges in the Pacific Northwest, including several in the Grande Ronde basin. This provides a large database from which we can correlate short-term gauges in the basin. [Note: Acquire streamflow data at: http://www.hydro.washington.edu/2860/products/sites/?site=4012. Also, see http://www.hydro.washington.edu/2860/products/primary_data/]

G. Data entry

For all habitat monitoring variables, download data loggers or enter data, metadata, and notes into Excel spreadsheets and Word documents. Apply QA/QC procedures to ensure data accuracy. Create or apply a process for digital data storage, retrieval, and preparation for entry to a database system.

Progress: Data entry was confirmed by reviewing all field notes after the first data entry to Excel spreadsheets to ensure accuracy. Temperature logger data were evaluated for outliers that might indicate that the loggers were out of the water and collecting water temperature data that went beyond physically feasible ranges. Also, the time periods for data collection were compared to the deployment periods recorded in notes for the individual serial numbers of each logger. For sediment samples it was not feasible to weigh the entire sample initially after drying and then weigh each size fraction sieved so that cumulative weights of all size fractions could be compared to the total because the total sample weights were too great for the balance. However, the plots of the overall particle distributions provide a general validation of achieving consistency in fractional weights.

Calculations for discharge cross-sections from wading were computed using ODEQ's Flowpro macro for Excel according to procedures described in ODEQ (2009).

H. Data summaries

From data entered into Excel spreadsheets or GIS, create data summaries and displays that portray preliminary trends. Some of this level of analysis will be needed to estimate statistically appropriate sample sizes. A data summary for water temperature and streamflows will be included in the annual progress report.

Progress: Data summaries for water temperature, surface sediment composition, bed sediment composition, and streamflows were summarized in separate reports. For these individual data collection efforts see the summaries for each:

Water temperature: **Appendix G**

Stream substrate sediment (surface and subsurface) composition: **Appendix H**

Streamflows: **Appendix F**.

Data were collected for low flow characteristics of key streams in the two study basins. Data were obtained from the Oregon Department of Water Resources (Cooper 2002). These data were summarized in **Appendix I** (see file: Summary of Data from Surface water availability in Oregon.pptx)

Air temperature data were collected from the website http://uspest.org/OR/ for future use in water temperature modeling. This source provides hourly air temperatures, relative humidity, and precipitation for the past 5 years. We compiled data from 4 stations in the vicinity of the study watersheds. These data will be useful in future water temperature modeling in the study watersheds. Sites from which local air temperature were derived for the past 5 years are shown in **Appendix J**.

Streamflow data are also available from the Climate Impacts Group at the University of Washington. Data available at: http://cses.washington.edu/cig/fpt/ccstreamflowtool/sft.shtml can be used in future climate change analysis to evaluate impacts to natural streamflows. This website reports: "The scenarios are currently available at 16 locations in the Columbia River basin (Figure 1). For each location, we provide 40 year monthly time-step streamflow scenarios for the 2020s and for the 2040s as well as simulated historical streamflow for water years 1950-1989. These flow records represent what historical observed (naturalized) flows would be if the average climate of the Pacific Northwest (PNW) changed as projected by global climate models."

The CIG sites: http://www.hydro.washington.edu/2860/products/sites/?site=4012 and

http://www.hydro.washington.edu/2860/products/primary_data/ provide data on streamflow statistics within the Grande Ronde basin. This provides excellent summaries of streamflows, against which flows from short-term gauges can be compared.

References

Cooper, R.M. 2002. Determining surface water availability in Oregon. Open File Report SW 02-002. Oregon Water Resources Department. Salem, Oregon. 170 p.

Cooper, R.M. 2005. Estimation of peak discharges for rural, unregulated streams in western Oregon. U.S. Geological Survey Scientific Investigations Report 2005-5116. 134 p.

G: 156. Develop RM&E Methods and Designs

Title: Review and develop monitoring protocols and statistical designs

Description: Review scientific literature on water temperature, fine sediment, streamflow, and climate data collection with a focus on standardly used monitoring protocols. Use this information in development of a final monitoring plan to be available by 2010.

Deliverable Specification: A preliminary plan for field data collection and monitoring protocols for temperature, sediment and flow in the upper Grande Ronde and Catherine creek that will be uploaded to PISCES.

A. Preliminary field manual for fine sediment, water temperature, streamflow monitor, climate

We will evaluate various protocols for assessing stream and water quality attributes, focusing initially on water temperature, streamflow, fine sediment, and habitat classification.

Progress: See our response submitted to ISRP concerning rotating panel designs (: D:\ClimateChange\BPA climate change proposals\BPA contract\Response to ISRP-2009). Subsequently, we evaluated several key papers on sampling theory related to panel designs. Most promising designs appear to be as shown in **Appendix K**. Urquhart and Kincaid (1999) found the greatest power to detect trends was provided by the first design (i.e., where sites are revisited every year), although it was only marginally better than designs with serially alternating panels, which provided considerably more information about the resource "status". We gave new thought to the benefits of various panel designs after our response to ISRP. In addition, we evaluated the use of GRTS sampling techniques for monitoring site selection and selected this method in preference to random, stratified random, or systematic sampling methods. We also applied EPA's (U.S. Environmental Protection Agency) SPSURVEY program (sometimes referred to as R-GRTS) (EMAP or Environmental Monitoring and Assessment Program, Messer et al. 1991) to select monitoring sites a program. These considerations for statistics of sampling are presented in **Appendix K**.

A preliminary field manual is provided in **Appendix L**. We plan to substantially improve this in April-May prior to the 2010 field season.

References

Messer, J.J., R.A. Linthurst, and W.S. Overton. 1991. An EPA program for monitoring ecological status and trends. Environmental Monitoring and Assessment 17, no. 1: 67-78.

B. Training in use of field Equipment

Gain training in use of the engineering level and rod; GPS equipment; stream hydrograph equipment; water temperature thermograph and data logger devices. This training is required to collect accurate and standardized surveys of stream channel morphology, water temperature and streamflow data.

Progress: In lieu of formal training in the use of field equipment, we studied the manuals that came with the level, temperature loggers, current meter, Nikon camera with built-in GPS, and Trimble GPS units. With the engineering level we followed the instrument's directions to confirm the level accuracy over the distances recommended using their described foresight and backsight method. Because we have yet to employ the full capabilities of the Trimble GPS with the laser rangefinder and with the "Blue Tooth" connection between the digital camera and the GPS, we want to schedule the training session that should accompany the instruments with purchase at the nearest opportunity before the coming field season (i.e., April-May).

C. Develop tool for streambed substrate characterization

Develop and test a device for statistically accurate estimation of substrate particle size distribution, emphasizing estimation of fine sediment surface particle frequency.

Progress: We designed a viewing tube for underwater identification and evaluation of surface particle size distribution. See **Appendix M**. This tube is a clear polycarbonate tube that is 1/16" thick material with an adjustable collar on the tube allowing it to be positioned in the center of the cells of a 3 x 3 aluminum grid frame with grid point spacing of 20 cm. This grid spacing was arrived at from the computer simulation of sampling surface substrate with grid frames of varying grid spacing and number of sample points. The viewing window had a clear plastic overlay with concentric circles of a diameter matching the particle size progression used in our sieve series. Larger particles were retrieved from the grid cell by hand and measured using a gravelometer. See **Appendix M**. This device was US SAH-97TM. It was described in Bunte and Abt (2001).

References

Bunte, K.and S.R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel-and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Fort Collins,CO. 428 p.

D. Develop modified McNeil sampler

Develop and test a McNeil sampler for use in monitoring changes in streambed substrate particle size composition at egg pocket depth. This sampler should offer the ability to retain fine sediment particles.

Progress: We designed a modified McNeil sampler based on dimensions and designs provided in McNeil and Ahnell (1964) and Plewe (2005). Our sampler had an outer bucket that was designed to hold the entire contents of a 6-L sample of gravel. The inner core volume also sampled to a typical egg-pocket depth and had a diameter capable to providing a sample of 6 L. The outside of the large barrel to the sampler had a circular handle that allowed the sampler to be easily turned into the streambed. This also served as a means of pouring a retained sample into a bucket in conjunction with the small central handle on the side of the barrel. The sampler also had a pour spout to facilitate pouring a liquid sample. The design for this sampler can be viewed in **Appendix N**.

One modification that we are considering making on this sampler for 2010 is to replace the stainless inner core with a hardened steel inner core. This inner core will have large teeth like the prototype, but the

hardness of this steel compared with stainless steel should make it more resistant to bending the teeth as the sampler is inserted into the streambed.

References

McNeil, W.J. and W.H. Ahnell. 1964. Measurement of gravel composition of salmon stream beds. University of Washington, Fisheries Research Institute, Circular No. 120.

Plewe, B.L. 2005. Comparison of qualitative and quantitative measurement of cobble embeddedness in Puget Sound streams. M.S. thesis. College of Forest Resources, University of Washington, Seattle, Washington. 110 p.

E. GIS analysis of sediment particle size distribution

Use GIS as a tool for statistical analysis of proper grid spacing relative to particle size distribution for characterizing the streambed substrate with accuracy and precision. The purpose of this is to use GIS as a simulation tool to assess coverage probabilities with different transect spacing to collect surface particle size analysis, and sample rates.

Progress: We generated three simulated surface streambed particle distributions to permit a GIS-based investigation of the influence of grid spacing, longitudinal trends in particle size composition (spatial diversity of particle distribution), and number of sample points on the accuracy and precision of estimates made of the percentage particle composition. A summary of this work is provided in **Appendix O**. [See file: Grid-transect presentation_DGedit.ppt].

F. Sampling Design

Test numerous sampling designs (e.g. ranked set sampling, stratified random, cluster sampling etc) to obtain precise, unbiased estimators. This will be done with GIS and field data, as well as reviewing literature in assessing the best design. In addition for key habitat parameters, we will assess the sample sizes needed to maintain a high power of analysis for detection of trends and before-after treatments.

Progress: Staff attended two online webinars on statistical techniques and monitoring methods.

On January 11-13 two of our staff attended the USGS webinar on basics in using the R language for statistical programming (Learn R, A Free Software Environment for Statistical Computing and Graphic). This experience provided essential training that facilitated application of R-GRTS sampling theory and also the use of software for mapping hydrography, basin area above stream points, and valley widths from DEM data.

	Command Approach		
Topic 10	10. Introduction to the R Language	Jan. 11	R10-topic10.wmv
Lab 5	More Data Manipulation	Jan. 12	R10-lab05.wmv
Topic 11	11. Introduction to R Graphics	Jan. 13	R10-topic11.wmv

Key habitat staff attended presentations on sampling theory hosted as a webinar by the USGS on March 8-11, 2010 (**Short Course on Designing Natural Resource Monitoring Surveys,** Conducted by webinar, March 8 - 11, 2010). This course provided us with links to the R-GRTS programming (also known as EPA's SPSURVEY program) that allows GIS users to create a spatially balanced set of sample points for any stream system using the R-based statistical package. We applied R-GRTS to the TRT spring Chinook spawning layers for the Upper Grande Ronde and Catherine Creek (see **Appendix K)**. These stream systems were stratified by intrinsic potential or IP (channel gradient and valley width) as proposed by the ICTRT. The GRTS point were then spatially distributed in all IP strata according to stream length available.

Monday, March 8, 2010
Introduction to short course and importance of probability sampling - Geissler SampGeisslerIntroduction.doc SampGeisslerIntroduction.ppt Samp100308JenkinsGeissler.wmv
Experiences designing a vegetation sampling design in the North Coast Cascades Network – Woodward SampWoodward.ppt
Experiences designing avian sampling design in the North Coast Cascades Network - Jenkins SampJenkins.ppt Samp100308JenkinsGeissler.wmv
Discussion of course objectives and experiences - Geissler moderates
Tuesday, March 9, 2010
Overview of Sampling, Selection methods (random, systematic, grid, GRTS) and allocation methods (unstratified, stratified and unequal probability) - Geissler Survey Simulator SampGeisslerDesignSim.doc SampGeisslerDesignSim.ppt SampGeissler.rSamp100309Geissler1.wmv
Domains, two-phase sampling, cluster sampling, Ratio and regression estimation, and Panel designs (sampling in time) - Geissler
Wednesday, March 10, 2010
Adaptive Sampling R Package - Dryver SampDryver.ppt Samp100310DryverSmith.wmv
Adaptive Sampling - Smith SampSmithAdaptive10_1.ppt SampSmithAdaptive10_2.ppt Samp100310DryverSmith.wmv
Discussion
Thursday, March 11, 2010
GRTS sampling - Garman SampSchweigerGarmanGRTS.ppt ExampleDesigns.r Samp100311Garman.wmv
Simulation program - Garman SampGarman.ppt
Sampling Bird Populations Considering Detectability - Sauer SampSauer2010.ppt Samp100311Sauer.wmv

G. Plant identification Training

Progress: We investigated sources of training and found a river restoration certificate program at Portland State University. See www.epp.esr.pdx.edu/coursedescriptions/html. This offers a course in streambank analysis and stabilization, aquatic macroinvertebrate biomonitoring; wetland plants of the Pacific Northwest; NW willow identification;

Gain training in identification of all locally significant tree and shrub species. This will be required for subsequent years for Riparian vegetation analysis in future years.

We were not able to complete this training in 2009. We wish to move this element into the 2010 contract and find an appropriate training opportunity for this.

Deliverable: H. A monitoring plan for temperature, sediment and flow measures on the Grande Ronde

H: 162. Analyze/Interpret Data

Title: Summarize preliminary findings

Description: Preliminary analysis on existing GIS data and collected stream flow and temperature will be conducted

Deliverable Specification: Maps and habitat attributes using GIS information will be generated.

A. GIS Analysis

Assess watershed and stream characteristics (inherent and current) using ArcMap (ESRI) based on available data. Examples of GIS data and analyses include: mean annual precipitation by grid cell and cumulative precipitation at watershed scale; basin area; hypsometric integral; relief ratio; valley width by stream reach; channel longitudinal gradient; road density; road density for riparian zones; land use; livestock density by tributary; lithology underlying stream reaches; hillslope lithology; soil type frequency; streamside soil types. B. Preliminary analysis on temperature and flow

Field data collected in the first year will be summarized. Data will be linked to GPS coordinates in a database that will be captured by a GIS project map for the study areas. Temperature analysis will include basic statistics (hourly, daily, monthly values for min., mean, max.; and 7DADMax). Correlations with air temperature statistics will be computed. Spatial trends will be evaluated to detect anomalies. Streamflow data will be computed for days sampled at all stream network nodes. Longitudinal trends will be evaluated for pattern and anomalies. Known irrigation diversions will be accounted for. Correlations with existing USGS gages will be made.

Progress:

B. Analysis of temperature, sediment, flow, riparian canopy

Field data collected will be summarized in WE D. Data will be linked to GPS coordinates in a database that will be captured by a GIS project map for the study areas. Temperature analysis will include basic statistics (hourly, daily, monthly values for min., mean, max.; and 7DADMax). Correlations with air temperature statistics will be computed. Spatial trends will be evaluated to detect anomalies. Streamflow data will be computed for days sampled at all stream network nodes. Longitudinal trends will be evaluated for pattern and anomalies. Known irrigation diversions will be accounted for. Correlations with existing USGS gages will be made. The stream water temperature model will be developed based on LiDAR, FLIR, and water temperature data.

Progress: Data were collected on water temperature (using Hobo data loggers), surface sediment composition (using our plastic viewscope with cross-hair particle identifier), subsurface sediment composition (using the modified McNeil sampler), riparian canopy coverage (with the LiDAR subcontract). The sample data points for these samples were mapped using GIS software and became part of the geodatabase for the Grande Ronde/Catherine Creek project. Additional streamflow data obtained from the USFS, OWRD (Oregon Water Resources Department), and USGS were stored in our data server.

Surface substrate particle size composition was analyzed by a variety of techniques. Some of these techniques have been described in **Appendix H** in the description of sediment particle size analysis. In

addition, staff developed a multinomial likelihood estimation process that is flexible enough to permit determination of mean and standard error of a variable number of particle size classes from surface size sampling. The mathematical basis for this analysis is given in **Appendix P**.

The contents of the geodatabase residing on the CRITFC network (I drive) are described in detail in **Appendix Q**.

Progress has been made in developing preliminary criteria for mapping of spawning habitat. This will be important as a means of selecting spawning habitat units for conducting sediment particle size analysis. A draft of this work is available at **Appendix R**.

For preliminary analyses of habitat quantity/quality data related to salmon productivity, see internal files:

D:\ClimateChange\BPA climate change proposals\Modeling habitat

Also see: D:\GISDATA\Remand_process\Grande_Ronde\FinalData\McHugh

Stream classification

A robust stream classification is an integral component of this project as it provides a basis for comparing units for analysis, facilitates understanding of ecological processes that vary under different watershed conditions, and creates common ground for administering management activities and communicating findings. While this section outlines our overall approach, a more thorough account can be found in **Appendix S**. Steps towards classification include (1) reviewing published literature on classification systems, (2) deciding on a conceptual framework for classification, (3) generating an accurate stream layer at the appropriate level of resolution, (4) modeling and verifying watershed attributes to be used in classification, and (5) using those attributes to group stream reaches into classes, which will be used as strata for probabilistic distribution of sampling locations. To date, we have completed steps 1-3 and are nearing completion of steps 4-5. After reviewing relevant literature and creating a stream layer from a 10m digital elevation model (DEM), our general approach was to create an a priori reach-scale classification composed of a minimal number of classes expected to explain variation in measured habitat metrics. Candidate variables for reach classification were area and precipitation depth of upstream the watershed, relative elevation, stream order, channel gradient, and valley width. After initial stratification, reaches will also be classified in a post hoc fashion in order to test several landscape/watershed-scale classifications with the goal of further reducing variance in measured habitat metrics. Candidates for landscape/watershed-scale classification include Omernik level IV-V ecoregions, hydrological landscape regions, parent geology, catchment identity, and—as a null model—geographic distance (spatial autocorrelation) among sites. Details and references for classification variables can be found in **Appendix S**. This classification using intrinsic watershed characteristics will replace the land use classification previously reported in the project proposal, providing strata to estimate the amount of available habitat for Chinook salmon life history stages and parameterize the life history model.

Structural equation modeling—justification and proof of concept

Determining the impact of human activities on habitat quality for Chinook salmon will involve factoring out variability associated with intrinsic watershed characteristics—addressed via the previously-mentioned stream classification—but will also require accounting for the interrelationships among

predictor variables. For example, if we want to know the impacts of fine sediment on fish habitat, we should not ignore the obvious impact that large woody debris has on fine sediment; therefore large woody debris has an indirect impact on fish habitat. The presence of large woody debris also has a direct impact on fish habitat (via provision of refuge) in addition to its indirect impact through fine sediment. To further complicate the issue, watershed class will also both directly and indirectly impact fish habitat. Tools for statistical analysis of complex, interrelated factors have existed in the form of path analysis and structural equations modeling for decades (Wright 1918, 1923), but have only recently been adopted by practitioners of natural resource management (Grace 2006).

As a proof of concept analysis, we developed a structural equation model to investigate interrelationships among several important factors affecting maximum water temperature using Oregon Department Fish & Wildlife's Aquatic Habitat Inventory data from the upper Grande Ronde River and Catherine Creek (Moore et al. 2008) (Fig. 1). Valley form—a latent variable composed of valley width index (VWI) and gradient—affects maximum temperatures measured in ODFW reaches directly in a negative manner and indirectly through land use intensity, riparian trees, and shade. For example, valley form positively affects land use intensity (with more intensive land use activities occurring in broad, low-gradient valleys) which negatively affects the abundance of riparian trees, the presence of which is positively correlated with shade, which reduces water temperature. Furthermore, valley form directly affects water temperature (possibly through hyporheic flow paths) and indirectly affects water temperature through shade not associated with riparian trees, such as topographic shading. This analysis, though intended for demonstrative purposes only, represents the utility that structural equation modeling has for unraveling complicated interrelationships that are probably the norm rather than the exception in ecological systems.

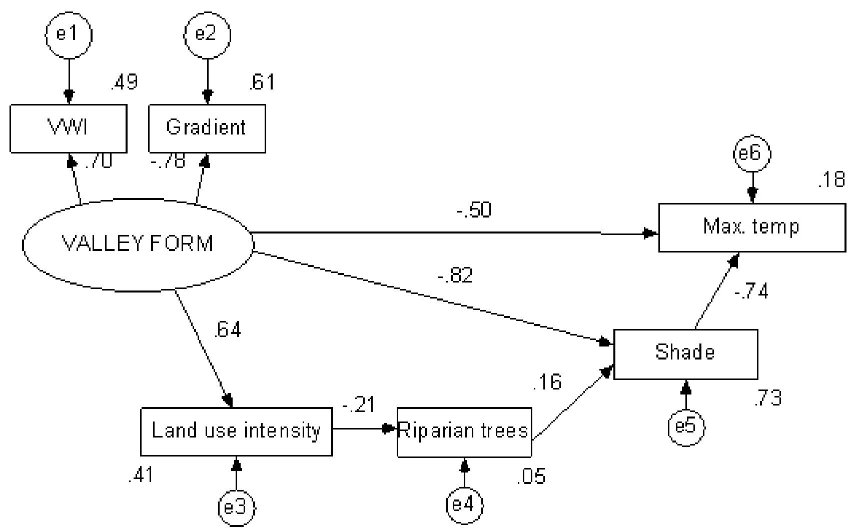


Figure 1. Structural equation model of interrelated factors affecting maximum water temperature measured in reaches during ODFW Aquatic Habitat Inventory surveys (n = 104 reaches, Chi-square = 5.98, d.f. = 5, p-value = 0.31 [p-values > 0.05 are significant]). Rectangles represent directly measured variables, ellipses (i.e., valley form) are latent variables composed of one or more measured variables, and circles represent error terms. Direction of arrows represents direction of causal influence among variables, adjacent values

are standardized path coefficients representing direction and relative magnitude of effects, and values adjacent to response variables are multiple R-squares.

Chinook spawning selectivity and land ownership disparity according to intrinsic spawning habitat potential

A preliminary analysis of Chinook salmon spawning locations, ODFW spawning index reaches, and private land ownership in the study area revealed several findings of interest: Sixty-five percent of potential spawning habitat in the upper Grande Ronde basin is in private land ownership, and private land owners enjoy the lion's share of areas with highest intrinsic spawning potential. This is important because we found that spring Chinook do in fact tend to spawn in ICTRT-designated reaches of high and moderate potential, meanwhile avoiding low potential reaches. However, the analysis also shows that ODFW spawning reaches under-represent high potential habitat and over-represent low potential habitat, probably as a direct consequence of where private land falls. This analysis involved using existing GIS layers of land ownership, intrinsic spawning potential, and newly-created maps of start and end points of spawning surveys and Chinook salmon redds located via GPS by our crew in the summer of 2009. The draft report is included as **Appendix T**.

References

Wright, J.F. 1994. Development of RIVPACS in the UK and the value of the underlying data-base. Limnética 10, no. 1: 15-31.

Grande Ronde Model Watershed Home page. http://www.grmw.org/.

Moore, K., K.K. Jones, J. Dambacher, and C. Stein. 2008. Methods for Stream Habitat Surveys Aquatic Inventories Project. Corvallis, OR: Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Conservation and Recovery Program. http://oregonstate.edu/dept/ODFW/freshwater/inventory/pdffiles/habmethod.pdf.

Grace, J.B. 2006. Structural Equation Modeling and Natural Systems. Cambridge, NY: Cambridge University Press.

Wright, S. 1918. On the nature of size factors. Genetics 3: 367-374.

Wright, S. 1921. Correlation and causation. Journal of Agricultural Research 20: 557-585.

ODEQ. 2009. Water monitoring and assessment mode of operations manual (MOMs) version 3.2. Hillsboro, Oregon: Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division.

Maltz, E. 2010. Burns Paiute Tribe Chinook salmon feasibility study. Draft proposal. Burns, Oregon: Burns Pauite Tribe, March 10.

I: 161. Disseminate Raw/Summary Data and Results

Deliverable: A. Presentation in AFS/JASA

B. B. Presentation in AFS and/or JASA

Attend American Fisheries Society meeting and/or American Statistical Association Meetings

Progress: Three staff attended the 2009 Oregon Chapter AFS meeting held in Eugene. This meeting provided a good opportunity to network with other habitat professionals working in NE Oregon.

C. Post data to the internet

Work with the Tribal Data Network project to make data available to regional trading partners by publishing metadata to the Internet and posting appropriate raw and summary data elements on the CRITFC web site.

Progress: Our database team hosted two tribal data workshops in March, 2010. In addition, the database staff entered temperature and flow data sets into storage on CRITFC servers. These data were validated and summarized for over 100 USGS and Forest Service gauges. Some of the gauges included 20+ years of collected data. For more detail on the function of the Tribal Data Network project and how it relates to our habitat monitoring project, see **Appendix U**.

D. D. Present findings and procedures in professional meetings

Disseminate data in Public forums and scientific meetings, as well as at agency/tribal meetings on RM&E.

Progress: We did not make formal presentations in scientific meetings.

J: 183. Produce Journal Article

Title: Produce journal publications on fish/habitat relationships

Description: Completion of a journal article in which water temperature criteria are applied to evaluation of the effectiveness of current state water quality standards in protecting coldwater fish. This work is linked to the development of quantitative means of estimating fish survival at a basin scale.

Deliverable Specification: A peer-reviewed review article evaluating the ability of common indices of fish population viability to protect salmonids. This paper will describe the importance of water temperature criteria in protecting salmon survival.

Deliverable: A. Are the Nation's Coldwater Fish Populations Actually Being Protected in Water Quality Standards?

D. Produce Journal Article on Fish Habitat Relationships

Produce Manuscript to send to a journal. Completion of a journal article in which water temperature criteria are applied to evaluation of the effectiveness of current state water quality standards in protecting coldwater fish. This work is linked to the development of quantitative means of estimating fish survival at a basin scale. Other proposed publications include recent studies of ocean climatic and marine conditions that affect marine survival of salmon stocks. These studies assist in completing the evaluation of effects of climate change on the entire salmon life cycle.

Progress: Staff completed three journal articles for submission to publication in peer-reviewed journals related to the habitat/fish relationship issues researched in this Accord project. Abstracts of the submitted papers are given below:

Paper 1. McCullough, D.A. The Diversity of Response to Full Protection of the Beneficial Use under the US's Clean Water Act. Submitted to Freshwater Reviews.

Abstract

A survey of the 50 states comprising the United States reveals that 46 states support either native salmonids or introduced salmonids that have become self-sustaining in streams. Although this distribution may not be extensive in some of the states, the problem of devising water quality criteria that support salmonids is one that is widespread. In addition, the current EPA Gold Book guidance for development of protective standards, dating from 1973, still recommends the use of MWAT (maximum weekly average temperature) as a means of assigning protective chronic temperature standards to coldwater fisheries. MWAT, applied according to EPA guidance, is typically used in conjunction with an acute upper limit. From its inception, evidence was available to show that MWAT was inadequate in protecting against chronic thermal impairment. In the US, each state has been permitted independently to develop protective temperature criteria that purport to provide full protection of designated uses (*e.g.*, coldwater fish use) and apply the best available science. A review of the 50 states' water temperature standards indicates a wide variety of quantitative criteria and levels of protection. Few states employ EPA recommendations to use MWAT, but inadequate standards are nonetheless common. The divergence of temperature standards found in state statutes to protect fish species with highly similar biological requirements is indicative of the failure of states to provide consistent levels of protection and of the EPA to ensure state application of the best science through its standards approval process.

Paper 2. McCullough, D.A. Are Coldwater Fish Populations of the United States Actually Being Protected in Water Quality Standards? Submitted to Freshwater Reviews.

Abstract

Governmental water quality agencies as a whole are faced with identifying water quality goals linked to a level of biotic protection, applying the best available science in development of water quality standards and associated management principles, implementing water quality laws so that there is consistency with goals, development of guidance documents for applying science to law, monitoring, and enforcement. Deviations in this path from goals to standards to enforcement are common across countries as well as among states within the United States and result in numerous means to fail in protecting aquatic biota. The Clean Water Act is the key US law for water quality protection. Its goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and to fully protect the most

sensitive beneficial uses. The US Environmental Protection Agency (EPA) Gold Book guidance for development of protective water temperature standards, dating from 1973, still recommends the use of MWAT (maximum weekly average temperature) as an index for assigning protective chronic temperature standards to coldwater fisheries. MWAT, applied according to EPA guidance, is typically used in conjunction with an acute upper limit. Unfortunately, MWAT is a criterion that is not protective, as can be shown by reference to several case studies on salmonids. Use of MWAT at a basin scale can result in considerable reduction in available salmonid rearing area and can in many cases be little better than recommending upper incipient lethal as a standard. Although MWAT is not used by many US states in standards, it is problematic in that it is cited as the official EPA model for a protective standard. The conceptual use of MWAT highlights some critical problems in application of the Clean Water Act and its associated federal regulations for protection of coldwater fishes, such as the concepts of full protection, protection of the most sensitive species, restoration of water quality, and support of species' viability at a basin scale. A recent review of the 50 states' water temperature standards indicates a wide variety of quantitative criteria and levels of protection applied to species having highly similar thermal requirements. Full implementation of the CWA in support of salmonids' thermal requirements has been spotty, with some states taking criteria development, monitoring, listing, and TMDL development seriously and others virtually ignoring the problem. In addition, Section 316 of the CWA poses conflicts with basic goals of the CWA by giving deference to the thermoelectric power industry to discharge heated effluent under a process where variances granted supersede water quality-based limits. This is exacerbated by EPA 316 guidance permitting evaluation of biological trends amidst shifting or uncertain baselines in a limited set of RIS (representative important species) rather than application of best available science to protect the most sensitive species as well as to protect the entire aquatic community that is reflective of high quality habitat conditions. Designing water temperature standards to be fully protective and supportive of species viability (abundance, productivity, spatial structure, and diversity) benefits from application of concepts of optimum growth and survival temperatures distributed at a basin scale with reference to the natural thermal potential along a river continuum. Some notable successes in standards development found in the US Pacific Northwest can be offered as future national models.

Paper 3. White, S.M., Li, H.W. and Giannico, G.R. "Application of a multi-species habitat selection theory to salmonid movement and foraging behavior in natural streams." Submitted to Freshwater Biology.

Abstract:

1. Observational studies of species distributions can mislead investigators regarding the cause of distribution patterns on the landscape. This may be the case for two, commonly-studied salmonids in the Pacific Northwest: rainbow trout Oncorhynchus mykiss and juvenile Chinook salmon O. tshawytscha, both of which appear to have distinct habitat preferences yet when they are sympatric appear to compete for food and territories, and therefore may prefer similar habitats. Determining whether habitat preferences are distinct vs. shared will involve an experimental approach and rigorous ecological theory. We examined fish habitat selection and foraging behavior in natural streams of eastern Oregon using isoleg theory, a multi-species perspective of the ideal free distribution.

2. We first examined rainbow trout foraging behavior using underwater video and multivariate analysis. Rainbow trout exhibited a range of risk-averse to risk-prone foraging behaviors involving foraging in

different horizontal strata of the stream and variable rates of intra- and interspecific aggression. We found three primary behavioral modes, and termed them “low strata foraging,” “aggressive surface foraging,” and “territory maintenance.” These behaviors were later examined as a response to experimental addition of food, changing competitor densities, and physical characteristics of the stream.

3. At 20 experimental sites, we created artificially good habitat via food supplementation and observed fish migration among pools via snorkeling, seine netting, and documented behavioral responses. Using the isoleg model and an information-theoretic approach (AIC), we found that both intra- and interspecific fish abundance affected rainbow trout habitat selection: migration into enriched patches decreased with increasing biomass of rainbow trout as expected, and we were thus able to demonstrate a limit to carrying capacity of pools. Inclusion of physical habitat variables did not improve the models, indicating that rainbow trout primarily selected habitat based on food availability and competitor densities. Rainbow trout selection of enriched patches increased when juvenile Chinook salmon were more abundant, which we attribute to interspecific attraction or other causes. Chinook salmon did not frequently migrate among pools and thus we were not able to assign a mechanism for their habitat selection.

4. Foraging behavior of rainbow trout was dependent on the abundance of competitors but not whether they occupied pools of food supplementation. Low strata foraging increased in the presence of competitors when only one species was present, but decreased with increasing competitors when both species where present in moderate to high abundance. Aggressive surface foraging decreased and territory maintenance increased in the presence of more conspecifics, but were not affected by abundance of juvenile Chinook. Inclusion of physical habitat variables did not improve models, indicating that competitor densities were of greater importance in determining behavioral mode.

5. Examining salmonid habitat selection and foraging behavior in a natural field setting using isoleg theory and an information-theoretic approach revealed novel insights that would have been overlooked if each had been evaluated separately, or in artificial conditions (e.g., aquaria) that bear little or no resemblance to their natural environment.

K: 160. Create/Manage/Maintain Database

Title: Develop and manage fish habitat condition database.

Description: A database will be designed and maintained for the habitat variables collected under this project.

Deliverable Specification: Database designed and collated with field data

Deliverable: A. Habitat Variables Database

B. Design database and Update it

Design database

M: 132. Produce (Annual) Progress Report

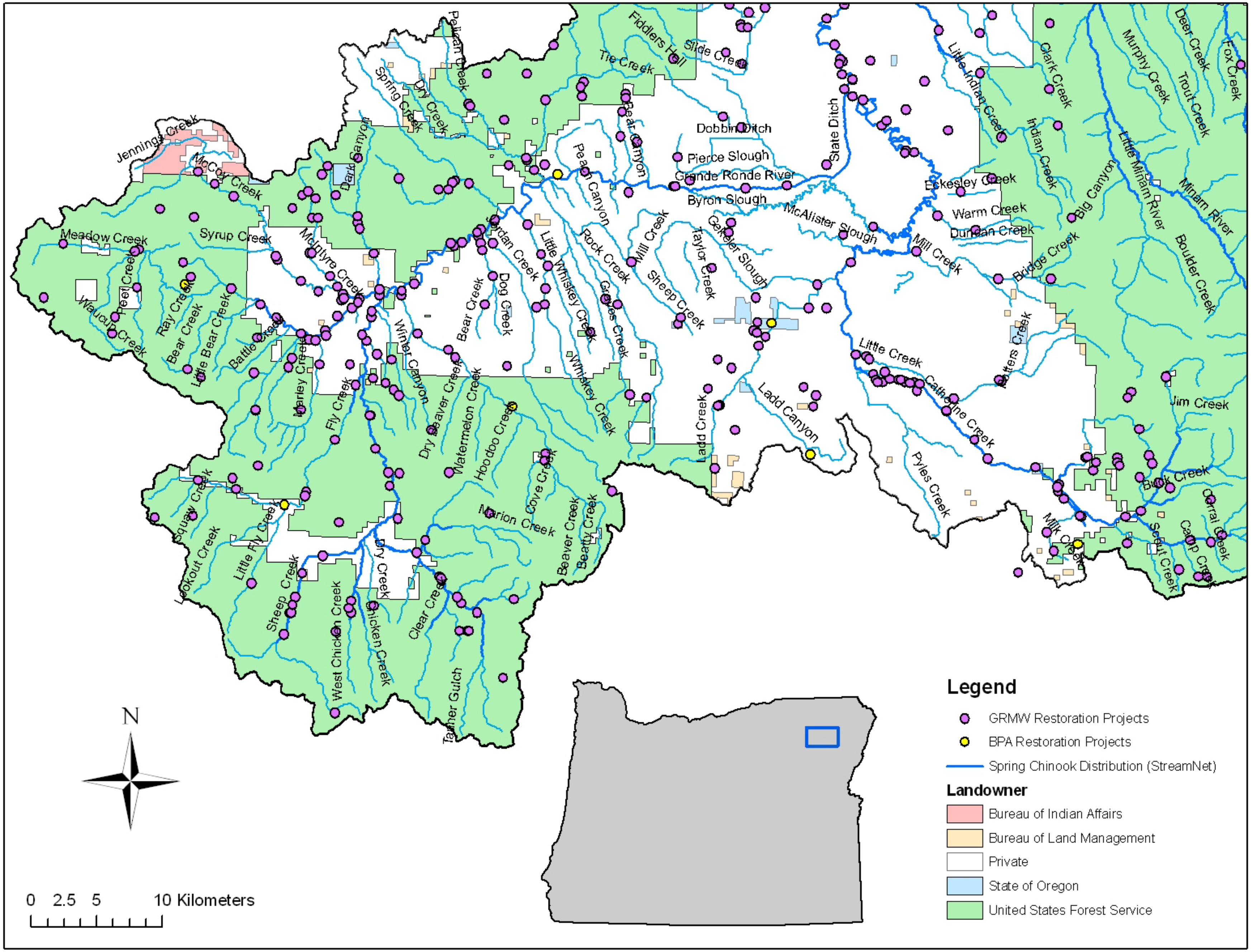
Title: Submit Progress Report for the period (April 1, 2009) to (March 31, 2010)

The progress report summarizes the project goal, objectives, hypotheses, completed and uncompleted deliverables, problems encountered, lessons learned, and long-term planning. Examples of long-term planning include future improvements, new directions, or level of effort for contract implementation, including any ramping up or ramping down of contract components or of the project as a whole. Apr 2009 to Mar 2010 will be agreed upon by the COTR and the contractor. This may or may not coincide with the contract period. For an ongoing project, a progress report covering a contract period may be submitted under the subsequent contract, if approved by the COTR.

List of Appendices

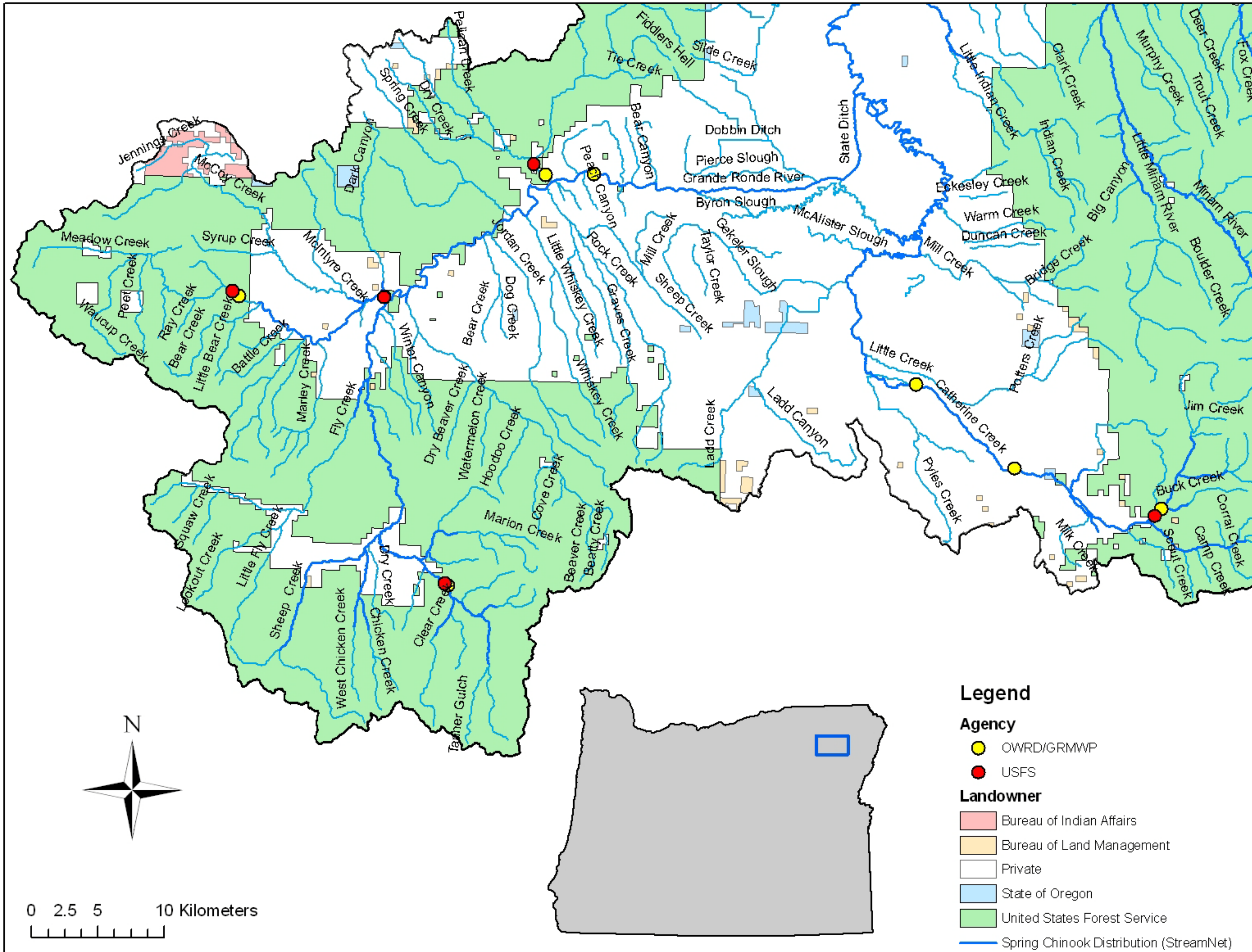
Appendix A

Map of Restoration Projects in the Study Basins Compiled by the Grande Ronde Model Watershed


Legend
GRMW Restoration Projects
BPA Restoration Projects
Spring Chinook Distribution (StreamNet)
Landowner
Bureau of Indian Affairs
Bureau of Land Management
Private
State of Oregon
United States Forest Service
N
0 2.5 5 10 Kilometers
Grande Ronde River
Meadow Creek
Syrup Creek
Jennings Creek
McCoy Creek
Dark Canyon
Pelican Creek
Spring Creek
Dry Creek
Fiddlers Hell
Tie Creek
Slide Creek
Dobbin Ditch
Pierce Slough
Byron Slough
State Ditch
McAlister Slough
Little Indian Creek
Clark Creek
Murphy Creek
Deer Creek
Fox Creek
Trout Creek
Indian Creek
Little Minam River
Minam River
Eskesley Creek
Warm Creek
Duncan Creek
Big Canyon
Mill Creek
Bridge Creek
Boulder Creek
Little Creek
Catherine Creek
Jim Creek
Buck Creek
Corral Creek
Camp Creek
Scout Creek
Milk Creek
Pyles Creek
Ladd Canyon
Ladd Creek
Sheep Creek
Taylor Creek
Gekeler Slough
Rock Creek
Graves Creek
Whiskey Creek
Little Whiskey Creek
Peach Canyon
Jordan Creek
Dog Creek
Bear Creek
Winter Canyon
Dry Beaver Creek
Watermelon Creek
Hoodoo Creek
Cove Creek
Marion Creek
Beaver Creek
Beatty Creek
McIntyre Creek
Fly Creek
Marley Creek
Battle Creek
Little Bear Creek
Ray Creek
Peet Creek
Waucup Creek
Squaw Creek
Lookout Creek
Little Fly Creek
Sheep Creek
West Chicken Creek
Chicken Creek
Clear Creek
Tanner Gulch

Appendix B

Map of Existing Streamflow Gauging Stations in the Upper Grande Ronde River and Catherine Creek Basins


Legend
Agency
OWRD/GRMWP
USFS
Landowner
Bureau of Indian Affairs
Bureau of Land Management
Private
State of Oregon
United States Forest Service
Spring Chinook Distribution (StreamNet)
N
0 2.5 5 10 Kilometers
Grande Ronde River
Dobbin Ditch
Pierce Slough
Byron Slough
McAlister Slough
State Ditch
Catherine Creek
Little Creek
Ladd Creek
Ladd Canyon
Pyles Creek
Milk Creek
Buck Creek
Corral Creek
Camp Creek
Scout Creek
Jim Creek
Potters Creek
Bridge Creek
Mill Creek
Duncan Creek
Warm Creek
Eckesley Creek
Big Canyon
Indian Creek
Little Indian Creek
Clark Creek
Murphy Creek
Deer Creek
Trout Creek
Fox Creek
Little Minam River
Minam River
Boulder Creek
Fiddlers Hell
Slide Creek
Tie Creek
Bear Canyon
Pearl Canyon
Jennings Creek
McCoy Creek
Meadow Creek
Syrup Creek
Peet Creek
Waucup Creek
Ray Creek
Bear Creek
Little Bear Creek
Battle Creek
McIntyre Creek
Dark Canyon
Spring Creek
Dry Creek
Pelican Creek
Jordan Creek
Little Whiskey Creek
Rock Creek
Mill Creek
Taylor Creek
Gekeler Slough
Sheep Creek
Graves Creek
Whiskey Creek
Dog Creek
Winter Canyon
Marley Creek
Fly Creek
Dry Beaver Creek
Watermelon Creek
Hoodoo Creek
Cove Creek
Marion Creek
Beaver Creek
Beatty Creek
Squaw Creek
Little Fly Creek
Lookout Creek
Sheep Creek
West Chicken Creek
Chicken Creek
Clear Creek
Tanner Gulch

Appendix C

Laboratory Set-Up for Processing Stream Substrate Sediment Samples and Macroinvertebrates


CAUTION!
TO REDUCE THE RISK OF FIRE HEATING ELEMENTS, BLOWER MOTOR AND SHELF SHOULD BE CLEANED SEMIANNUALLY
PACIFIC NORTHWEST
< 0.125


HOMER'S ALL-PURPOSE BUCKET


FAN
HEATER
2 AMP FUSE
SWITCH


GILSON
COMPANY, INC.
www.globalgilson.com
WARNING
DANGER
DANGER
VOLTS

Appendix D

Recommended sites for collection of water temperature data using water temperature data loggers suggested by Watershed Sciences, Inc.

Figure 8 - Map of designated current (red) and potential (blue) Spring Chinook spawning reaches.

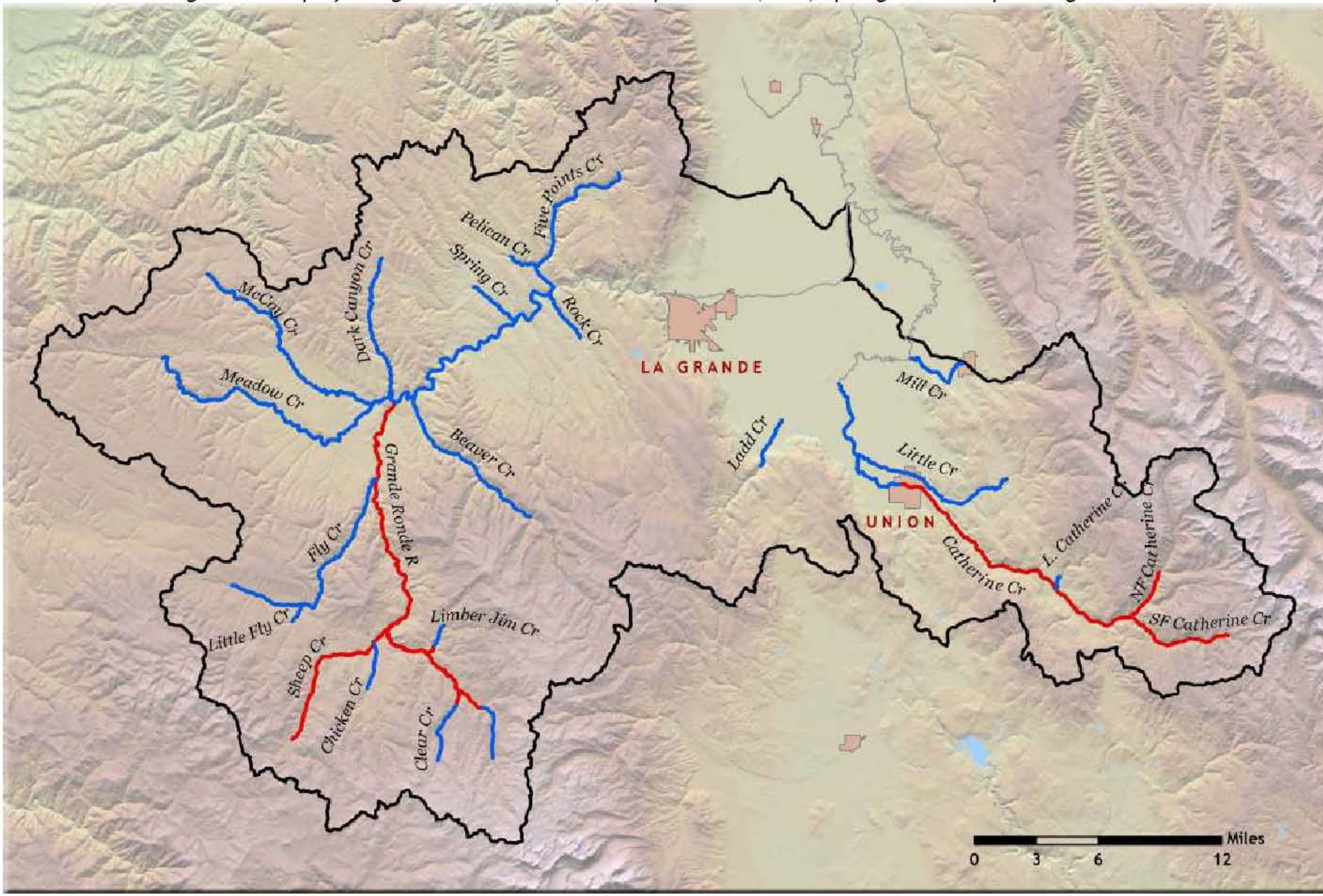


Figure 9 – Map of stream reaches recommended for stream temperature modeling.

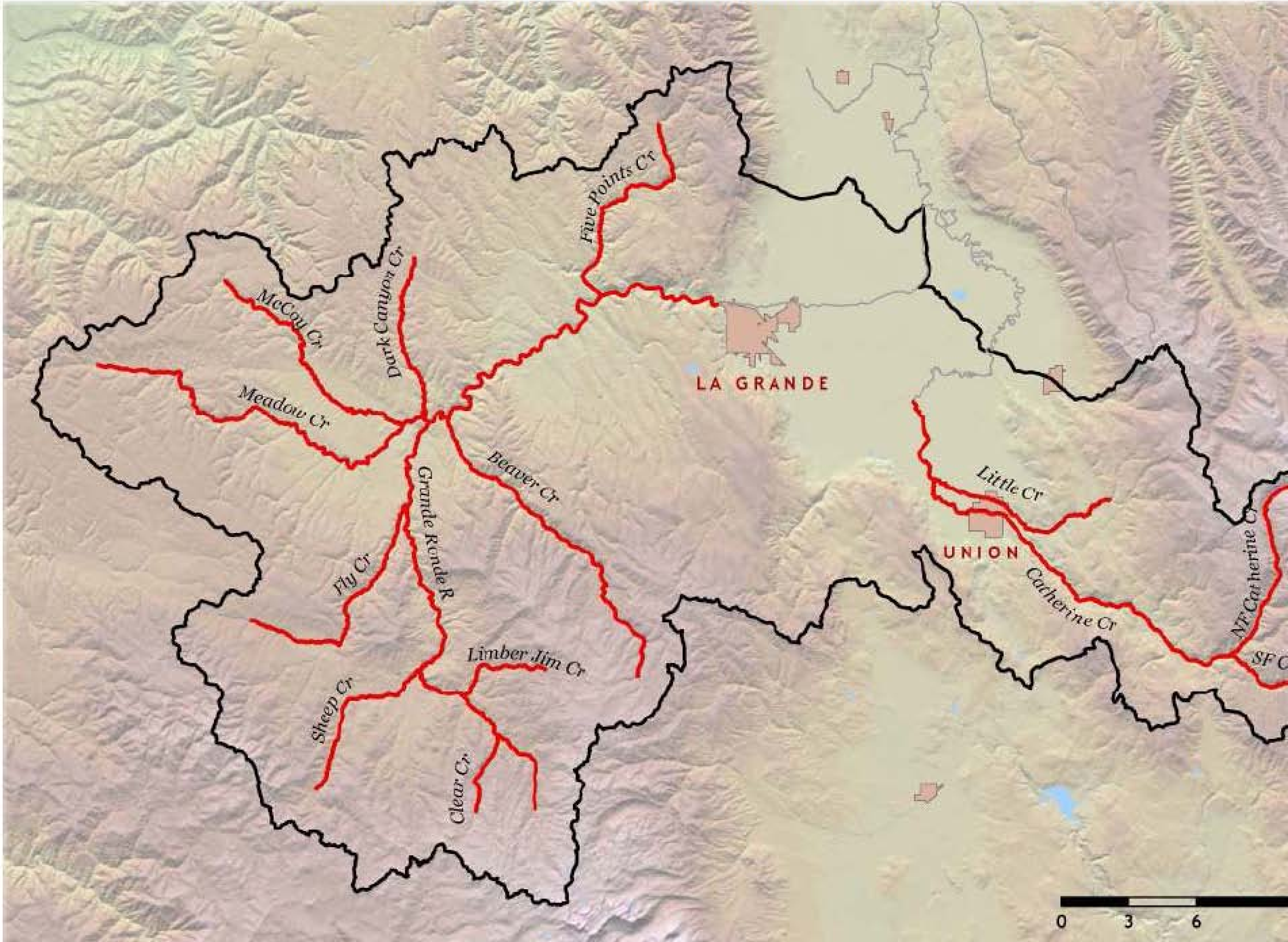
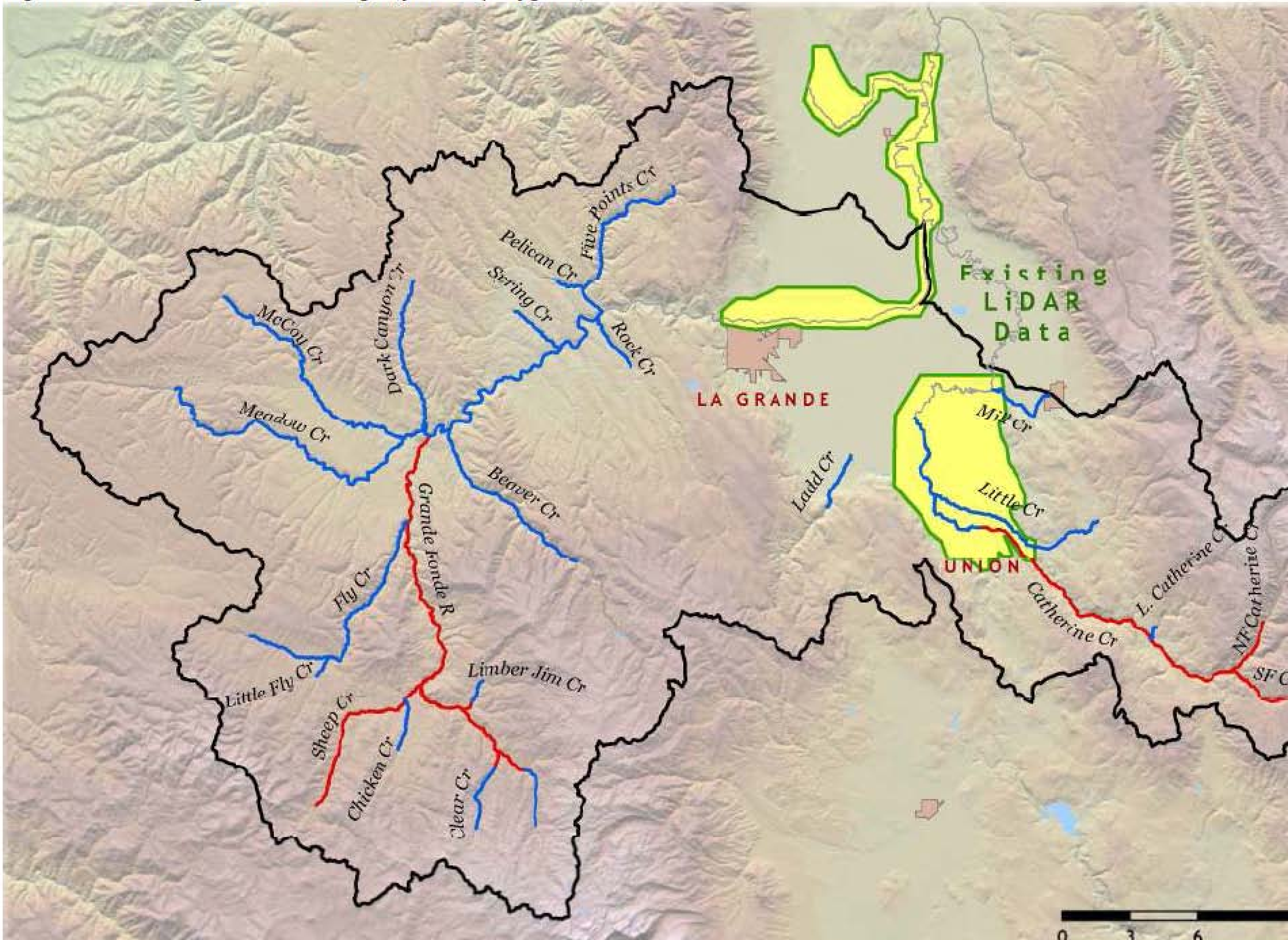
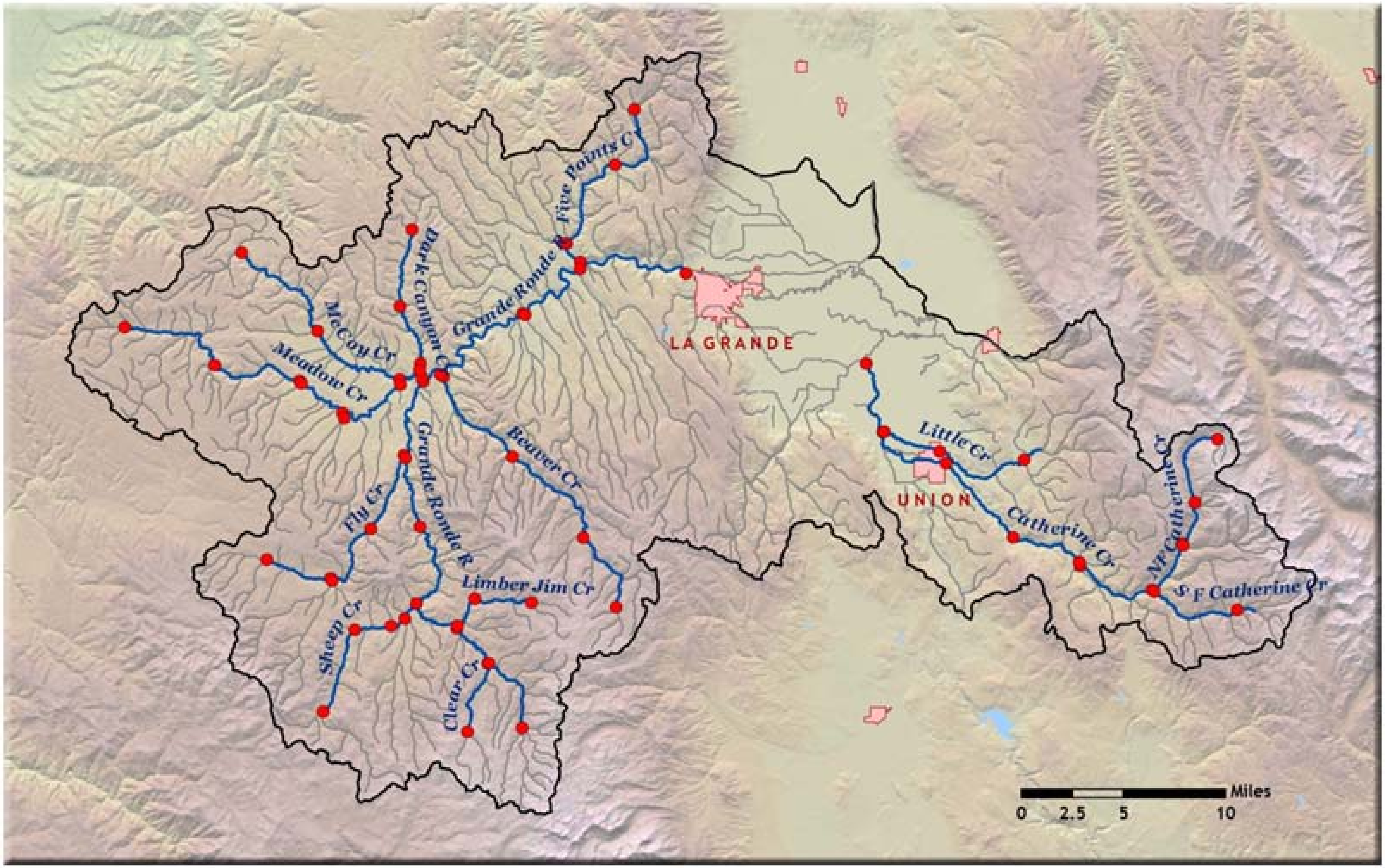


Figure 2 – Existing LiDAR coverage (yellow polygons).





Five Points Cr
Grande Ronde R
Dark Canyon Cr
McCoy Cr
Meadow Cr
Grande Ronde R
Beaver Cr
Fly Cr
Limber Jim Cr
Sheep Cr
Clear Cr
LA GRANDE
UNION
Little Cr
Catherine Cr
NF Catherine Cr
S F Catherine Cr
Miles
0 2.5 5 10

Appendix E

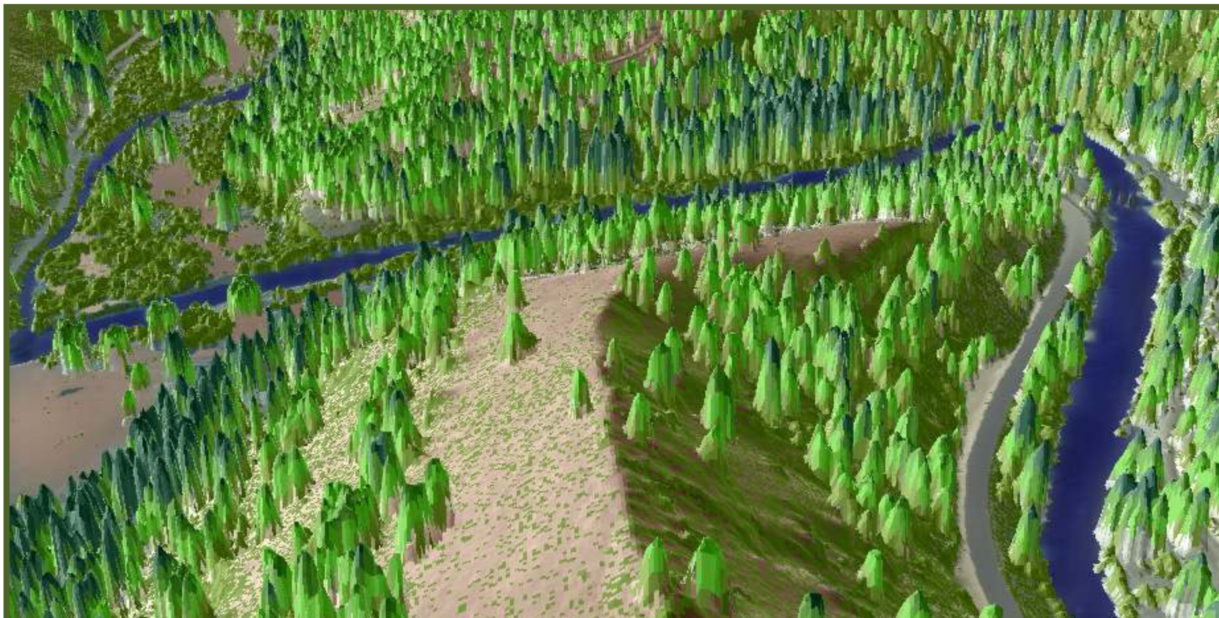
LiDAR Data Collection Phase

Grande Ronde River Basin

December 23, 2009

Watershed Sciences, Inc.

LIDAR DATA COLLECTION PHASE
GRANDE RONDE RIVER BASIN
DECEMBER 23, 2009



South westerly view of The Grand Ronde River and highway 224 west of Spring Creek Road. Image is derived from ground classified and highest hit LiDAR points.

Submitted to:

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LiDAR Remote Sensing Data:

Grande Ronde River Basin, Oregon

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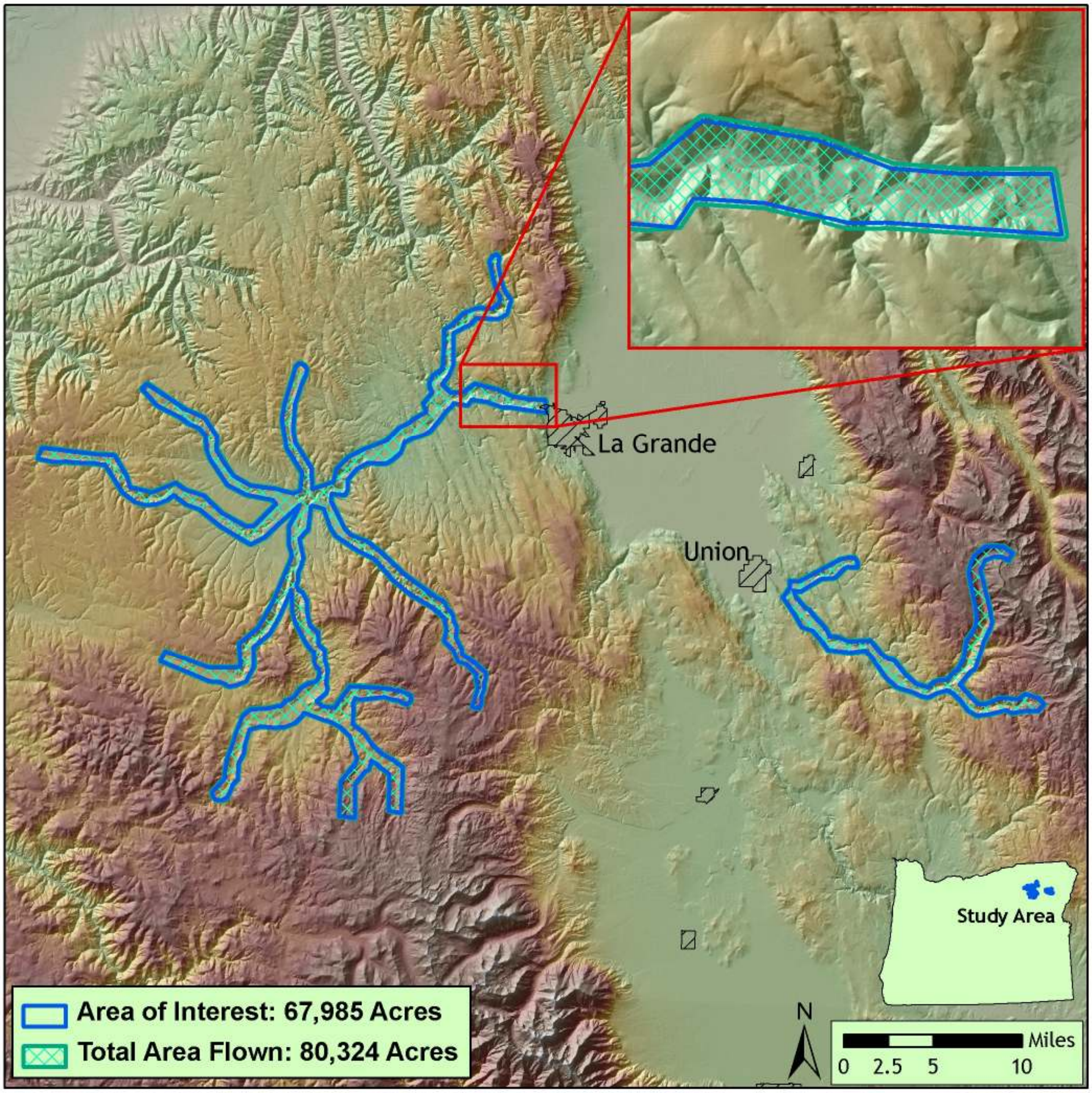
1. Overview

1.1 Study Area

Watershed Sciences, Inc. collected Light Detection and Ranging data (LiDAR) of the Grande Ronde River basin study area for the Columbia River Inter-Tribal Fish Commission (CRITFC). The requested LiDAR Area of Interest (AOI) totals approximately 67,985 acres, and was buffered to ensure data coverage, resulting in a Total Area Flown (TAF) of 80,324 acres.

Figure 1.1. *Grande Ronde River basin study area, displayed over a 10-meter DEM.*



1.2 Accuracy and Resolution

Real-time kinematic (RTK) surveys were conducted in the study area for quality assurance purposes. The accuracy of the LiDAR data is described as standard deviations of divergence (sigma ~ σ) from RTK ground survey points and root mean square error (RMSE) which considers bias (upward or downward). The Grande Ronde River basin study area data have the following accuracy statistics:

RMSE	1-sigma absolute deviation	2-sigma absolute deviation
0.05 meter	0.05 meter	0.09 meter

Data resolution specifications are for ≥8 points per square meter. Total average and ground pulse density statistics for the study area are as follows:

Total Pulse Density	Ground Pulse Density
8.15 points per square meter	2.42 points per square meter

1.3 Data Format, Projection, and Units

Grande Ronde River basin data are delivered in UTM Zone 11, with units in meters, in the NAD83 HARN/NAVD88 datum (Geoid 03).

Deliverables include:

- All return point data in *.las v 1.2 format
- 1-meter resolution bare ground model ESRI GRID
- 1-meter resolution above ground modeled ESRI GRID
- 0.5-meter resolution intensity images in GeoTIFF format
- Ground control RTK point file in shapefile format
- Trajectory data in both ASCII point file and ESRI shapefile formats
- Shapefiles of delivery area in 0.75’, 3.75’ and 7.5’ USGS quadrangle delineations
- Report of data collection methods and summary statistics

2. Acquisition

2.1 Airborne Survey Overview – Instrumentation and Methods

The LiDAR survey utilized a Leica ALS50 Phase II sensor mounted in Cessna Caravan 208B. The Leica ALS50 Phase II system was set to acquire ≥105,000 laser pulses per second (i.e., 105 kHz pulse rate) and flown at 900 meters above ground level (AGL), capturing a scan angle of ±14° from nadir[1] (see **Table 2.1**). These settings are developed to yield points with an average native pulse density of ≥8 points per square meter over terrestrial surfaces. Some types of surfaces (i.e., dense vegetation or water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to distributions of terrain, land cover, and water bodies.

The Cessna Caravan is a powerful and stable platform, ideal for the mountainous terrain of the Pacific Northwest. The Leica ALS50 sensor head installed in the Caravan is shown on the right.

The area of interest was surveyed with opposing flight line side-lap of ≥50% (≥100% overlap) to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernable laser returns were processed for the output dataset. To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and measured twice per second (2 Hz) by an onboard differential GPS unit. Aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU).

Table 2.1 *LiDAR Survey Specifications*

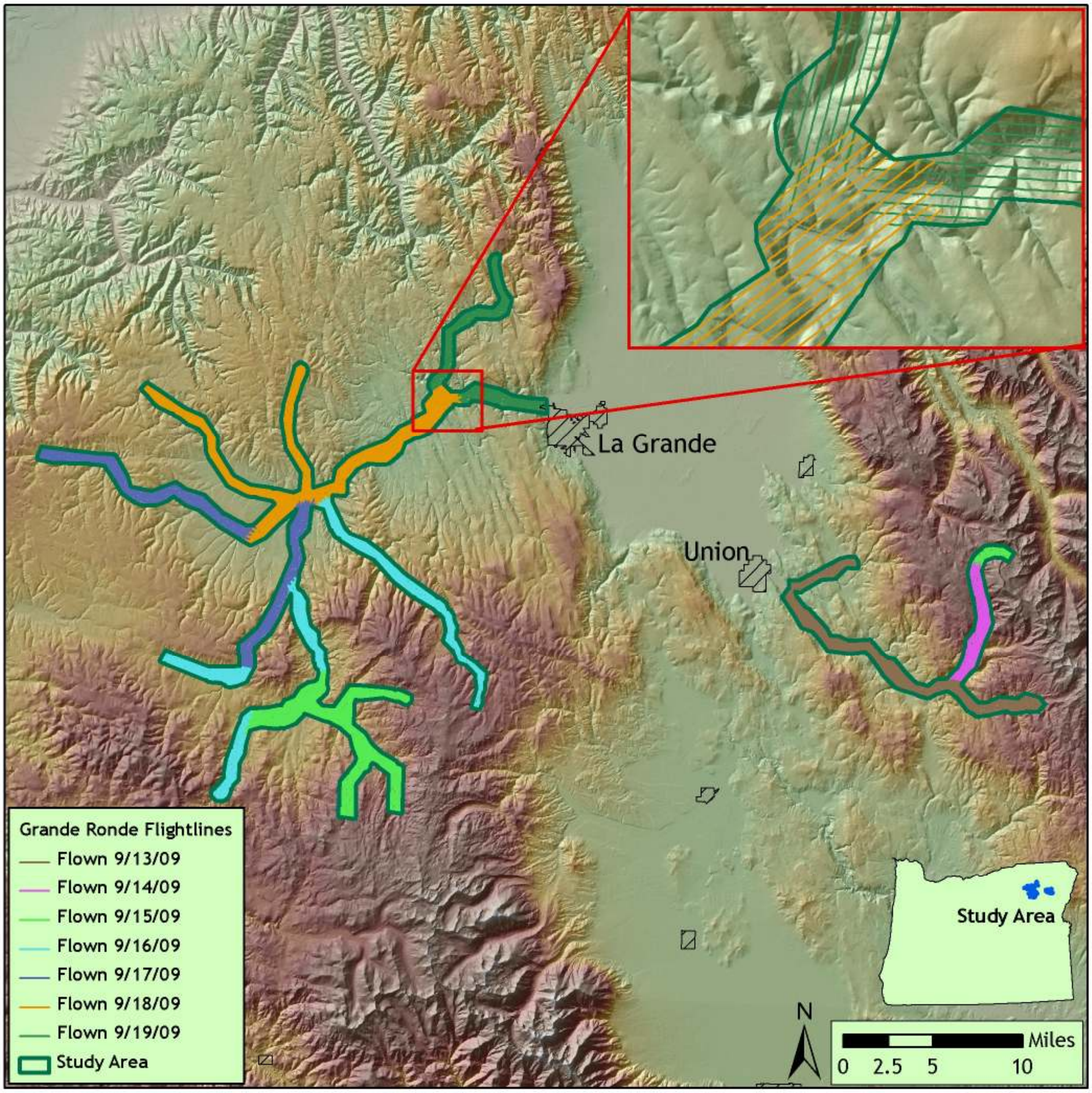
Sensor	Leica ALS50 Phase II
Survey Altitude (AGL)	900 m
Pulse Rate	>105 kHz
Pulse Mode	Single
Mirror Scan Rate	52.2 Hz
Field of View	28° (±14° from nadir)
Roll Compensated	Up to 20°
Overlap	100% (50% Side-lap)

[1] Nadir refers to a vector perpendicular to the ground directly below the aircraft. Nadir is commonly used to measure the angle from the vector and is referred to as "degrees from nadir".

2.2 LiDAR Acquisition

LiDAR data were collected of the Grande Ronde River basin study area between September 13 and 19, 2009. The flightlines are illustrated in the figures below.

Figure 2.1. *Flightlines over the Grande Ronde River basin study area, displayed over a 30-meter DEM.*

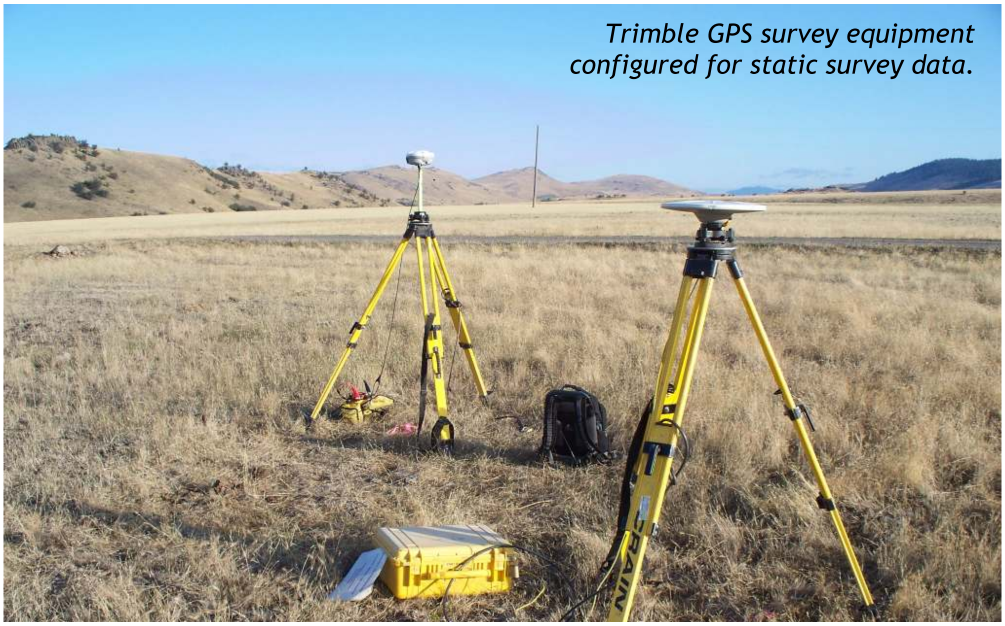


2.3 Ground Survey – Instrumentation and Methods

During the LiDAR survey, static (1 Hz recording frequency) ground surveys were conducted over monuments with known coordinates. Base station coordinates are provided in the table below. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and checked against the Online Positioning User Service (OPUS[2]) to quantify daily variance. Multiple sessions were processed over each monument to confirm antenna height measurements and reported position accuracy.

Table 2.2. *Base Station Surveyed Coordinates, (NAD83/NAVD88, OPUS corrected) used for kinematic post-processing of the aircraft GPS data for the Grande Ronde River basin study area.*

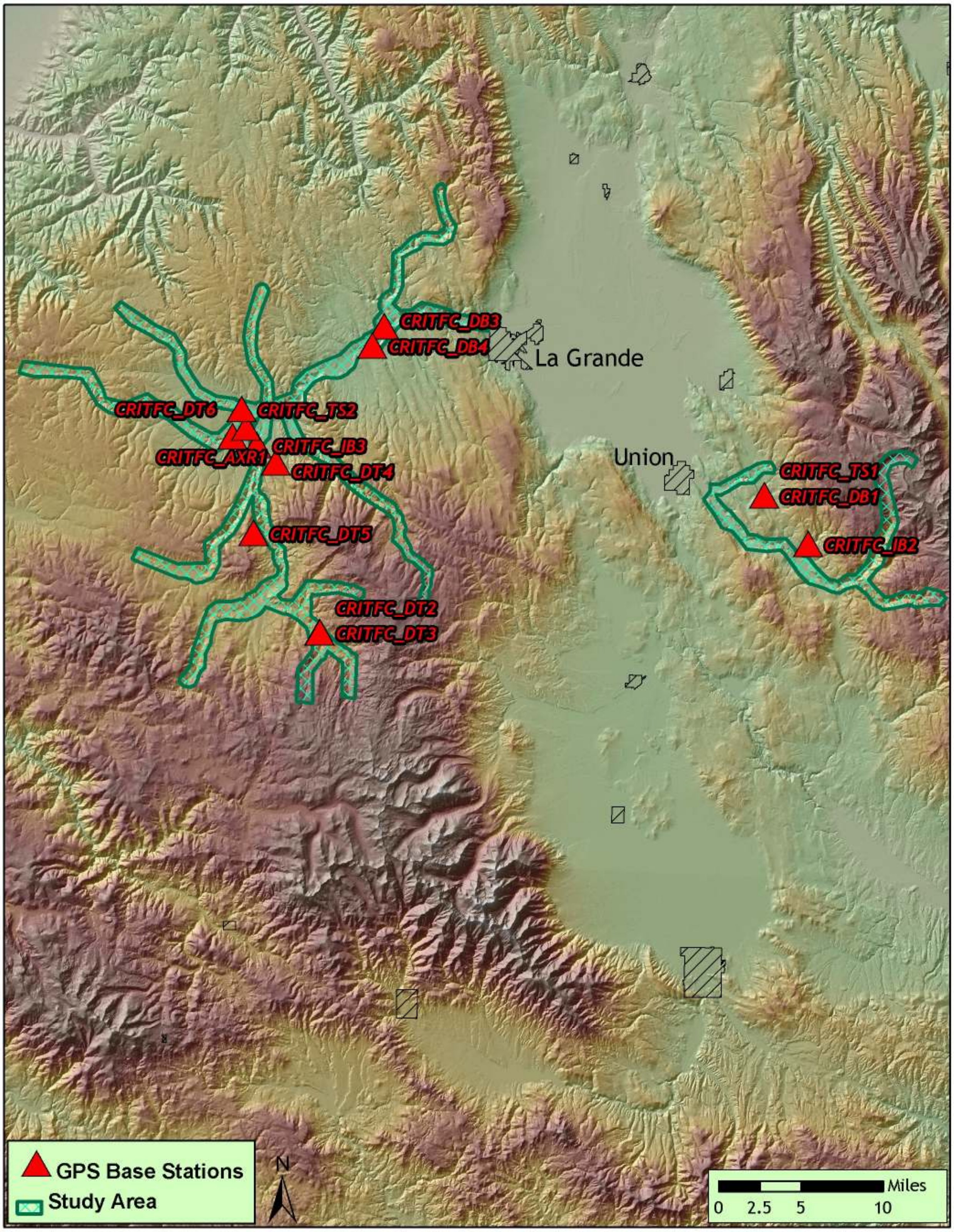
	Datum NAD83(HARN)		GRS80
Base Station ID	**Latitude (North)**	**Longitude (West)**	**Ellipsoid Height (m)**
CRITFC_AXR1	45 14 54.76587	118 24 30.32320	1046.43
CRITFC_DB1	45 11 43.08486	117 45 41.13318	1025.71
CRITFC_DB3	45 20 24.52125	118 14 17.47204	907.65
CRITFC_DB4	45 19 22.24197	118 15 9.86183	918.66
CRITFC_DT2	45 04 10.37269	118 18 47.04357	1363.24
CRITFC_DT3	45 04 10.16709	118 18 46.78870	1363.09
CRITFC_DT4	45 13 6.61659	118 22 14.89157	1212.08
CRITFC_DT5	45 9 21.79931	118 23 50.94230	1546.46
CRITFC_DT6	45 14 27.24778	118 25 31.57552	1080.65
CRITFC_IB2	45 09 10.64952	117 42 21.55503	1225.98
CRITFC_IB3	45 14 0.47358	118 23 43.01866	1030.42
CRITFC_TS1	45 11 43.15785	117 45 41.27188	1025.70
CRITFC_TS2	45 15 54.82767	118 24 53.21442	1013.26



Trimble GPS survey equipment configured for static survey data.

[2] Online Positioning User Service (OPUS) is run by the National Geodetic Survey to process corrected monument positions.

Figure 2.2. *GPS base station locations in the Grande Ronde River basin study area, displayed over 30-meter DEM.*



Multiple differential GPS units were used in the ground based real-time kinematic (RTK) portion of the survey. To collect accurate ground surveyed points, a GPS base unit was set up over monuments to broadcast a kinematic correction to a roving GPS unit. The ground crew used a roving unit to receive radio-relayed kinematic corrected positions from the base unit. This RTK survey allowed precise location measurement ($\sigma \leq 1.5$ cm). **2138 RTK ground points** were collected throughout the Grande Ronde River basin study area and compared to LiDAR data for accuracy assessment.

Figure 2.3. *Sample selection of RTK point locations in the eastern portion of the study area, displayed over NAIP orthoimages.*

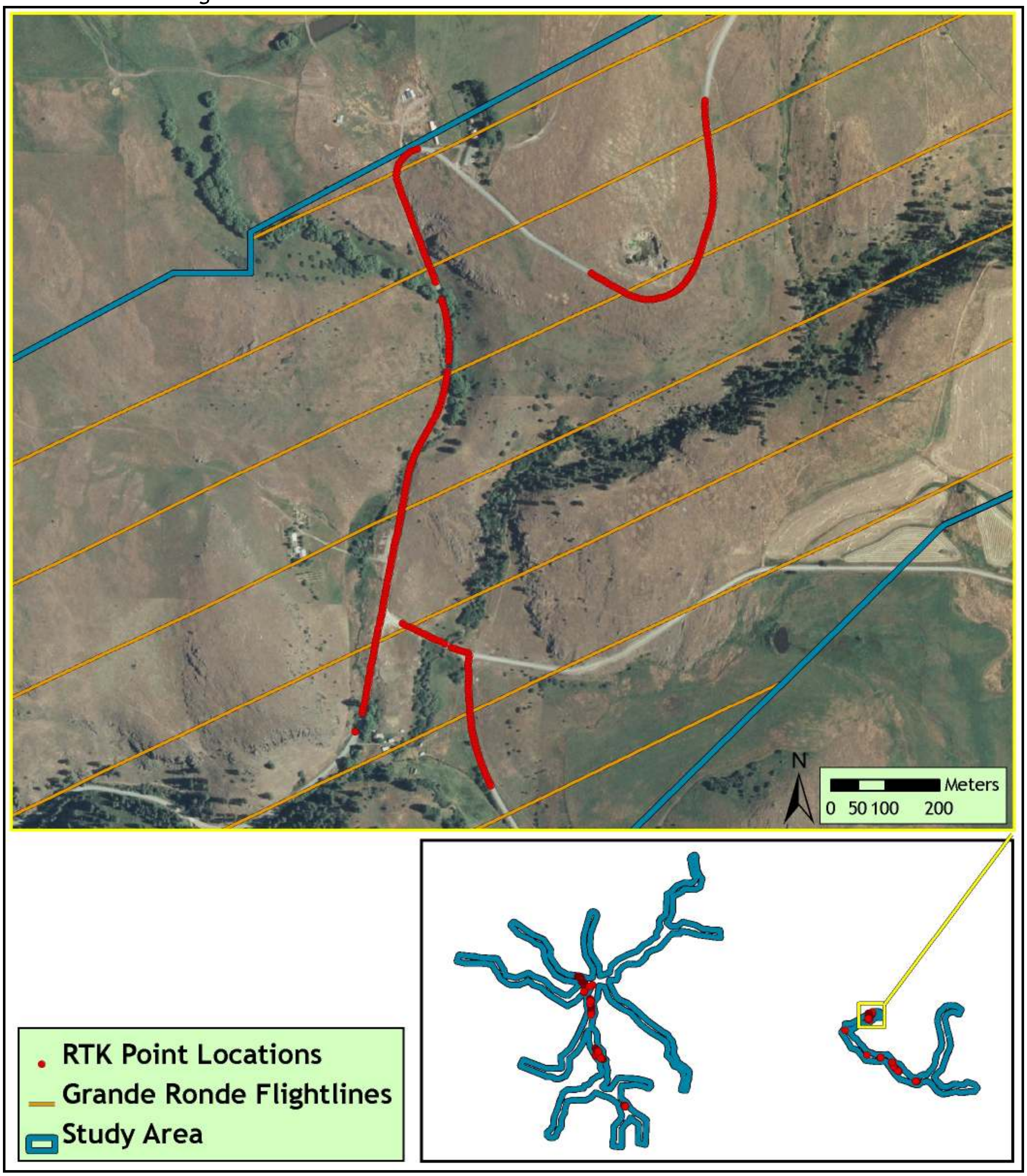
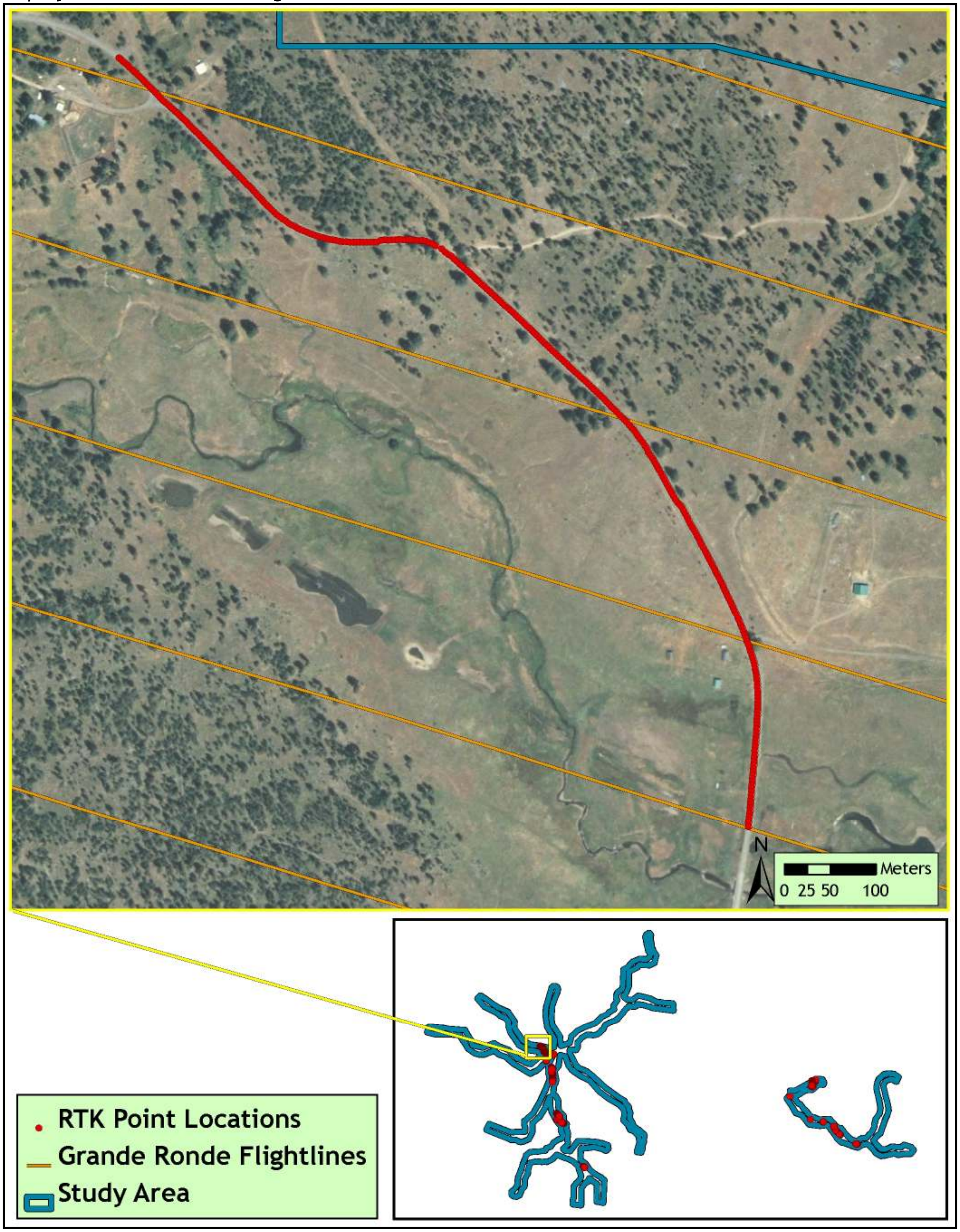


***Figure 2.4**. Sample selection of RTK point locations in the western portion of the study area, displayed over NAIP orthoimages.*



3. LiDAR Data Processing

3.1 Applications and Work Flow Overview

1. Resolved kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data.
   Software: Waypoint GraphNav v.8.10, Trimble Geomatics Office v.1.63
2. Developed a smoothed best estimate of trajectory (SBET) file blending post-processed aircraft position with attitude data. Sensor head position and attitude were calculated throughout the survey. The SBET data were used extensively for laser point processing.
   Software: IPAS Pro v.1.3
3. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in .las (ASPRS v1.2) format.
   Software: ALS Post Processing Software
4. Imported raw laser points into manageable blocks (less than 500 MB) to perform manual relative accuracy calibration and filtered for pits/birds. Ground points were then classified for individual flight lines (to be used for relative accuracy testing and calibration).
   Software: TerraScan v.9.001
5. Using ground classified points for each flight line, the relative accuracy was tested. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Calibrations were performed on ground classified points from paired flight lines. Every flight line was used for relative accuracy calibration.
   Software: TerraMatch v.9.001
6. Position and attitude data were imported. Resulting data were classified as ground and non-ground points. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Data were then converted to orthometric elevations (NAVD88) by applying a Geoid03 correction. Ground models were created as a triangulated surface and exported as ArcInfo ASCII grids.
   Software: TerraScan v.9.001, TerraModeler v.9.001

3.2 Aircraft Kinematic GPS and IMU Data

LiDAR survey datasets were referenced to 1 Hz static ground GPS data collected over a pre-surveyed monument with known coordinates. While surveying, the aircraft collected 2 Hz kinematic GPS data and the inertial measurement unit (IMU) collected 200 Hz attitude data. Waypoint GraphNav v.8.10 was used to process the kinematic corrections for the aircraft. The static and kinematic GPS data were then post-processed after the survey to obtain an accurate GPS solution and aircraft positions. IPAS Pro v.1.3 was used to develop a trajectory file including corrected aircraft position and attitude information. The trajectory data for the entire flight survey session were incorporated into a final smoothed best estimated trajectory (SBET) file containing accurate and continuous aircraft positions and attitudes.

3.3 Laser Point Processing

Laser point coordinates were computed using the IPAS and ALS Post Processor software suites based on independent data from the LiDAR system (pulse time, scan angle), and aircraft trajectory data (SBET). Laser point returns (first through fourth) were assigned an associated (x, y, and z) coordinate along with unique intensity values (0-255). The data were output into large LAS v. 1.2 files; each point maintaining the corresponding scan angle, return number (echo), intensity, and x, y, and z (easting, northing, and elevation) information.

Flightlines and LiDAR data were then reviewed to ensure complete coverage of the study area and positional accuracy of the laser points.

Once the laser point data were imported into TerraScan, a manual calibration was performed to assess the system offsets for pitch, roll, heading and mirror scale. Using a geometric relationship developed by Watershed Sciences, each of these offsets was resolved and corrected if necessary.

The LiDAR points were then filtered for noise, pits and birds by screening for absolute elevation limits, isolated points and height above ground. The data were then inspected for pits and birds manually, and spurious points were removed. For a .las file containing approximately 7.5-9.0 million points, an average of 50-100 points were typically found to be artificially low or high. These spurious non-terrestrial laser points must be removed from the dataset. Common sources of non-terrestrial returns are clouds, birds, vapor, and haze.

Internal calibration was refined using TerraMatch. Points from overlapping lines were tested for internal consistency and final adjustments made for system misalignments (i.e., pitch, roll, heading offsets and mirror scale). Automated sensor attitude and scale corrections yielded 3-5 cm improvements in the relative accuracy. Once the system misalignments were corrected, vertical GPS drift was resolved and removed per flight line, yielding a slight improvement (<1 cm) in relative accuracy. In summary, the data must complete a robust calibration designed to reduce inconsistencies from multiple sources (i.e., sensor attitude offsets, mirror scale, GPS drift).

The TerraScan software suite is designed specifically for classifying near-ground points (Soininen, 2004). The processing sequence begins by 'removing' all points that are not 'near' the earth based on geometric constraints used to evaluate multi-return points. The resulting bare earth (ground) model is visually inspected and additional ground point modeling is performed in site-specific areas (over a 50-meter radius) to improve ground detail. This is only done in areas with known ground modeling deficiencies, such as: bedrock outcrops, cliffs, deeply incised stream banks, and dense vegetation. In some cases, ground point classification includes known vegetation (i.e., understory, low/dense shrubs, etc.) and these points are manually reclassified as non-grounds. Ground surface rasters are developed from triangulated irregular networks (TINs) of ground points.

4. LiDAR Accuracy and Resolution

4.1 Laser Point Accuracy

Laser point absolute accuracy is largely a function of internal consistency (measured as relative accuracy) and laser noise:

- **Laser Noise**: For any given target, laser noise is the breadth of the data cloud per laser return (i.e., last, first, etc.). Lower intensity surfaces (roads, rooftops, still/calm water) experience higher laser noise. The laser noise range for this mission is approximately 0.02 meters.

- **Relative Accuracy**: Internal consistency refers to the ability to place a laser point in the same location over multiple flight lines, GPS conditions, and aircraft attitudes.

- **Absolute Accuracy**: RTK GPS measurements taken in the study areas compared to LiDAR point data.

Statements of statistical accuracy apply to fixed terrestrial surfaces only, not to free-flowing or standing water surfaces, moving automobiles, et cetera.

Table 4.1. *LiDAR accuracy is a combination of several sources of error. These sources of error are cumulative. Some error sources that are biased and act in a patterned displacement can be resolved in post processing.*

Type of Error	Source	Post Processing Solution
GPS (Static/Kinematic)	Long Base Lines	None
	Poor Satellite Constellation	None
	Poor Antenna Visibility	Reduce Visibility Mask
Relative Accuracy	Poor System Calibration	Recalibrate IMU and sensor offsets/settings
	Inaccurate System	None
Laser Noise	Poor Laser Timing	None
	Poor Laser Reception	None
	Poor Laser Power	None
	Irregular Laser Shape	None

4.1.1 Relative Accuracy

Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the LiDAR system is well calibrated, the line to line divergence is low (<10 cm). Internal consistency is affected by system attitude offsets (pitch, roll and heading), mirror flex (scale), and GPS/IMU drift.

Operational measures taken to improve relative accuracy:

1. Low Flight Altitude: Terrain following was targeted at a flight altitude of 900 meters above ground level (AGL). Laser horizontal errors are a function of flight altitude above ground; lower flight altitudes decrease laser noise on all surfaces.
2. Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes maintained.
3. Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of $\pm 14^{o}$ from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.
4. Quality GPS: The flight took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). During all flight times, a dual frequency DGPS base station recording at 1–second epochs was utilized and a maximum baseline length between the aircraft and the control point was less than 24 km (13 nautical miles).
5. Ground Survey: Ground survey point accuracy (i.e., <1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. The absolute accuracy of this dataset is based on 2,138 RTK points that are distributed throughout multiple flight lines in the study area.
6. 50% Side-Lap (100% Overlap): Overlapping areas were optimized for relative accuracy testing. Laser shadowing was minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the most nadir portion of one flight line coincides with the edge (least nadir) portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.
7. Opposing Flight Lines: All overlapping flight lines are opposing. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

Relative Accuracy Calibration Methodology

1. Manual System Calibration: Calibration procedures for each mission require solving geometric relationships relating measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration and reported for the study area.
2. Automated Attitude Calibration: All data were tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. The resulting overlapping ground points (per line) in this study area total over 2 billion points from which to compute and refine relative accuracy. System misalignment offsets (pitch, roll and heading) and mirror scale were solved for each individual mission. Attitude misalignment offsets (and mirror scale) occurs for each individual mission. The data from each mission were then blended when imported together to form the entire area of interest.
3. Automated Z Calibration: Ground points per line were utilized to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

Relative Accuracy Calibration Results

Relative accuracy statistics for the Grande Ronde River basin study area are based on the comparison of 359 flightlines and over 2 billion points. For flightline coverage of the study area, see **Figure 2.1** in Section 2.2.

- Project Average = 0.05 m
- Median Relative Accuracy = 0.05 m
- 1σ Relative Accuracy = 0.06 m
- 2σ Relative Accuracy = 0.07 m

***Figure 4.1**. Distribution of relative accuracies, non slope-adjusted.*

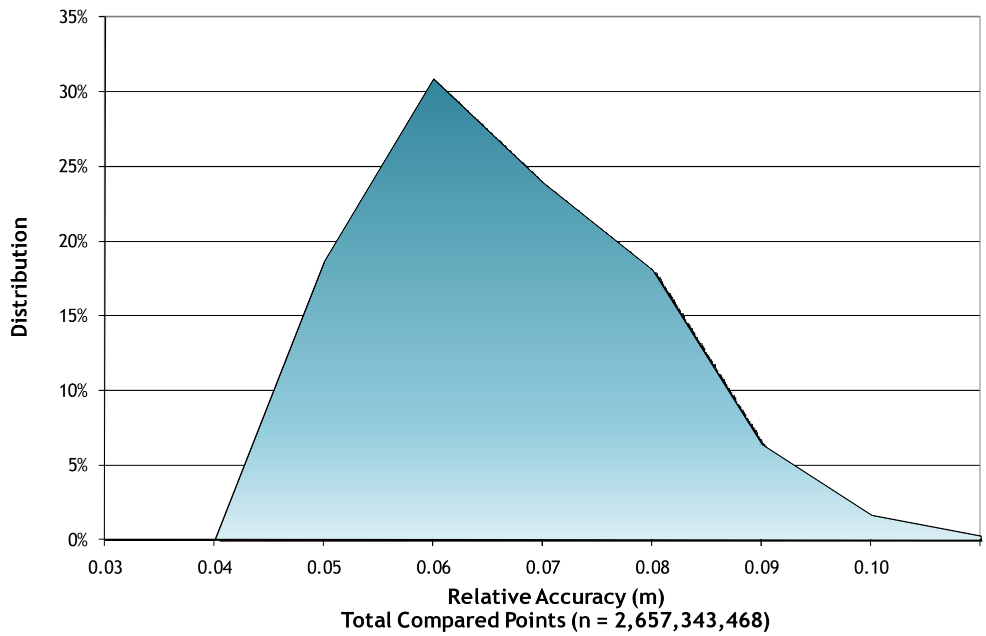
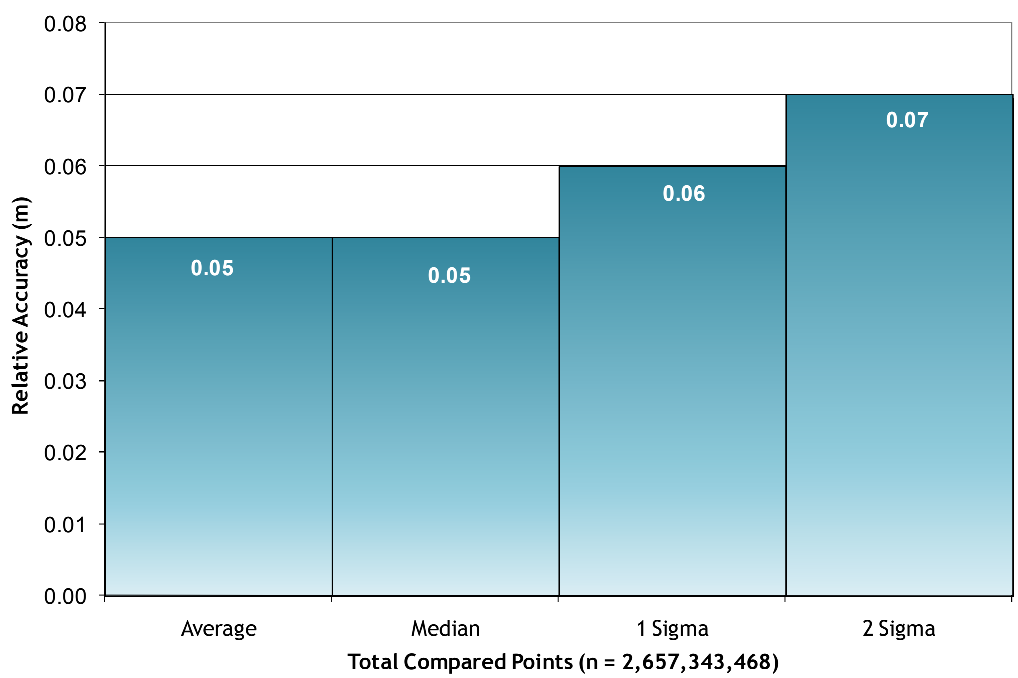


***Figure 4.2**. Statistical relative accuracies, non slope-adjusted.*



4.1.2 Absolute Accuracy

The final quality control measure is a statistical accuracy assessment that compares known RTK ground survey points to the closest laser point. For the Grande Ronde River basin study area, 2,138 RTK points were collected. Accuracy statistics are reported in **Table 4.2** and shown in Figures **4.3-4.4.**

Table 4.2. *Absolute Accuracy – Deviation between laser points and RTK survey points.*

Sample Size (n): 2,138	
Root Mean Square Error (RMSE): 0.05 m	
Standard Deviations	**Deviations**
1 sigma (σ): 0.05 m	**Minimum Δz:** -0.21 m
2 sigma (σ): 0.09 m	**Maximum Δz:** 0.12 m
	Average Δz: 0.04 m

Figure 4.3. *Histogram Statistics*

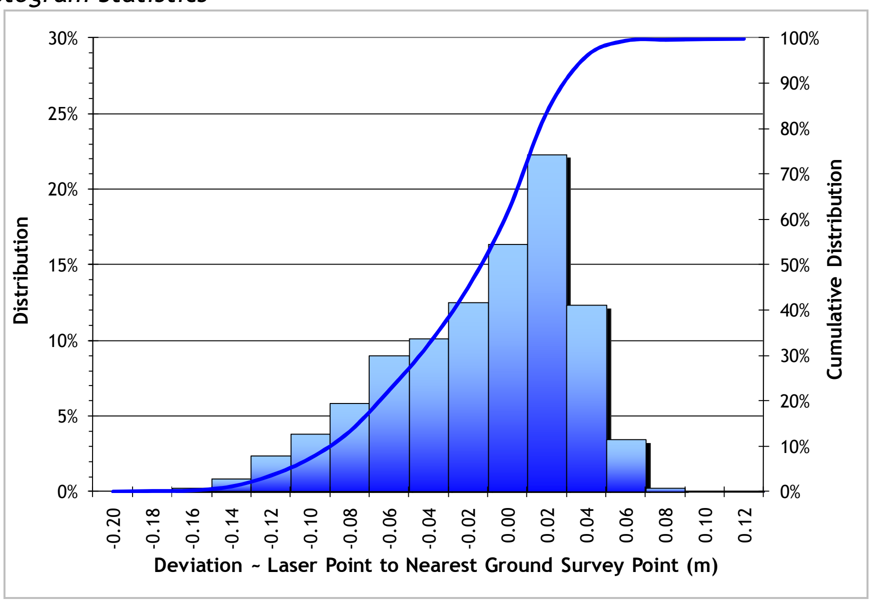
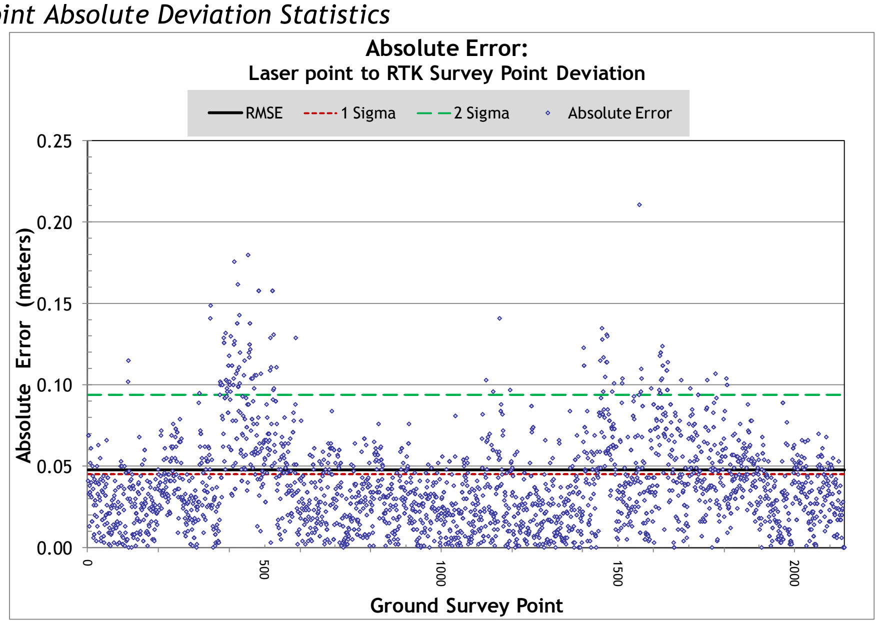


Figure 4.4. *Point Absolute Deviation Statistics*



4.2 Data Density/Resolution

Some types of surfaces (i.e., dense vegetation or water) may return fewer pulses than originally emitted by the laser. Delivered density may therefore be less than the native density and vary according to distributions of terrain, land cover, and water bodies. Density histograms and maps (**Figures 4.5-4.10**) have been calculated based on first return laser point density and ground-classified laser point density.

Table 4.3. *Average Densities for the Grande Ronde River basin study area.*

Average Pulse Density (per square m)	Average Ground Density (per square m)
8.15	2.42

4.2.1 First Return Data Density

Figure 4.5. *Histogram of first return laser point density for the entire Grande Ronde River basin study area.*

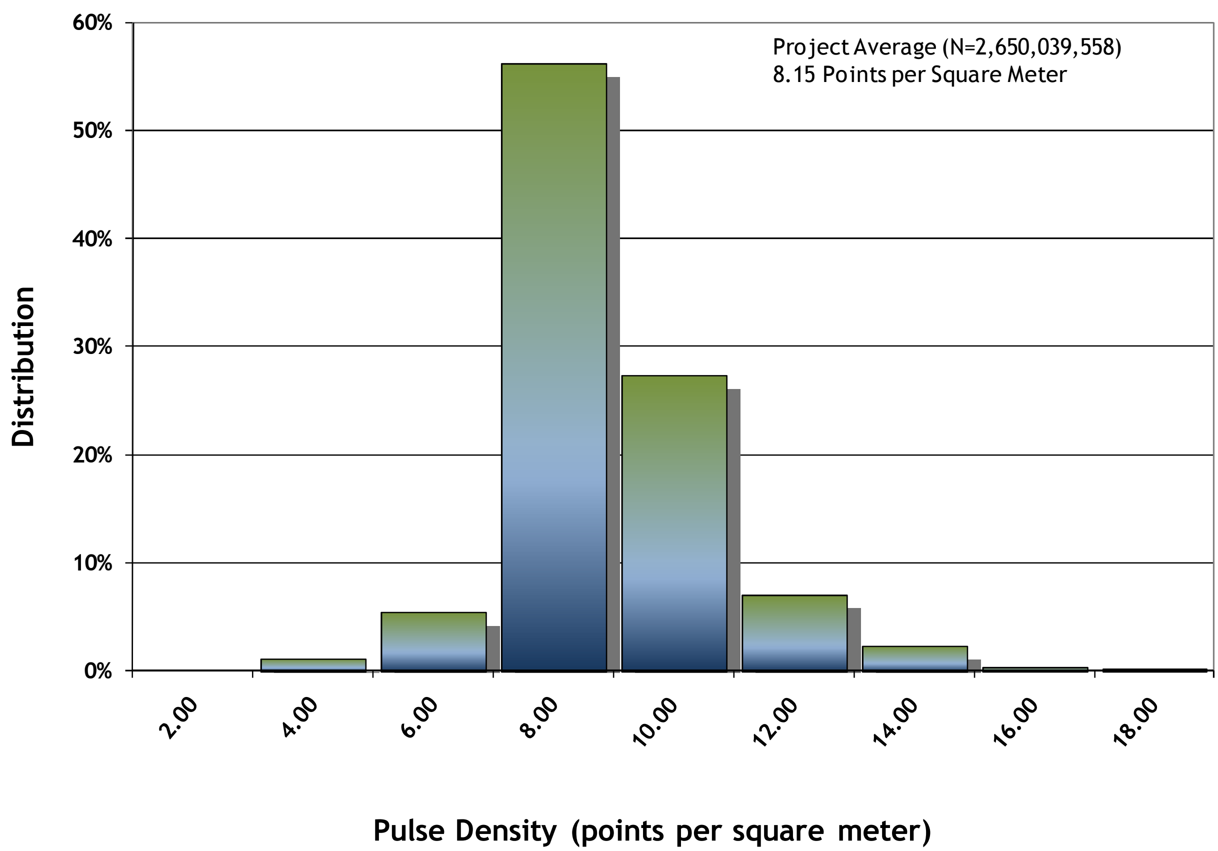


***Figure 4.6**. First return laser point data density in the western portion of the Grande Ronde River basin study area, per 0.75' USGS Quad.*

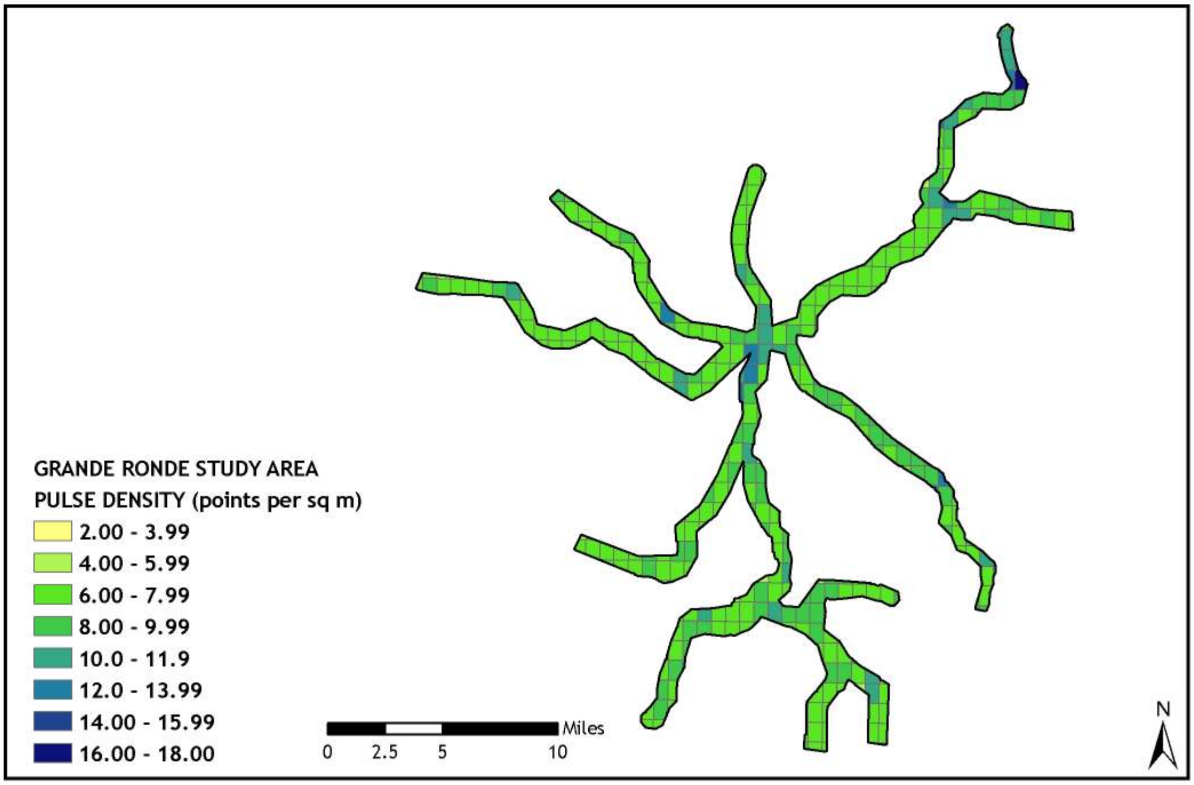
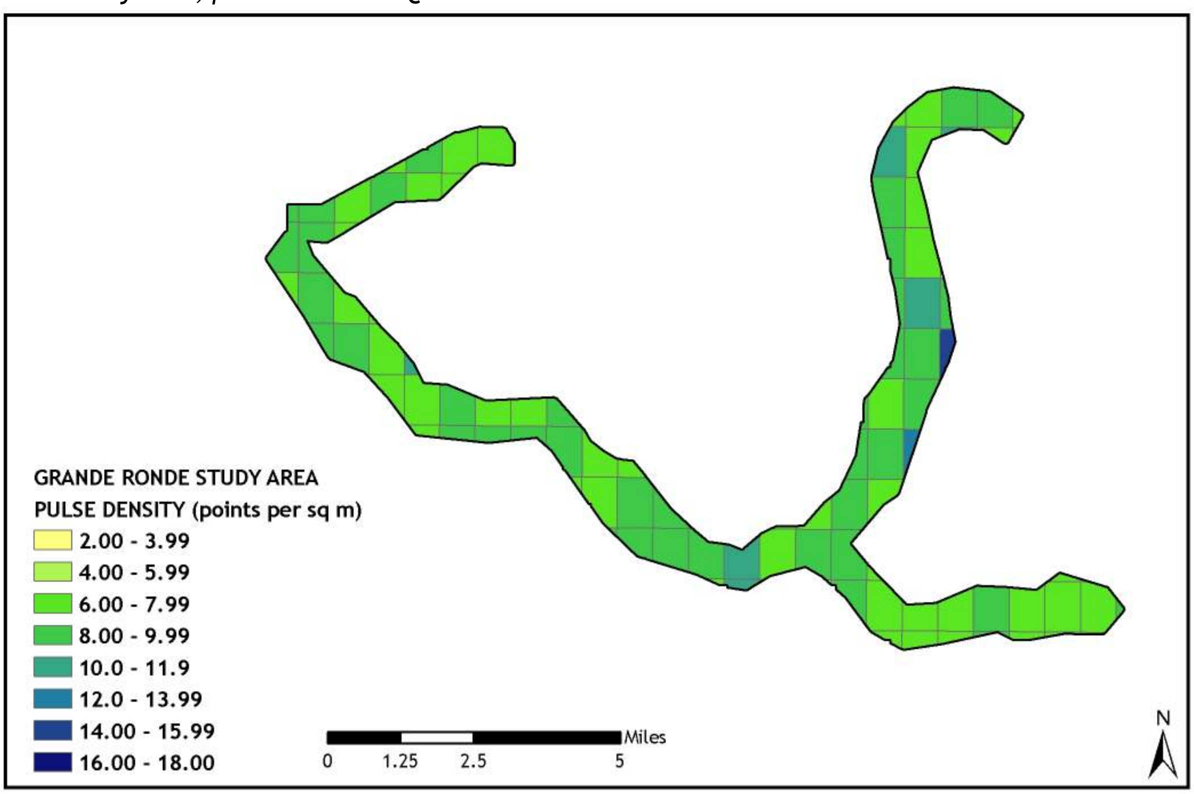


***Figure 4.7**. First return laser point data density in the eastern portion of the Grande Ronde River basin study area, per 0.75' USGS Quad.*



4.2.2 Ground-Classified Data Density

Figure 4.8. *Histogram of ground-classified laser point density for the entire Grande Ronde River basin study area.*

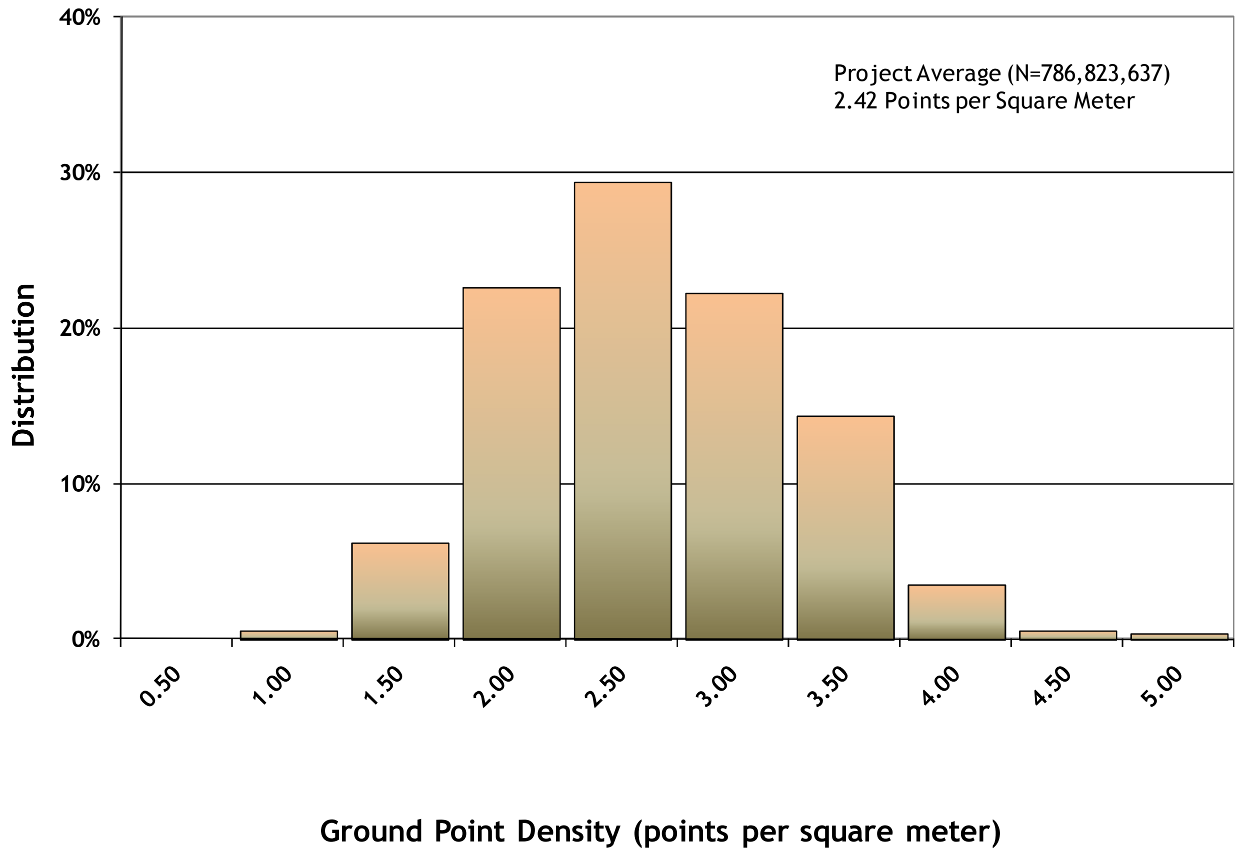


Figure 4.9. Ground-classified laser point data density in the western portion of the Grande Ronde River basin study area, per 0.75' USGS Quad.

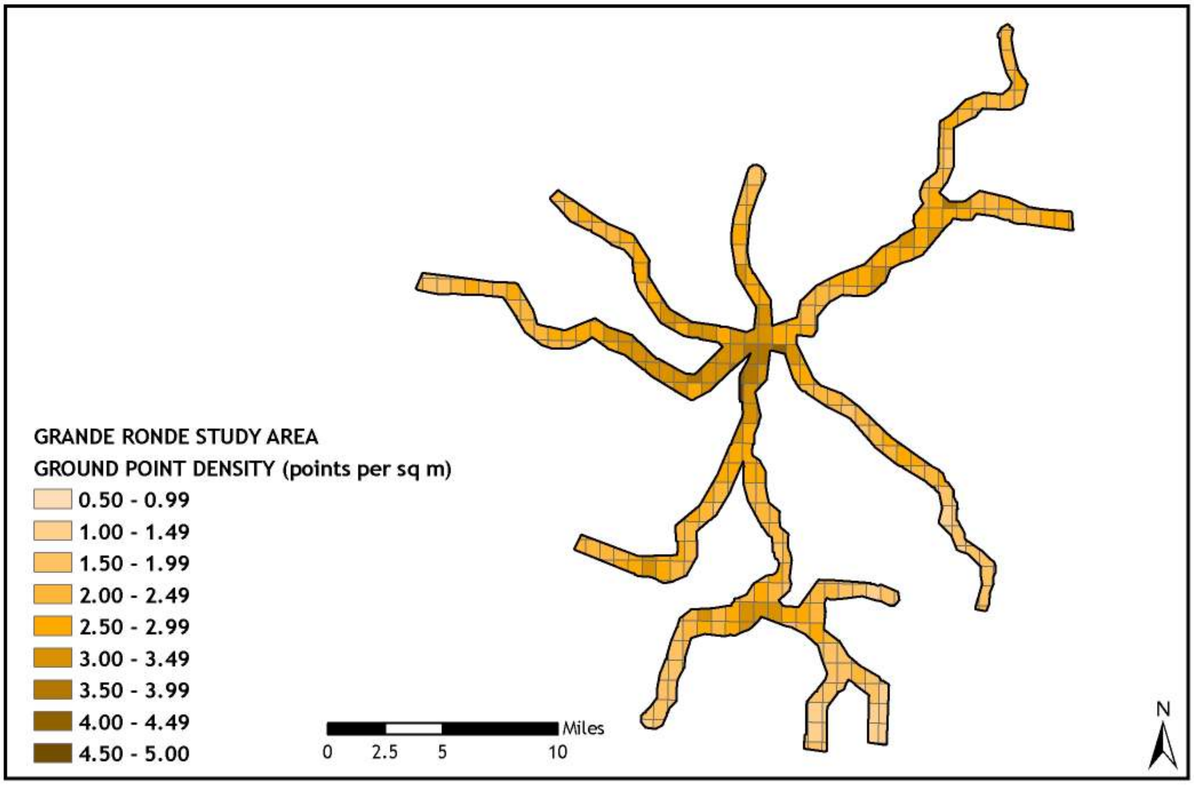
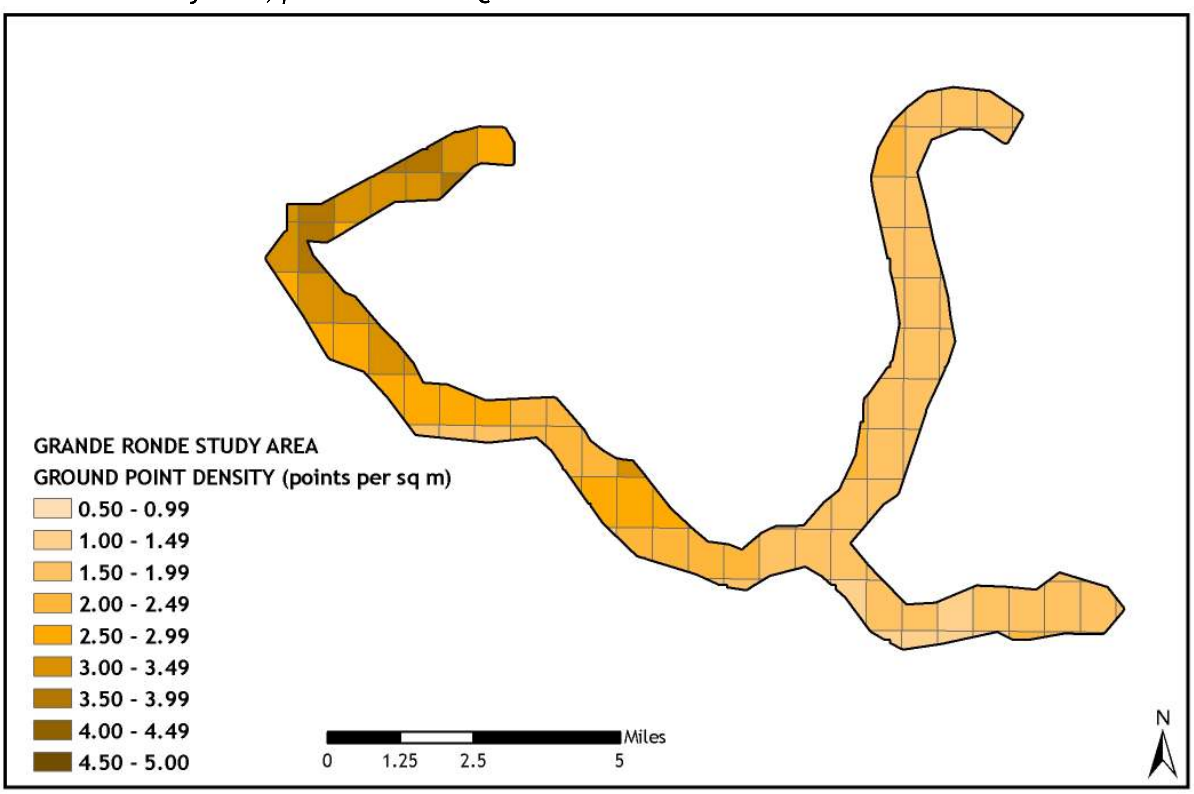


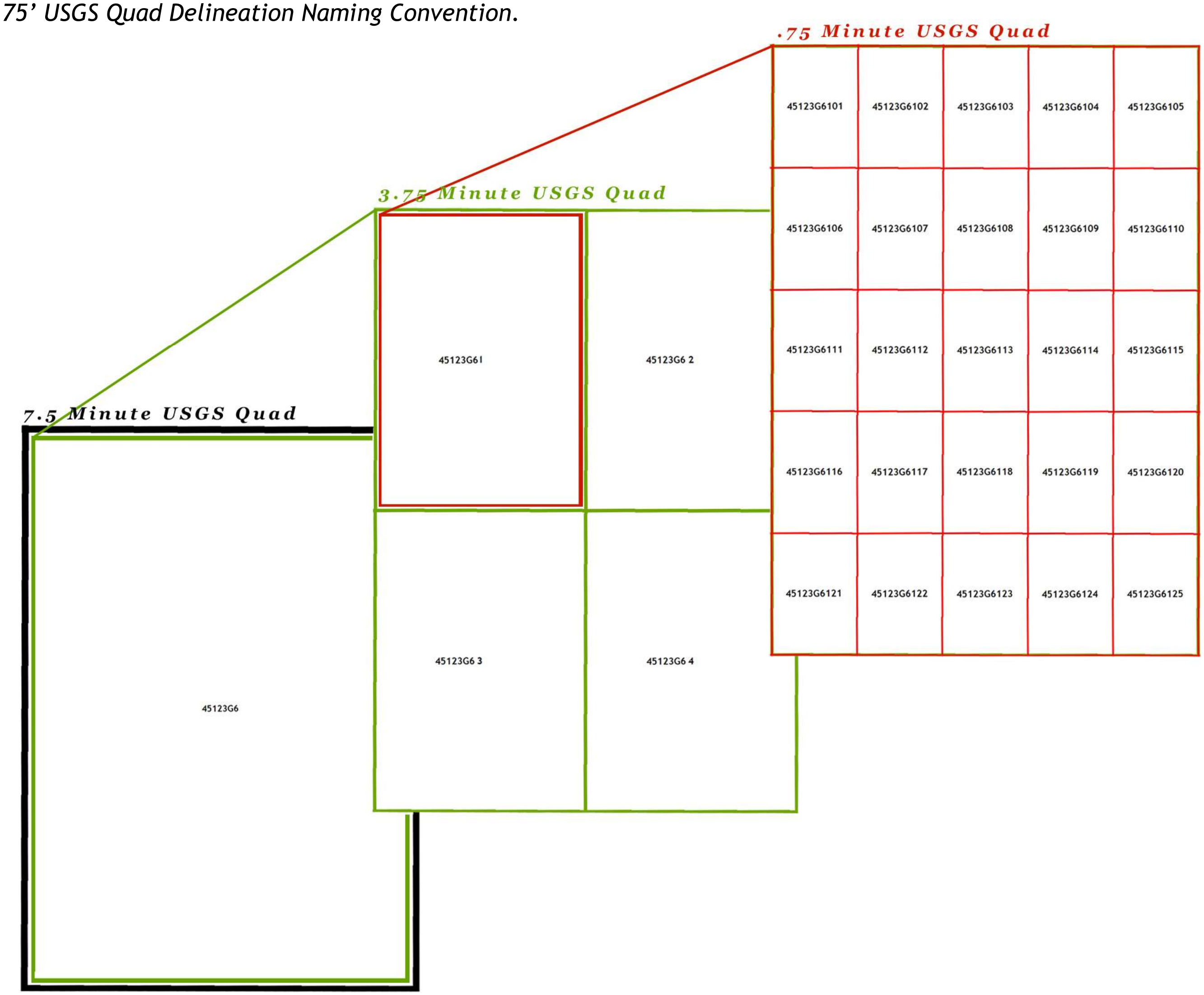
Figure 4.10. Ground-classified laser point data density in the western portion of the Grande Ronde River basin study area, per 0.75' USGS Quad.



5. Deliverables

Data delivered in the Grande Ronde River basin study area conform to the following tiling scheme:

Figure 5.1. *0.75' USGS Quad Delineation Naming Convention.*



5.1 Point Data

All Return Point data in las v 1.2 format (delivered in 0.75' USGS quad delineation) with the following attributes:

- GPS week (integer) and second
- Easting, Northing, Elevation
- Intensity
- Return Number
- Return Classification
- Offnadir Angle

Aircraft trajectory flightline data in ASCII point format, with the following attributes:

- Aircraft position (Easting, Northing, Elevation)
- Aircraft attitude (Heading, Pitch, Roll)
- GPS Time (sampled at ≤1 second intervals)

5.2 Vector Data

- Aircraft Trajectory Flightlines in shapefile format (one per flight day)
- RTK Ground Control Point File in shapefile format
- Total Area Flown
    - 7.5' USGS quad delineation in shapefile format
    - 3.75' USGS quad delineation in shapefile format
    - 0.75' USGS quad delineation in shapefile format

5.3 Raster Data

- ESRI GRID of Bare Earth Modeled LiDAR data Points (1-meter resolution) delivered in 3.75' USGS quad delineation
- ESRI GRID of Above Ground Modeled LiDAR data Points (1-meter resolution) delivered in 3.75' USGS quad delineation
- Intensity Images in GeoTIFF format (.5-meter resolution) delivered per 0.75' USGS quad delineation

5.4 Data Report

- Full Report containing introduction, methodology, accuracy, and sample imagery.
    - Word Format (*.doc)
    - PDF Format (*.pdf)

5.5 Datum and Projection

The data were processed as ellipsoidal elevations and required a Geoid transformation to be converted into orthometric elevations (NAVD88). In TerraScan, the NGS published Geiod03 model is applied to each point. The data were processed using meters in the Universal Transverse Mercator (UTM) Zone 11 and NAD83 (CORS96)/NAVD88 datum.

6. Selected Images

Figure 6.1. *Image set depicting the Grande Ronde River, southwest of Hilgard State Park.*

Figure 6.2. *Image set a 3-D oblique view of an area southeast of Whitman National Forest. Top image is created from highest hit LiDAR points and bottom image is derived from ground classified LiDAR points.*

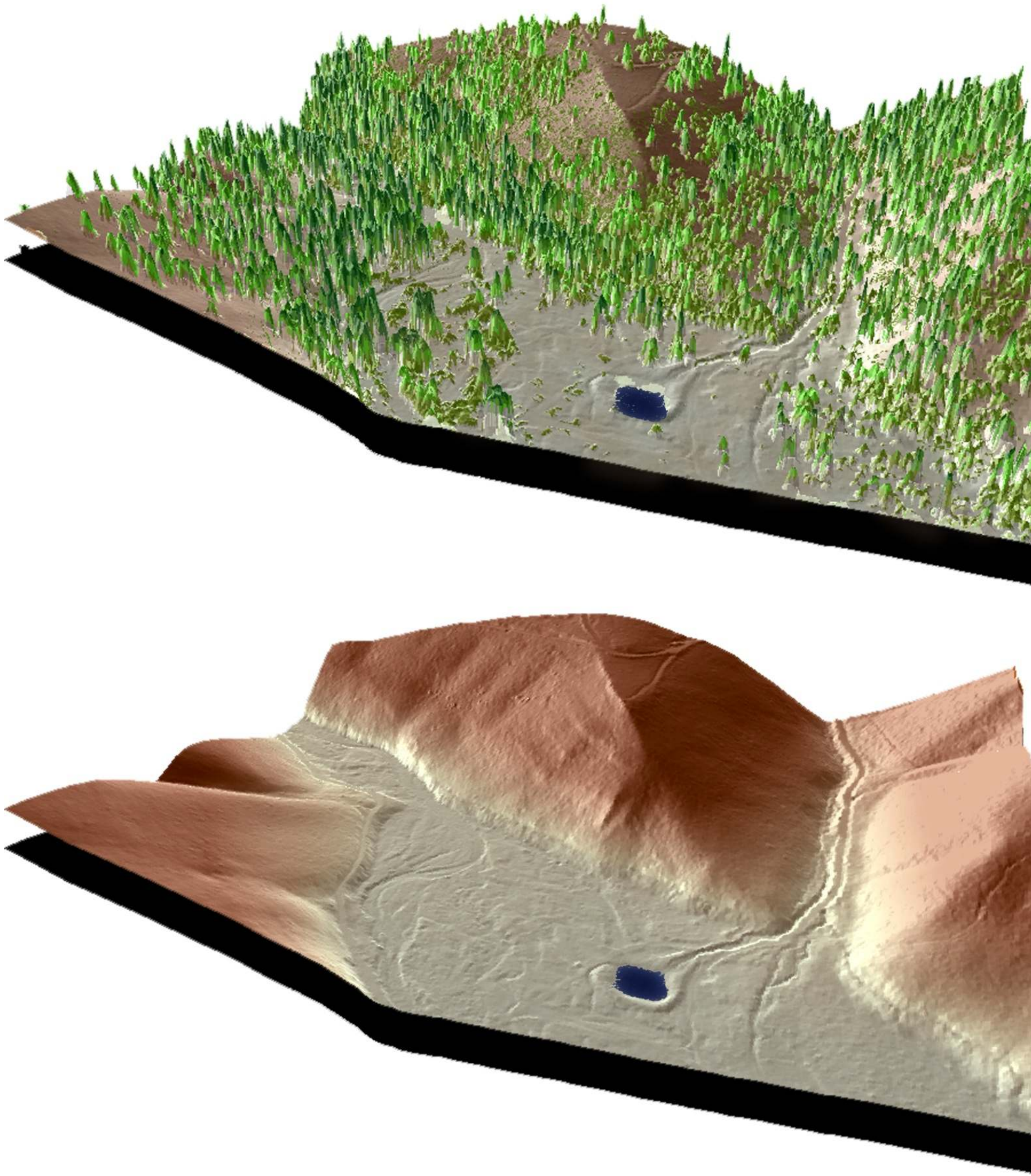


Figure 6.3*. Image set a 3-D oblique view the Grande Ronde River and highway 224 west of Spring Creek Road. Top image is created from highest hit LiDAR points and bottom image is derived from ground classified LiDAR points.*

7. Glossary

<u>1-sigma (σ) Absolute Deviation</u>: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

<u>2-sigma (σ) Absolute Deviation</u>: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set.

<u>Root Mean Square Error (RMSE)</u>: A statistic used to approximate the difference between real-world points and the LiDAR points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

<u>Pulse Rate (PR)</u>: The rate at which laser pulses are emitted from the sensor; typically measured as thousands of pulses per second (kHz).

<u>Pulse Returns</u>: For every laser pulse emitted, the Leica ALS 50 Phase II system can record *up to four* wave forms reflected back to the sensor. Portions of the wave form that return earliest are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

<u>Accuracy</u>: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma, σ) and root mean square error (RMSE).

<u>Intensity Values</u>: The peak power ratio of the laser return to the emitted laser. It is a function of surface reflectivity.

<u>Data Density</u>: A common measure of LiDAR resolution, measured as points per square meter.

<u>Spot Spacing</u>: Also a measure of LiDAR resolution, measured as the average distance between laser points.

<u>Nadir</u>: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

<u>Scan Angle</u>: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

<u>Overlap</u>: The area shared between flight lines, typically measured in percents; 100% overlap is essential to ensure complete coverage and reduce laser shadows.

<u>DTM / DEM</u>: These often-interchanged terms refer to models made from laser points. The digital elevation model (DEM) refers to all surfaces, including bare ground and vegetation, while the digital terrain model (DTM) refers only to those points classified as ground.

<u>Real-Time Kinematic (RTK) Survey</u>: GPS surveying is conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

8. Citations

Soininen, A. 2004. TerraScan User's Guide. TerraSolid.

Appendix F

Calculations of Streamflows made at Selected Stations in the Upper Grande Ronde and Catherine Creek

			m^3/sec
Stream Name	**Grande Ronde**		
Site Name	mine tailings area	9/2/2009	0.205158
Stream Name	Grande Ronde	9/1/2009	0.344573
Site Name	downstream of Vey Meadows		
Stream Name	Grande Ronde	9/1/2009	0.701618
Site Name	upstream Fly Cr.		
Stream Name	Grande Ronde	9/1/2009	0.601817
Site Name	upstream Meadow Cr.		
Stream Name	Grande Ronde	9/2/2009	0.586296
Site Name	upstream of Jordan Cr.; approx 100 m downstream of temperature logger; logger waypoint is #30		
Stream Name	Grande Ronde	8/31/2009	0.47205
Site Name	above Five Point Cr.		

		m3/sec
Stream Name	**Grande Ronde**	
Site Name	mine tailings area	0.20515

Stream Name	Clear Cr.	0.0425	9/2/2009
Site Name	above mouth at USFS gage		

Stream Name	Limber Jim	0.1788	9/2/2009
Site Name	above Vey fence		

Stream Name	Chicken Cr.	0.0397	9/2/2009
Site Name	upstream of mouth		

Stream Name	Sheep Cr.	0.0370	9/2/2009
Site Name	at 5182/5160 intersection		

0.5032 total of all UGR major tribs

Stream Name	Five Point	0.0202	9/1/2009
Site Name	mouth		

Stream Name	Pelican Cr.	0.0000
Site Name	mouth	

		m3/sec		
Stream Name Site Name	NF Catherine Cr. 3 m above edge of concrete drive crossing-natural channel	0.251353		9/3/2009
Stream Name Site Name	MF Catherine Cr. 7 m upstream of temperature logger at mouth	0.216803		9/3/2009
Stream Name Site Name	SF Catherine Cr. at temperature logger location	0.277096		9/3/2009
	cumulative streamflow in Catherine Creek		0.745253	
	This misses the small streamflow contribution entering between the confluence of MF and NF Catherine and the SF Catherine			
Stream Name Site Name	Catherine Cr. below bridge at E end of Union	0.684492		9/4/2009
Stream Name Site Name	Little Cr. middle site, approx. 70m upstream of temp. logger	0.046167		9/4/2009
Stream Name Site Name	Little Cr. at corner of Hwy 203 and 237	0.03342		9/4/2009

Appendix G

Water Temperature Data Collection Summary

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
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Summary of Stream Temperature in the Upper Grande Ronde River and Catherine Creek During Summer 2009

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

February 2010

Casey Justice

Dale McCullough

Seth White


Methods

We summarized stream temperature data collected from 37 sites throughout the Upper Grande Ronde River and Catherine Creek basins during the summer of 2009 (Jul 24 – Oct 8) (Table 1). Stream temperature measurements were mostly limited to areas within the range of historical spawning or rearing habitat for spring Chinook salmon as defined by the NOAA Technical Recovery Team (TRT) (Pers. Comm. Damon Holzer, NOAA). Exact logger locations within the drainage network were based on data requirements for calibration of a basin-wide heat source temperature model similar to that described in Boyd and Kasper (2003). Continuous stream temperature data will provide a ground truth for temperature measurements made with forward looking infrared (FLIR) technology, as well as information about temporal patterns in stream temperature that cannot be adequately assessed using FLIR.

Loggers were placed near the mouth of all tributary streams contributing at least 5% of the total mainstem discharge and in the mainstem just upstream of tributary confluences. Additional loggers were deployed at mainstem sites to capture longitudinal variation in mainstem temperatures. We did not deploy loggers at some sites because access was denied by private landowners, or because those sites were already being monitored by other agencies.

Temperature data was recorded hourly using Onset Hobo U22 Pro v2 temperature loggers (accuracy = 0.2 °C). Prior to deployment, we checked the accuracy each logger using methods described in Ice et al. (1999). We compared the temperature measurements from each logger with measurements made with a National Institute of Standards and Technology (NIST) certified thermometer to ensure an accuracy of at least 0.3 °C. Temperature loggers were secured to the streambed using ¼ inch rebar stakes and stainless steel cable. Most loggers were placed in steel housings to protect against physical damage and direct solar radiation (Figure 2). Accuracy checks were repeated after field deployment to determine if logger accuracy was maintained throughout the entire sampling period. A subset of the loggers was redeployed to collect winter and spring temperatures.

After downloading data from all of the temperature loggers, we checked the data for quality assurance using methods described in Dunham et al. (2005). Specifically, we flagged all observations that fell below -1 °C or above 30 °C, or if the rate of change was greater than 3°C between successive hourly or daily measurements. All flagged observations were then verified with personnel involved in data logger programming and field sampling, and obvious erroneous observations were removed from the database. Additionally, we examined plots of daily temperature observations to check for evidence of dewatering during the sampling period.

We calculated various temperature metrics to characterize thermal conditions at each sampling location. These metrics included average daily temperature for the summer period (Avg), the highest instantaneous temperature recorded during summer (Max), the lowest instantaneous temperature recorded during summer (Min), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the cumulative number of days that the daily maximum temperature exceeded the thresholds 14, 18, and 22°C. MWAT is the calculated as the maximum 7-day moving average of the daily average temperatures, while MWMT represents the maximum 7-day moving average of the daily maximum temperatures. MWMT was adopted as the statistical measure of the stream temperature standard used by Oregon Department of Environmental Quality (ODEQ) in their total maximum daily load (TMDL) evaluations (ODEQ 2000). Prior to calculating temperature metrics, we limited the data to include the summer period only (25 Jul – 15 Sep) to ensure that temperature conditions were comparable across sites. We examined the correlation between these different temperature metrics using simple linear correlation. Correlations between different metrics should highlight potential statistical redundancies among the various metrics, and likewise, identify those metrics that provide unique information about thermal conditions in the Grande Ronde Basin.

Unfortunately, we did not deploy temperature loggers until July 24 at the earliest, so there was some risk that the warmest period of the summer was not captured. To evaluate this possibility, we examined air temperature data from a weather station near Beaver Creek Reservoir (site id: 18D09S) in Upper Grande Ronde drainage basin and calculated the date range corresponding to the maximum weekly maximum temperature (MWMT). We assumed that if the time period during which air temperatures reached their

maximum was encompassed by our sampling period (i.e., 24 Jul – 8 Oct), then the period of warmest stream temperatures was likely captured during our study. Air temperature data was obtained from the Oregon Natural Resource Conservation Service web site (http://www.or.nrcs.usda.gov).

Results

Two temperature loggers were lost during the study period, and one site was dewatered, resulting in 34 usable sites for evaluation of stream temperature. Average summer stream temperatures across all sites (i.e., mean from 25 Jul – 15 Sep) ranged from 10.2 to 19.6 °C (mean = 14.5 °C), with the warmest temperatures observed in the Grande Ronde River upstream of Five Points Creek (Table 2, Figure 3). Similarly, maximum weekly maximum temperatures (MWMT) ranged from 14.1 °C in the Middle Fork of Catherine Creek to 28.8 °C in the Grande Ronde River upstream of Five Points Creek (mean = 21.9 °C) (Figure 4). The cumulative number of days that maximum temperatures exceeded certain temperature thresholds was more variable than the other temperature metrics evaluated, but the general patterns across sites were similar. For example, the number of days that maximum temperatures exceeded 18 °C ranged from 0 to 51 (mean = 25.6), with the highest cumulative days exceeding 18 °C occurring in the Grande Ronde River upstream of Five Points Creek (Figure 5).

Stream temperatures peaked between the last week of July and first week of August at most sites (Figures 6-9). An examination of air temperatures at a weather station near Beaver Creek Reservoir confirmed that our sampling dates sufficiently captured the warmest period of the summer (Figure 10). The maximum weekly maximum air temperature at this site was 29.4 °C and occurred between July 30 and August 5.

Temperatures were generally cooler in the Catherine Creek basin compared with the Grande Ronde River basin, with MWMT in Catherine Creek sites ranging from 14.1 to 25.7 °C (mean = 19.7 °C) and MWMT in Grande Ronde River sites ranging from 14.3 to 28.8 °C (mean = 22.7 °C). As expected, temperatures were generally cooler in higher elevation, headwater streams and grew progressively warmer at sites closer to the river mouth. For example, MWMT in the Grande Ronde River upstream of Clear Creek was approximately 8.3 degrees cooler than the Grande Ronde River at the 2nd Street Bridge

in La Grande, located approximately 66 river kilometers downstream (Figure 11). Similarly, MWMT in Catherine Creek increased by approximately 8 °C from North Fork Catherine Creek above Middle Fork Catherine Creek to mainstem Catherine Creek near Union, approximately 27 km downstream (Figure 12).

In the upper Grande Ronde Basin, only Clear Creek and upper sections of Limber Jim and Sheep Creeks met the water temperature standard of 17.8 °C MWMT as defined by the Oregon Department of Environmental Quality (ODEQ 2000). This temperature standard represents the level above which significant impacts to salmonid spawning, egg incubation, and fry emergence are expected to occur. In the Catherine Creek Basin, only sites upstream of the North Fork and South Fork Catherine Creek confluences met the ODEQ temperature standard.

We found strong correlations between most of the temperature metrics we evaluated with the exception of the cumulative days exceeding 14 and 22 °C, which were only moderately correlated ($r = 0.608$, $P < 0.001$). The weaker correlation between these two metrics was likely due to the large number of zero values for days > 22 °C. The strong correlation among temperature metrics suggests that the all of the metrics provide relatively consistent information with respect to quantifying thermal patterns in stream temperature. However, inclusion of additional years of data and more sites might reveal that these correlations are not quite as strong as suggested by these data. In addition, the correlations among different temperature metrics may be useful for comparing the equivalence of information from other agencies or sites where temperature data may be limited to a single temperature metric such as MWAT.

References

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Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user's guide. General Technical Report. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station, March.

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Oregon Department of Environmental Quality. 2000. Upper Grande Ronde River sub-basin total maximum daily load (TMDL). Portland, OR: Oregon Department of Environmental Quality, Water Quality Division, April. http://waterquality.deq.state.or.us/wq/.

Table 1. Temperature logger sites in Catherine Creek and the Grande Ronde River deployed during the summer of 2009.

Number	Basin	Stream	Site	Owner	Latitude	Longitude	Date deployed	Date retrieved
1	CC	Catherine Creek	CC_E_Union	City of Union	45.20932500	-117.85394301	28-Jul-09	8-Oct-09
2	CC	Catherine Creek	CC_Hwy_203	ODOT	45.15450600	-117.78338201	28-Jul-09	8-Oct-09
3	CC	Little Catherine Creek	Little_CC_mouth	Forest Capital Partners	45.14379001	-117.71890801	28-Jul-09	8-Oct-09
4	CC	Little Creek	Little_Cr_High_Valley_Rd	Union County	45.20905901	-117.78134501	28-Jul-09	8-Oct-09
5	CC	Little Creek	Little_Cr_N_Union	ODOT	45.21717900	-117.86024101	28-Jul-09	8-Oct-09
6	CC	Middle Fork Catherine Creek	MF_CC_mouth	Wallowa Whitman NF	45.15216801	-117.61722001	28-Jul-09	8-Oct-09
7	CC	North Fork Catherine Creek	NF_CC_above_MF_CC	Wallowa Whitman NF	45.15344500	-117.61601201	28-Jul-09	8-Oct-09
8	CC	North Fork Catherine Creek	NF_CC_mouth	Wallowa Whitman NF	45.12264800	-117.64176001	28-Jul-09	8-Oct-09
9	CC	South Fork Catherine Creek	SF_CC_mouth	Wallowa Whitman NF	45.11574600	-117.63727601	28-Jul-09	8-Oct-09
10	GR	Bear Creek	Bear_Cr_below_Little_Bear_Cr	Wallowa Whitman NF	45.24857600	-118.52466701	26-Jul-09	8-Oct-09
11	GR	Burnt Corral Creek	Burnt_Corral_Cr_mouth	Wallowa Whitman NF	45.23449900	-118.45886601	26-Jul-09	8-Oct-09
12	GR	Clear Creek	Clear_Cr_mouth	Wallowa Whitman NF	45.06316400	-118.31099201	25-Jul-09	7-Oct-09
13	GR	Clear Creek	Clear_Cr_upper	Wallowa Whitman NF	45.03832800	-118.32474001	25-Jul-09	7-Oct-09
14	GR	Five Points Creek	Five_Points_Cr_above_Little_JD_Cr	Wallowa Whitman NF	45.41832600	-118.19252101	27-Jul-09	8-Oct-09
15	GR	Five Points Creek	Five_Points_Cr_above_Pelican_Cr	Wallowa Whitman NF	45.36083400	-118.23960701	24-Jul-09	6-Oct-09
16	GR	Five Points Creek	Five_Points_Cr_mouth	ODOT	45.34706900	-118.22280401	27-Jul-09	6-Oct-09
17	GR	Fly Creek	Fly_Cr_below_Little_Fly_Cr	Wallowa Whitman NF	45.12129100	-118.45400901	26-Jul-09	7-Oct-09
18	GR	Fly Creek	Fly_Cr_below_Squaw_Cr	Wallowa Whitman NF	45.13376801	-118.53324601	26-Jul-09	7-Oct-09
19	GR	Fly Creek	Fly_Cr_mouth	Wallowa Whitman NF	45.21018400	-118.39592501	25-Jul-09	Logger lost
20	GR	Grande Ronde River	GR_above_Clear_Cr	Wallowa Whitman NF	45.06325100	-118.31019501	25-Jul-09	7-Oct-09
21	GR	Grande Ronde River	GR_above_Five_Points_Cr	OR State Parks	45.34641401	-118.22265801	27-Jul-09	6-Oct-09
22	GR	Grande Ronde River	GR_above_Fly_Cr	Wallowa Whitman NF	45.20842301	-118.39560101	25-Jul-09	6-Oct-09
23	GR	Grande Ronde River	GR_above_Jordan_Cr	Wallowa Whitman NF	45.31119200	-118.28137201	25-Jul-09	Logger lost
24	GR	Grande Ronde River	GR_above_Meadow_Cr	Wallowa Whitman NF	45.26212800	-118.37920601	25-Jul-09	6-Oct-09
25	GR	Grande Ronde River	GR_at_2nd_St_Bridge	ODOT	45.34224601	-118.09923901	27-Jul-09	7-Oct-09
26	GR	Grande Ronde River	GR_at_acclimation_site	Wallowa Whitman NF	45.07918300	-118.33189501	25-Jul-09	7-Oct-09
27	GR	Grande Ronde River	GR_at_Time_and_Half_Bridge	Wallowa Whitman NF	45.15893000	-118.38050001	25-Jul-09	7-Oct-09
28	GR	Grande Ronde River	GR_below_Vey	Wallowa Whitman NF	45.12762000	-118.36033601	26-Jul-09	7-Oct-09
29	GR	Limber Jim Creek	Limber_Jim_Cr_below_NF	Wallowa Whitman NF	45.10792600	-118.32633601	25-Jul-09	7-Oct-09
30	GR	Limber Jim Creek	Limber_Jim_Cr_mouth	Wallowa Whitman NF	45.09037300	-118.33661601	25-Jul-09	7-Oct-09
31	GR	Limber Jim Creek	Limber_Jim_Cr_upper	Wallowa Whitman NF	45.10724300	-118.29761801	25-Jul-09	7-Oct-09
32	GR	Meadow Creek	Meadow_Cr_above_Bear_Cr	Wallowa Whitman NF	45.26555901	-118.52159401	26-Jul-09	8-Oct-09
33	GR	Meadow Creek	Meadow_Cr_below_FS22_Bridge	Wallowa Whitman NF	45.29084900	-118.60467301	26-Jul-09	8-Oct-09
34	GR	Meadow Creek	Meadow_Cr_mouth	ODOT	45.26437701	-118.37775301	25-Jul-09	6-Oct-09
35	GR	Pelican Creek	Pelican_Cr_mouth	Wallowa Whitman NF	45.36213300	-118.24074501	24-Jul-09	1-Sep-09
36	GR	Sheep Creek	Sheep_Cr_below_E_Sheep_Cr	Wallowa Whitman NF	45.02605600	-118.47506801	26-Jul-09	7-Oct-09
37	GR	Sheep Creek	Sheep_Cr_Rd_junction	Wallowa Whitman NF	45.05880800	-118.45582901	26-Jul-09	7-Oct-09

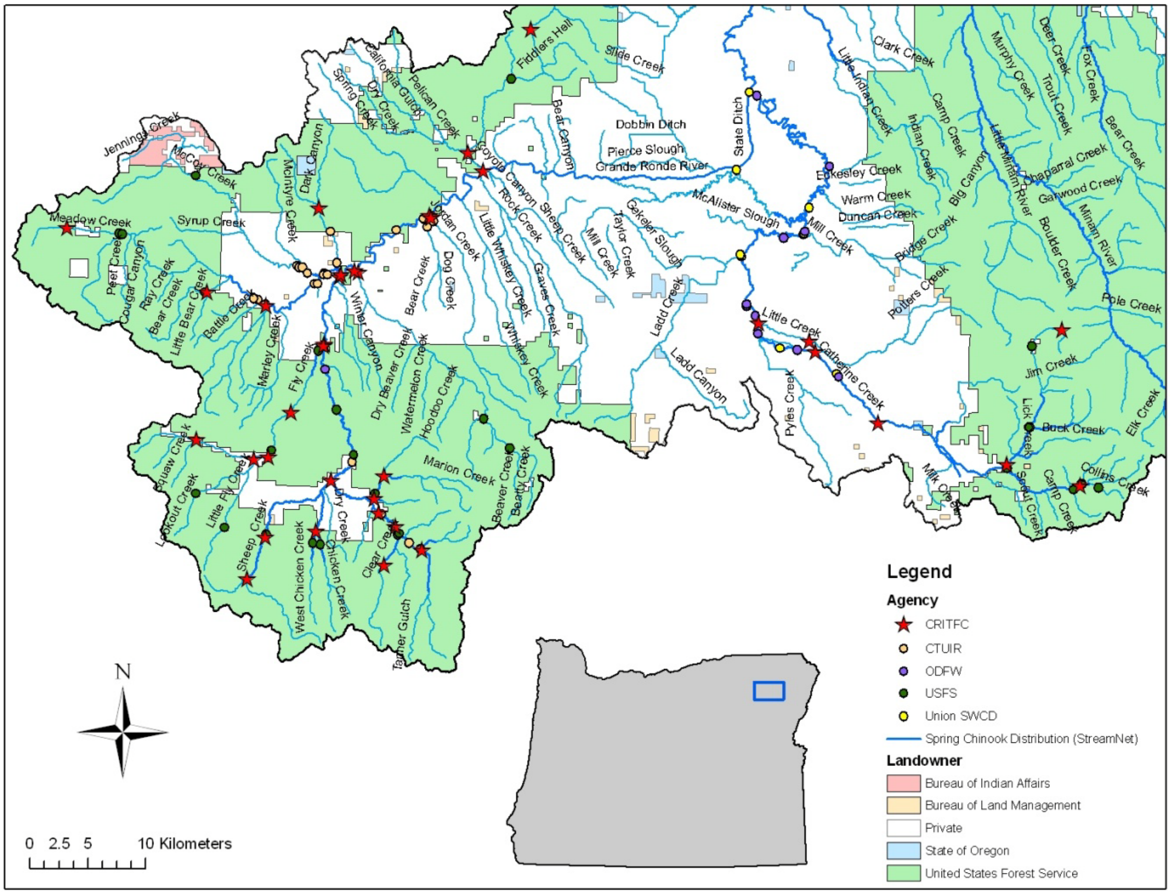

Figure 1. Temperature monitoring sites in the Upper Grande Ronde River and Catherine Creek basins, 2009.

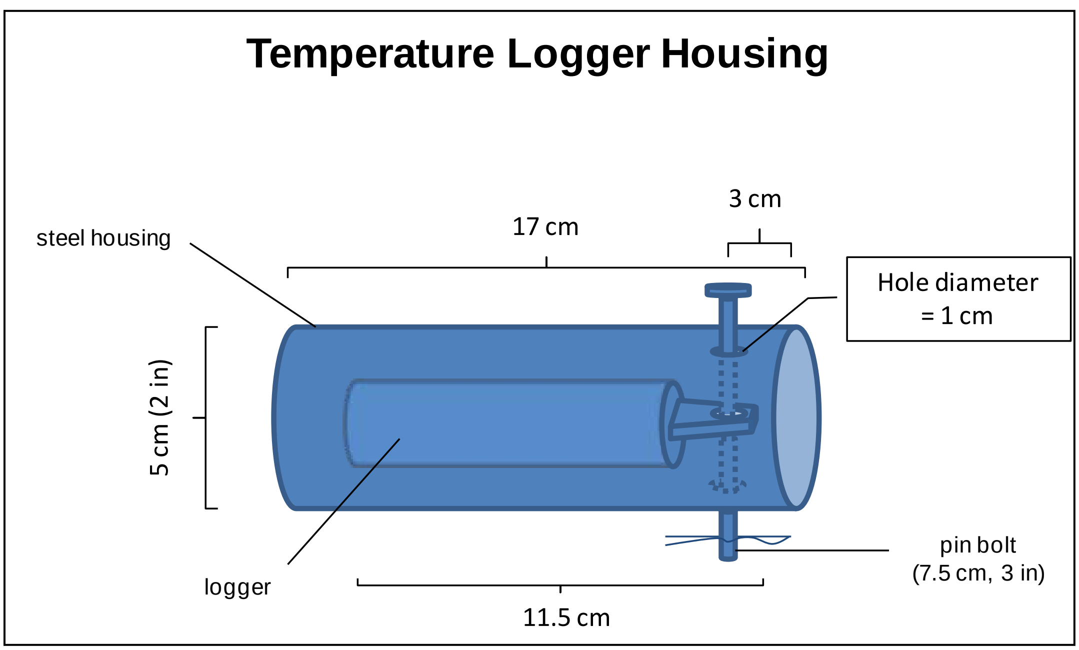

Figure 2. Diagram of steel housing used to protect temperature loggers during field deployment.

Table 2. Summary of stream temperatures (°C) at 34 sites in Catherine Creek and the Grande Ronde River during the summer of 2009 (25 Jul – 15 Sep). Different temperature metrics include average daily temperature for the summer period (Avg), the highest instantaneous temperature recorded during summer (Max), the lowest instantaneous temperature recorded during summer (Min), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the cumulative number of days that the daily maximum temperature exceeded the thresholds 14, 18, and 22°C.

						Days max exceeded threshold		
Site	Avg	Max	Min	MWAT	MWMT	> 14°C	> 18°C	> 22°C
Catherine Creek Basin								
CC_E_Union	16.8	24.2	9.5	19.9	23.4	49	39	10
CC_Hwy_203	15.1	23.0	7.3	18.1	22.2	48	29	4
Little_CC_mouth	14.0	20.2	7.2	16.7	19.7	44	11	0
Little_Cr_High_Valley_Rd	15.0	22.6	8.0	17.7	21.8	48	27	2
Little_Cr_N_Union	17.8	26.8	9.3	20.9	25.7	49	48	26
MF_CC_mouth	10.6	14.3	6.0	12.5	14.1	4	0	0
NF_CC_above_MF_CC	11.1	15.9	5.8	12.9	15.4	16	0	0
NF_CC_mouth	12.2	18.5	6.1	14.3	17.8	41	3	0
SF_CC_mouth	12.0	17.1	6.2	14.6	16.9	19	0	0
Average (Catherine Creek)	13.8	20.3	7.3	16.4	19.7	35.3	17.4	4.7
Grande Ronde River Basin								
Bear_Cr_below_Little_Bear_Cr	14.0	26.9	6.7	18.1	25.3	41	18	11
Burnt_Corral_Cr_mouth	14.4	25.6	5.6	18.3	24.6	49	32	10
Clear_Cr_mouth	11.6	17.4	5.4	14.3	17.1	21	0	0
Clear_Cr_upper	10.6	14.8	7.2	12.9	14.5	8	0	0
Five_Points_Cr_above_Little_JD_Cr	15.1	22.5	9.0	17.8	22.2	50	29	5
Five_Points_Cr_above_Pelican_Cr	16.7	26.5	8.4	19.5	26.0	53	50	24
Five_Points_Cr_mouth	16.1	23.5	10.1	18.9	23.3	50	37	11
Fly_Cr_below_Little_Fly_Cr	17.4	28.7	7.2	21.4	27.7	51	49	35
Fly_Cr_below_Squaw_Cr	13.1	23.4	4.8	17.5	21.8	39	18	2
GR_above_Clear_Cr	12.3	19.2	5.4	14.8	18.9	44	10	0
GR_above_Five_Points_Cr	19.6	29.4	9.4	23.8	28.8	50	49	43
GR_above_Fly_Cr	16.5	26.5	7.0	20.4	25.1	52	44	14
GR_above_Meadow_Cr	17.7	28.7	7.5	21.6	27.8	52	51	36
GR_at_2nd_St_Bridge	19.0	27.8	10.6	23.4	27.2	50	46	24
GR_at_acclimation_site	13.5	19.8	7.1	15.7	19.4	28	11	0
GR_at_Time_and_Half_Bridge	16.3	26.4	6.9	20.3	24.9	51	43	13
GR_below_Vey	16.4	26.1	7.3	20.1	25.5	50	44	16
Limber_Jim_Cr_below_NF	10.8	16.2	4.8	13.5	15.6	12	0	0
Limber_Jim_Cr_mouth	12.7	20.2	5.5	15.7	19.7	40	10	0
Limber_Jim_Cr_upper	10.2	14.8	4.8	12.5	14.3	6	0	0
Meadow_Cr_above_Bear_Cr	16.7	26.4	7.6	20.7	26.3	51	43	17
Meadow_Cr_below_FS22_Bridge	15.7	26.9	5.4	19.7	26.2	50	44	17
Meadow_Cr_mouth	18.1	26.2	9.4	21.9	25.4	52	46	22
Sheep_Cr_below_E_Sheep_Cr	11.1	16.4	5.7	13.7	15.9	13	0	0
Sheep_Cr_Rd_junction	14.4	24.0	5.7	17.8	23.5	50	38	9
Average (Grande Ronde)	14.8	23.4	7.0	18.2	22.7	40.5	28.5	12.4
Average (All Sites)	14.5	22.5	7.1	17.7	21.9	39.1	25.6	10.3

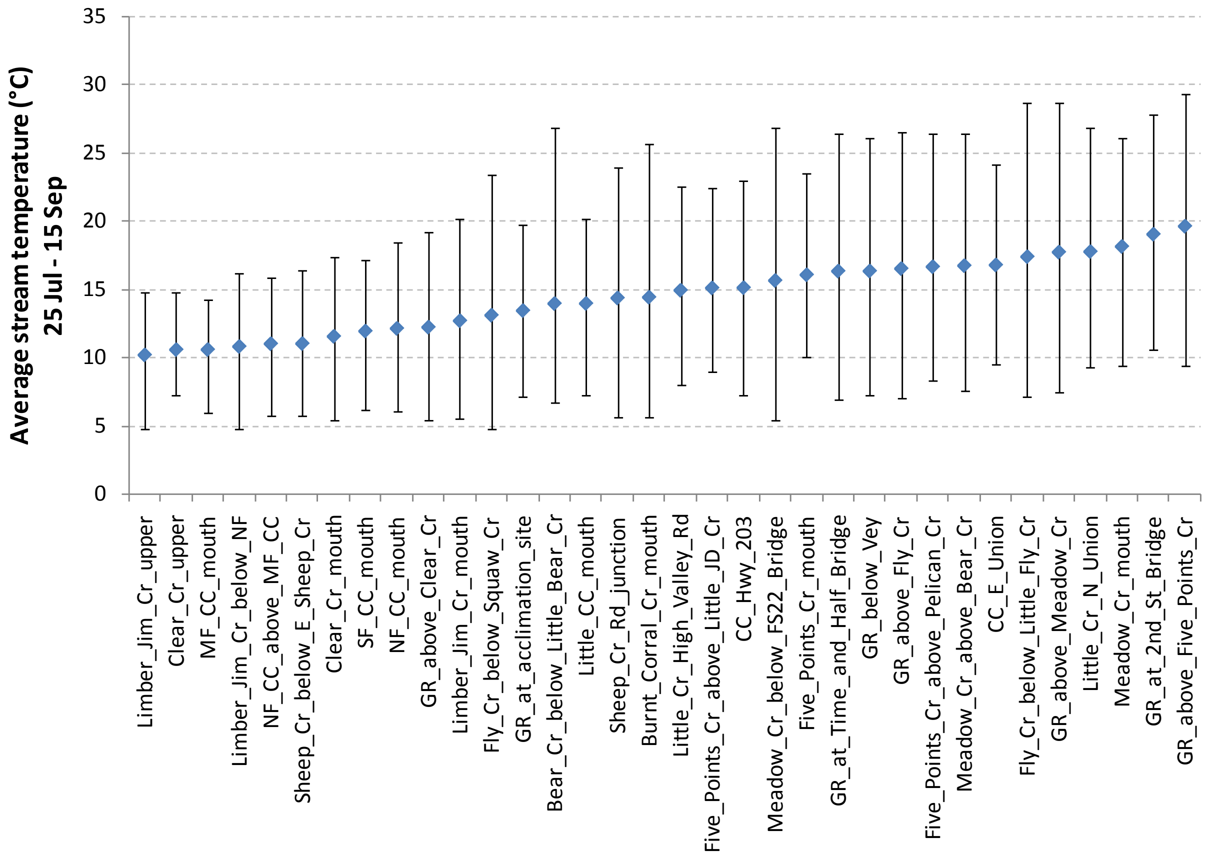

Figure 3. Average daily stream temperature (°C) at 34 sites in Catherine Creek and the Grande Ronde River during summer (25 Jul – 15 Sep) 2009. Error bars represent the highest instantaneous temperature recorded during summer (Max) and the lowest instantaneous temperature recorded during summer (Min).

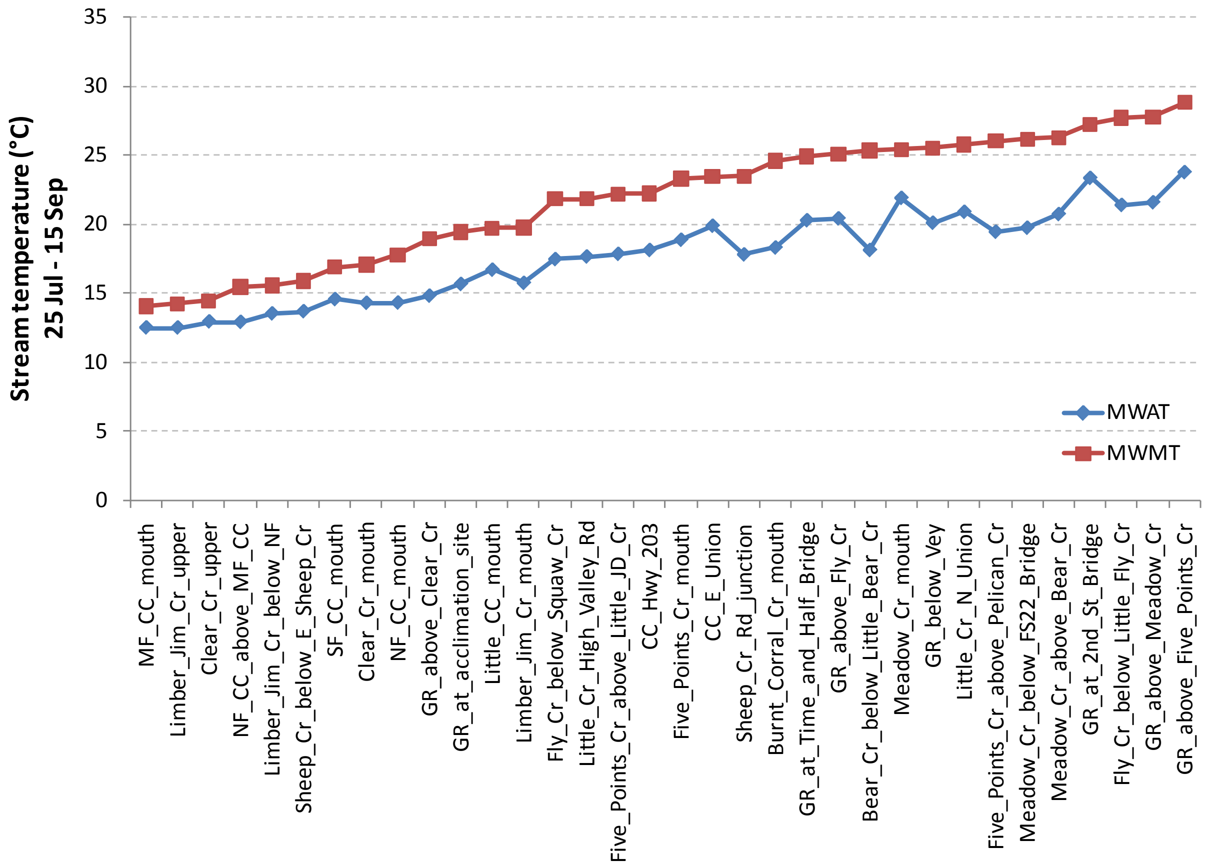

Figure 4. Maximum weekly average temperature (MWAT; °C) and maximum weekly maximum temperature (MWMT) at 34 sites in Catherine Creek and the Grande Ronde River during summer (25 Jul – 15 Sep) 2009. Data were sorted by MWAT in ascending order.

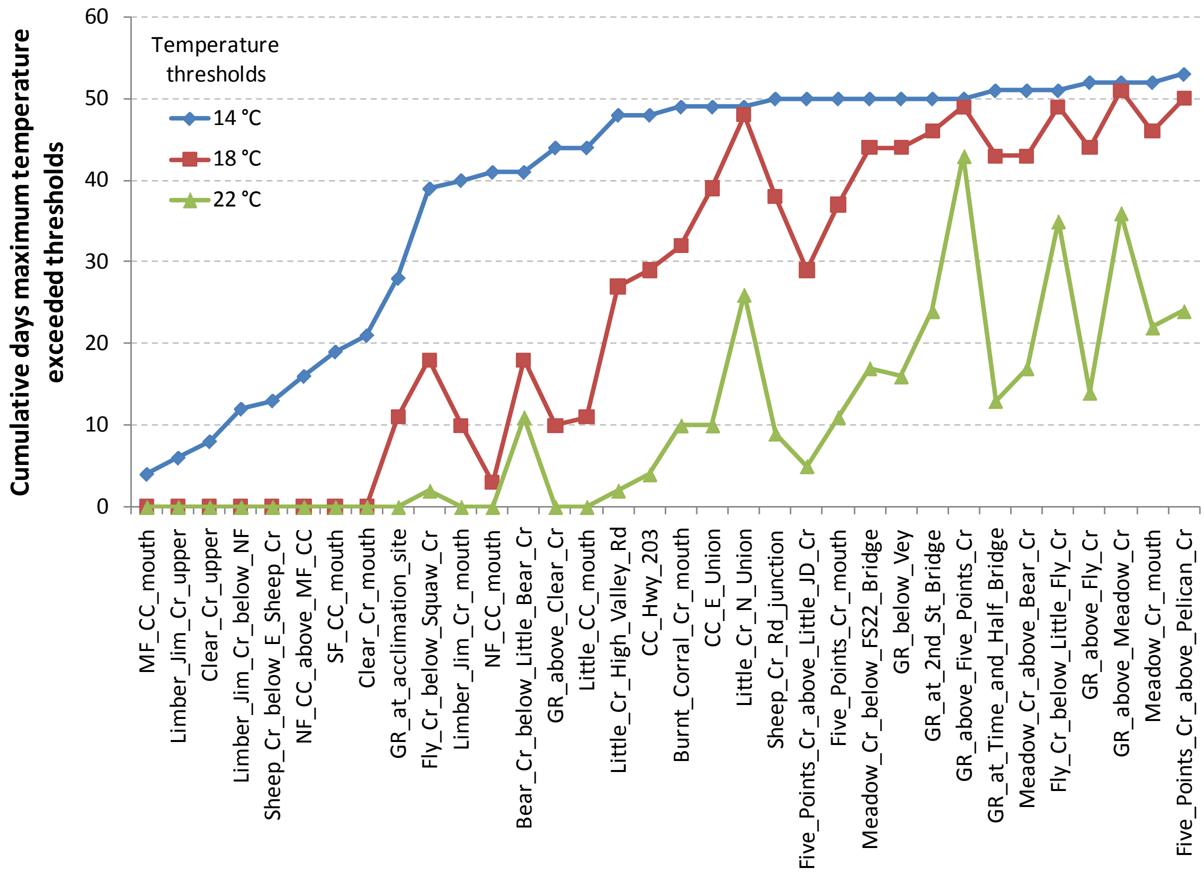

Figure 5. Cumulative number of days that maximum daily stream temperatures exceeded thresholds of 14, 18, and 22°C at 34 sites in Catherine Creek and the Grande Ronde River during summer (25 Jul – 15 Sep) 2009.

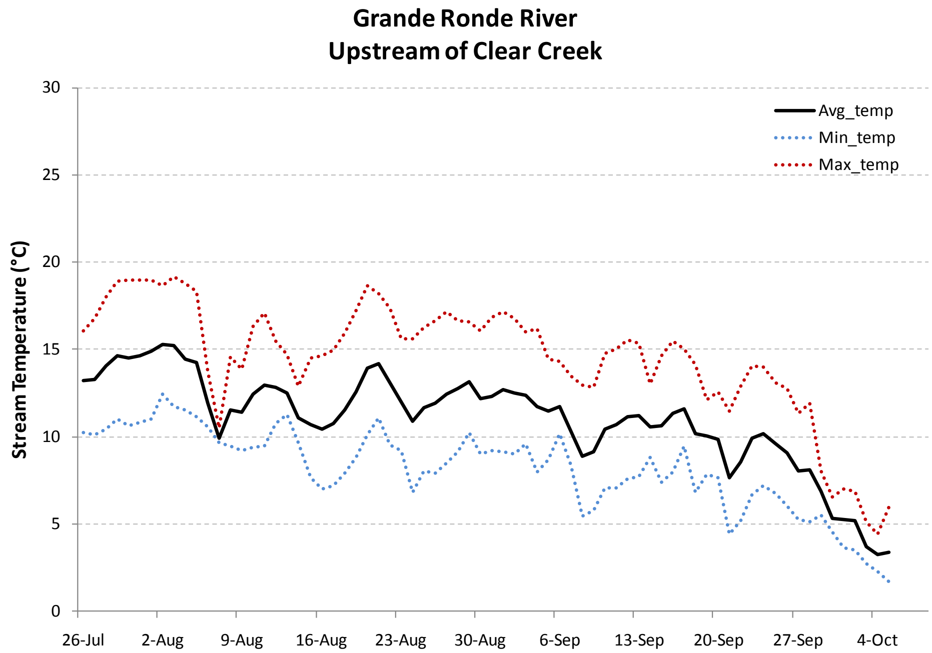

Figure 6. Daily average, minimum, and maximum stream temperatures (°C) in the Grande Ronde River upstream of Clear Creek from 26 Jul – 6 Oct, 2009.

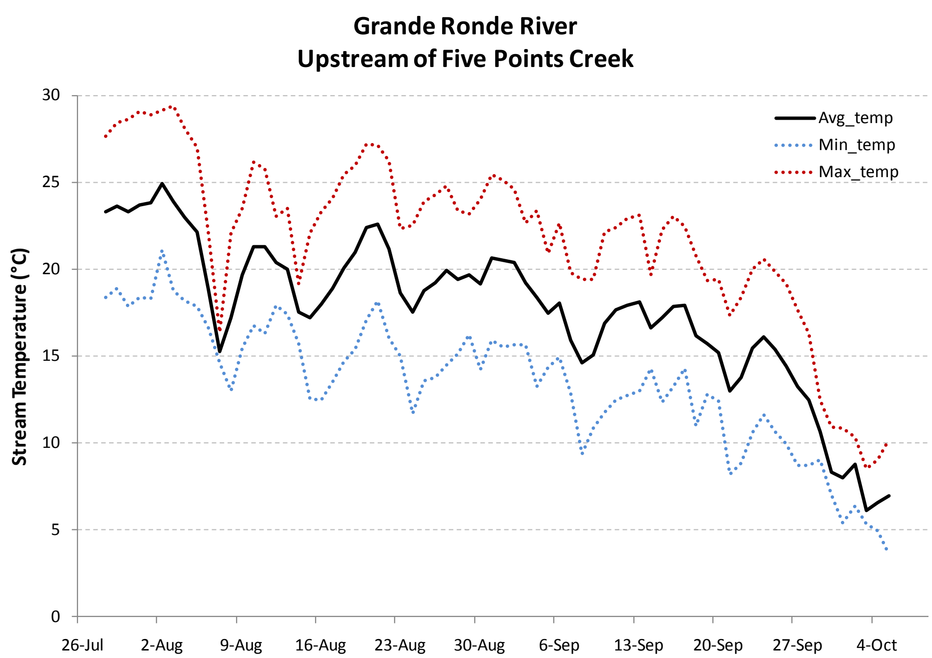

Figure 7. Daily average, minimum, and maximum stream temperatures (°C) in the Grande Ronde River upstream of Five Points Creek from 28 Jul – 5 Oct, 2009.

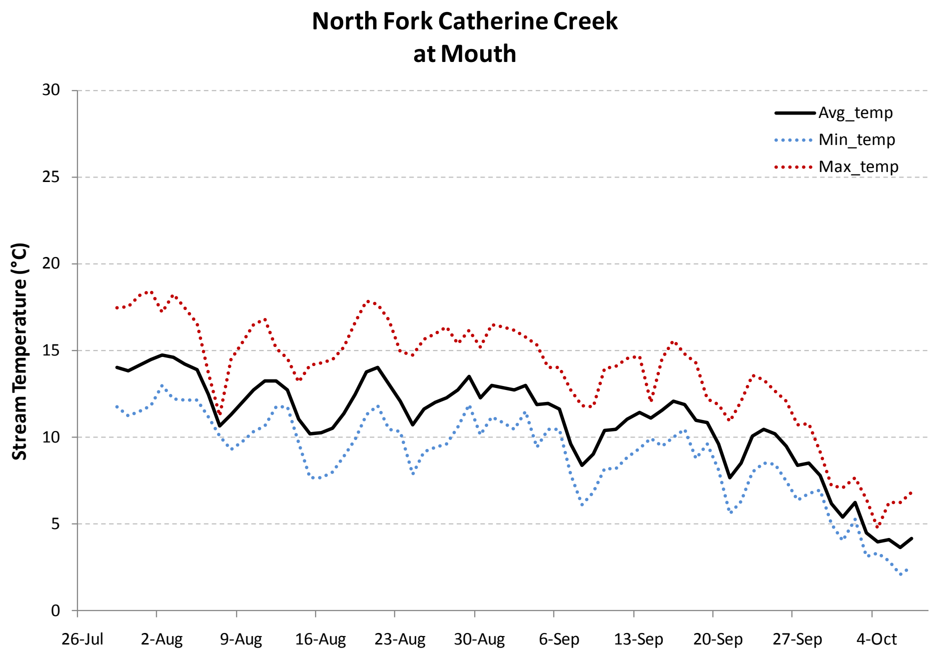

Figure 8. Daily average, minimum, and maximum stream temperatures (°C) in North Fork Catherine Creek at the mouth from 29 Jul – 7 Oct, 2009.

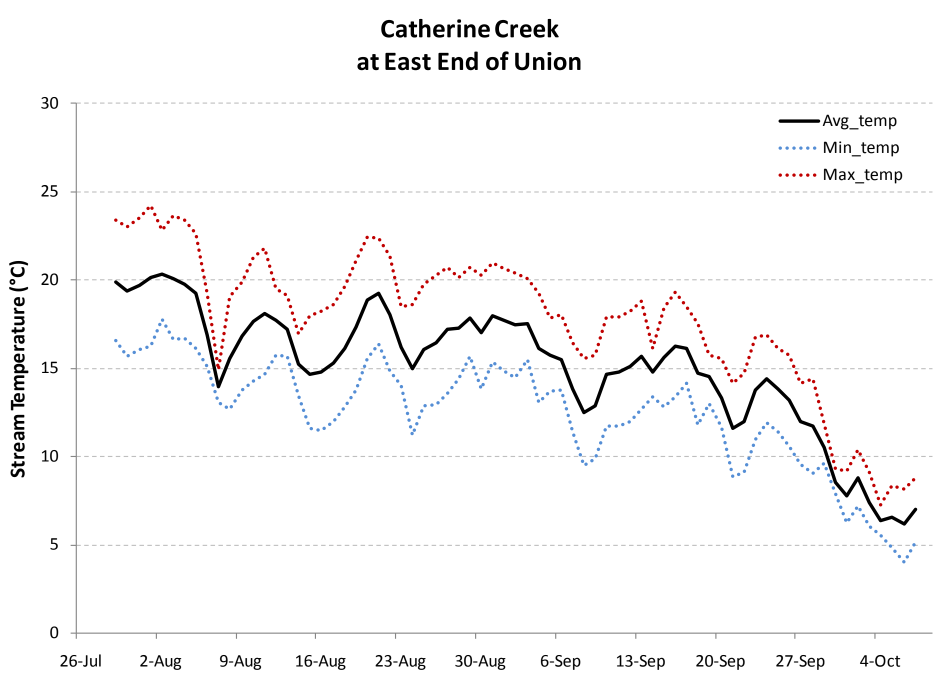

Figure 9. Daily average, minimum, and maximum stream temperatures (°C) in Catherine Creek at the east end of Union from 29 Jul – 7 Oct, 2009.

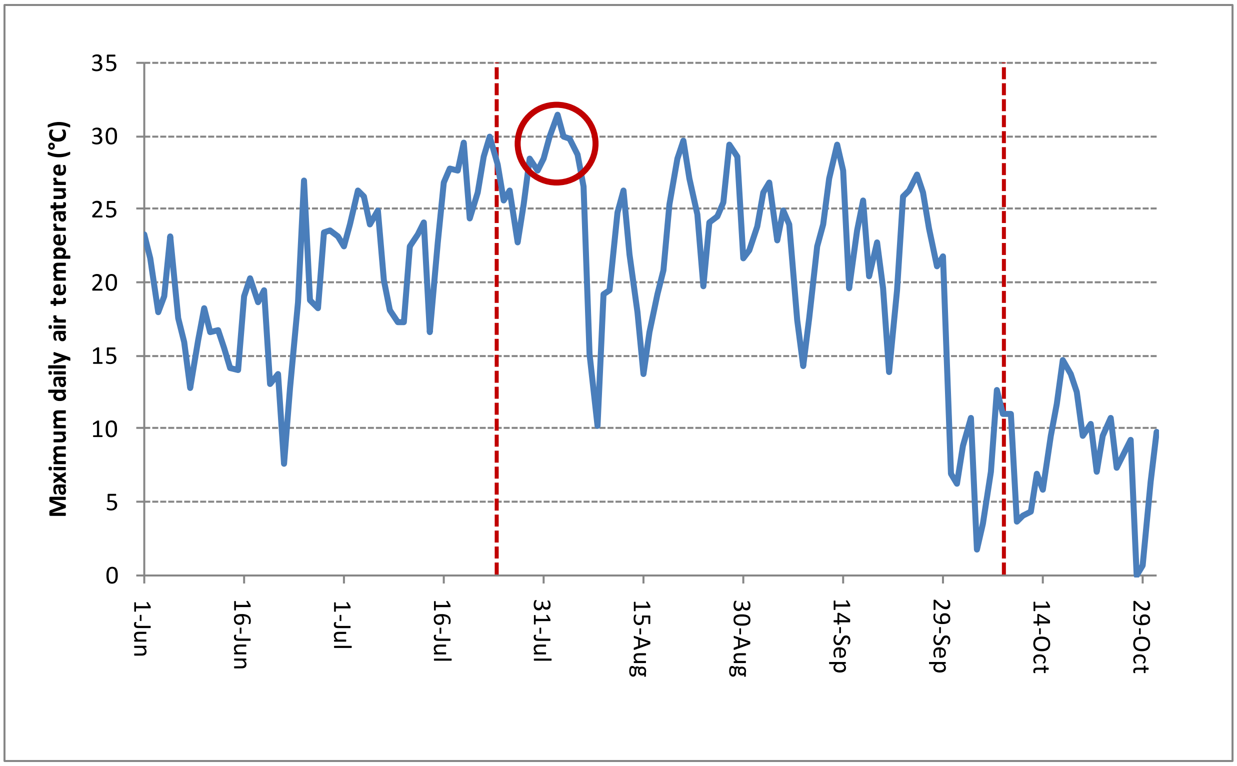

Figure 10. Maximum daily air temperature near Beaver Creek Reservoir in the Upper Grande Ronde Basin during 2009. Dashed line denote the sampling period for water temperature (24 Jul – 8 Oct), and the circle denotes the time period corresponding with the maximum weekly maximum air temperature (MWMT).

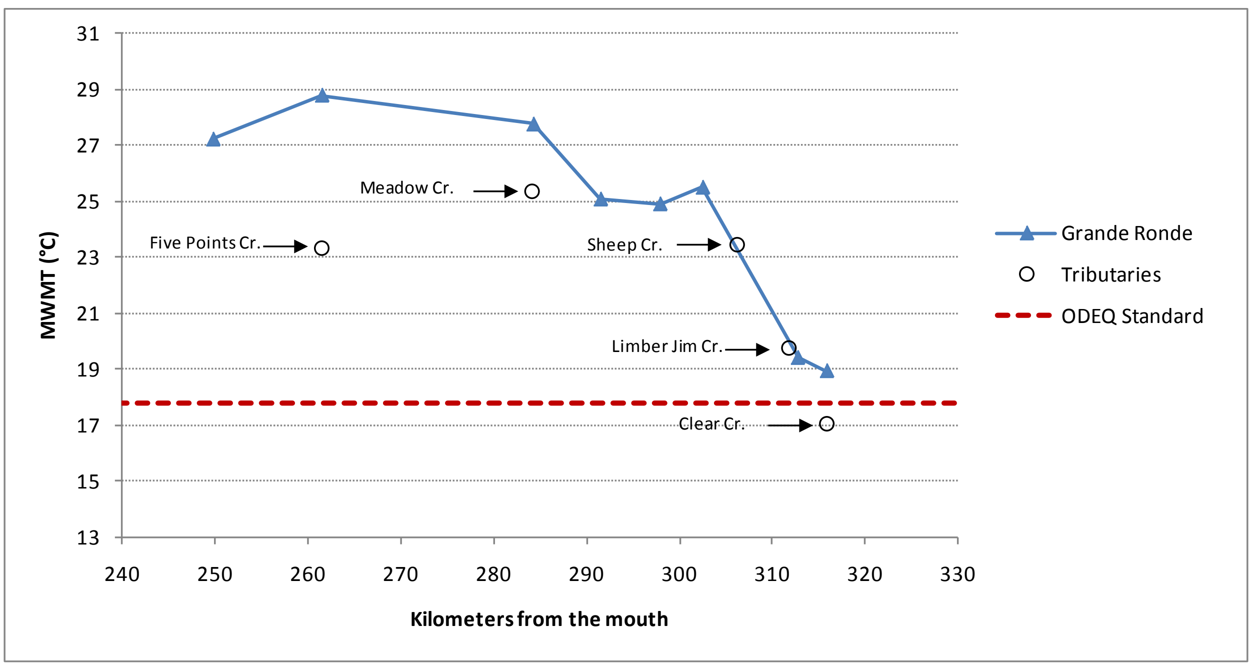

Figure 11. Longitudinal water temperature profile in the Upper Grande Ronde River and associated tributaries during summer (25 Jul – 15 Sep) 2009. Temperatures are given as the maximum weekly maximum temperature (MWMT °C).

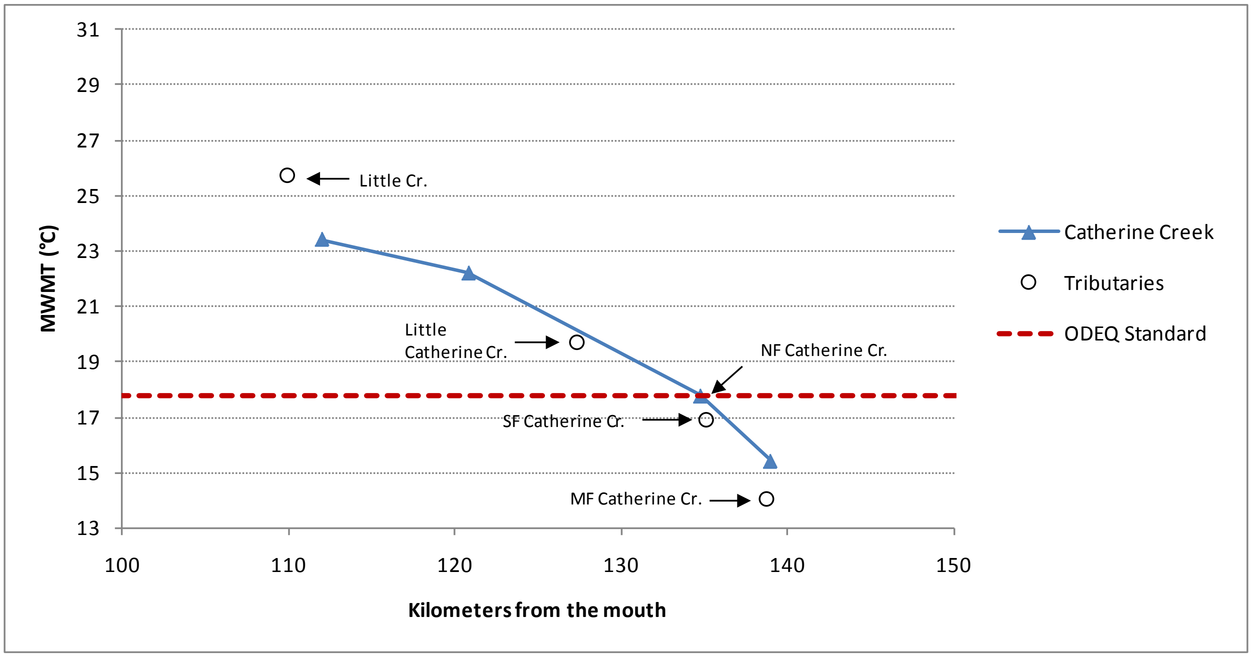

Figure 12. Longitudinal water temperature profile in Catherine Creek and associated tributaries during summer (25 Jul – 15 Sep) 2009. Temperatures are given as the maximum weekly maximum temperature (MWMT °C).

Table 3. Correlation matrix for each of eight temperature metrics used to evaluate stream temperature in Catherine Creek and the Grande Ronde River.

	Avg	*Max*	*MWAT*	*MWMT*	*Days Max > 14*	*Days Max > 18*	*Days Max > 22*
Avg	1.000						
Max	0.932	1.000					
MWAT	0.987	0.964	1.000				
MWMT	0.944	0.997	0.969	1.000			
Days Max > 14	0.851	0.890	0.853	0.895	1.000		
Days Max > 18	0.952	0.943	0.952	0.951	0.858	1.000	
Days Max > 22	0.862	0.838	0.865	0.848	0.608	0.848	1.000

Appendix H

Stream Substrate Sediment (Surface and Subsurface) Particle Size Analysis

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A Pilot Analysis of Sediment Size in Potential Spring Chinook Spawning Areas in the Grande Ronde River Basin

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

February 2010

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Summary

We evaluated size composition of both surface and subsurface sediment samples collected at five different sites in the upper Grande Ronde River basin during the summer of 2009 (September 14-17) in order to gain a preliminary understanding of the quality of potential spawning gravels, to test and refine sampling methods, and to determine sample size requirements for future sampling efforts. The percentage of surface particles less than 6.3 mm ranged from 3.4 to 13% across sites (mean = 7.5%), with Fly Creek having the highest percent surface fines of the sites measured. Percent fines < 6.3 mm in subsurface samples was generally higher and more consistent across sites compared with surface samples, with values ranging from 20.5% at Limber Jim Creek to 28.8% at Sheep Creek (mean = 22.9%). The minimum number of particles in a surface pebble count necessary to detect a statistically significant difference of 10% in percent fines < 6.3 mm ranged from 113 to 201, depending on the value for percent fines used to define the *reference* condition. Consequently, we selected a conservative value of 200 as the minimum sample size required for future surface sediment samples. Similarly, the estimated number of subsurface bulk samples required per site to detect a significant difference of 10% in mean percent fines ranged from 3 to 9, depending on the particle size threshold used to define percent fines. Using a conservative particle size threshold of 9.5 mm to define percent fines, we estimated a minimum samples size of 9 bulk samples per site for future subsurface sampling. Using predictive formulas that describe the relationship between fine sediment and Chinook egg-to-fry survival (Tappel and Bjornn 1983), estimated survival-to-emergence ranged from 44.6 to 78.5% (mean = 62.2%), with the lowest survival occurring in Sheep Creek. However, confidence intervals for survival estimates were quite large (e.g., [0, 77.7] at Sheep Creek) as a result of relatively high variability in fine sediment conditions within sites. Overall, these data are helpful in describing sediment conditions at a select number of sites in the Upper Grande Ronde basin, and provide reasonable estimates of sample size requirements for future monitoring efforts.

Methods

Surface sediment sampling

Surface samples were collected in three sites in the Upper Grande Ronde basin including Fly Creek, mainstem Grande Ronde River, and Meadow Creek during the summer of 2009 (September 14-17) (Table 1; Figure 1). Sample sites were chosen to correspond with concurrent monitoring efforts including measurement of stream temperature, discharge, and channel cross sections, and represented a fairly broad range of channel sizes and habitat types. At each site, we conducted a brief preliminary evaluation of the available spawning habitat based on visual estimates of suitable habitat type, depth, water velocity, and dominant substrate size. Criteria for determining suitable habitat conditions generally conformed with recommendations by Schuett-Hames et al. (1999). Within areas deemed to be potential spawning habitat, we randomly selected channel transects with the initial objective of collecting 360 surface particles per site. Our initial sample size goals were based on a simulation study of sediment size composition and sample size requirements using a grid-based surface sampling technique (McCullough, unpublished data).

We used a modified grid frame sampling method similar to that described by Bunte and Abt (2001a) to collect and measure sediment particles on the bed surface. The grid frame was 60cm X 60cm, and consisted of 9 equally spaced cells (cell width = 20cm) (Figure 2). The cell spacing was chosen to minimize the probability of double counting large particles while maintaining a sufficiently small overall grid size for ease and practicality of use in the field. Approximately 95% of surface particles estimated visually in the Grande Ronde River during a previous study were less than 20cm (McCullough and Green 2006). We used an underwater viewing scope equipped with crosshairs on the viewing window to identify a single sediment particle in the center of each grid cell. The scope was mounted to the grid frame using plastic mounting brackets to stabilize the scope and ensure accurate identification of the center particle. Once particles were identified

Table 1. Description of sediment sampling sites in the Grande Ronde River basin during summer, 2009.

Stream	Site	Owner	Date	Sample type	Sample no.	UTM Easting	UTM Northing
Limber Jim Creek	Limber_Jim_Cr_mouth	Wallowa Whitman NF	9/16/2009	subsurface	1	394871.4742800	4994027.4440700
Limber Jim Creek	Limber_Jim_Cr_mouth	Wallowa Whitman NF	9/16/2009	subsurface	2-3	394858.1476190	4994011.6630100
Limber Jim Creek	Limber_Jim_Cr_mouth	Wallowa Whitman NF	9/16/2009	subsurface	4-5	394789.3710180	4993846.0093000
Sheep Creek	Sheep_Cr_road_junction	Wallowa Whitman NF	9/16/2009	subsurface	1-3	385406.1733950	4990641.3921500
Sheep Creek	Sheep_Cr_road_junction	Wallowa Whitman NF	9/16/2009	subsurface	4-5	385423.1207270	4990685.9816300
Fly Creek	Fly_Cr_mouth	Wallowa Whitman NF	9/16/2009	surface, subsurface	1	390473.6853020	5007210.8060200
Fly Creek	Fly_Cr_mouth	Wallowa Whitman NF	9/16/2009	surface, subsurface	2	390405.4282540	5007251.8795200
Fly Creek	Fly_Cr_mouth	Wallowa Whitman NF	9/16/2009	surface, subsurface	3-4	390398.2725330	5007246.8926400
Fly Creek	Fly_Cr_mouth	Wallowa Whitman NF	9/16/2009	surface, subsurface	5	390388.2535440	5007244.3977900
Grande Ronde River	GR_above_Five_Points_Cr	OR State Parks	9/14/2009	surface, subsurface	1-5	404218.3598760	5022160.8250500
Meadow Creek	Meadow_Cr_above_Bear_Cr	Wallowa Whitman NF	9/17/2009	surface, subsurface	1	380451.5680460	5013781.2957400
Meadow Creek	Meadow_Cr_above_Bear_Cr	Wallowa Whitman NF	9/17/2009	surface, subsurface	2-3	380463.3637810	5013707.8357900
Meadow Creek	Meadow_Cr_above_Bear_Cr	Wallowa Whitman NF	9/17/2009	surface, subsurface	4	380467.2213860	5013691.8721400
Meadow Creek	Meadow_Cr_above_Bear_Cr	Wallowa Whitman NF	9/17/2009	surface, subsurface	5	380474.5490840	5013668.5060000

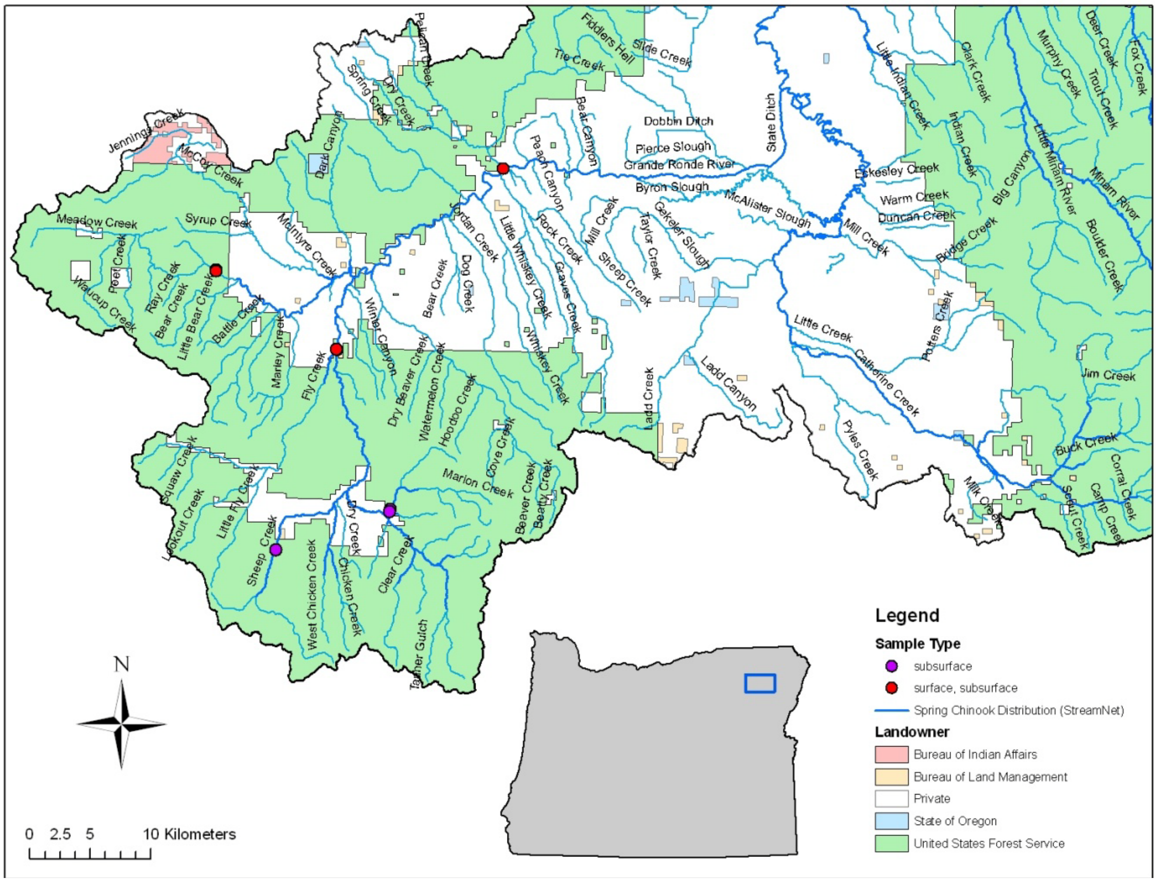

Figure 1. Surface (red circles) and subsurface (purple circles) sediment sampling sites in the Upper Grande Ronde River basin during summer, 2009.

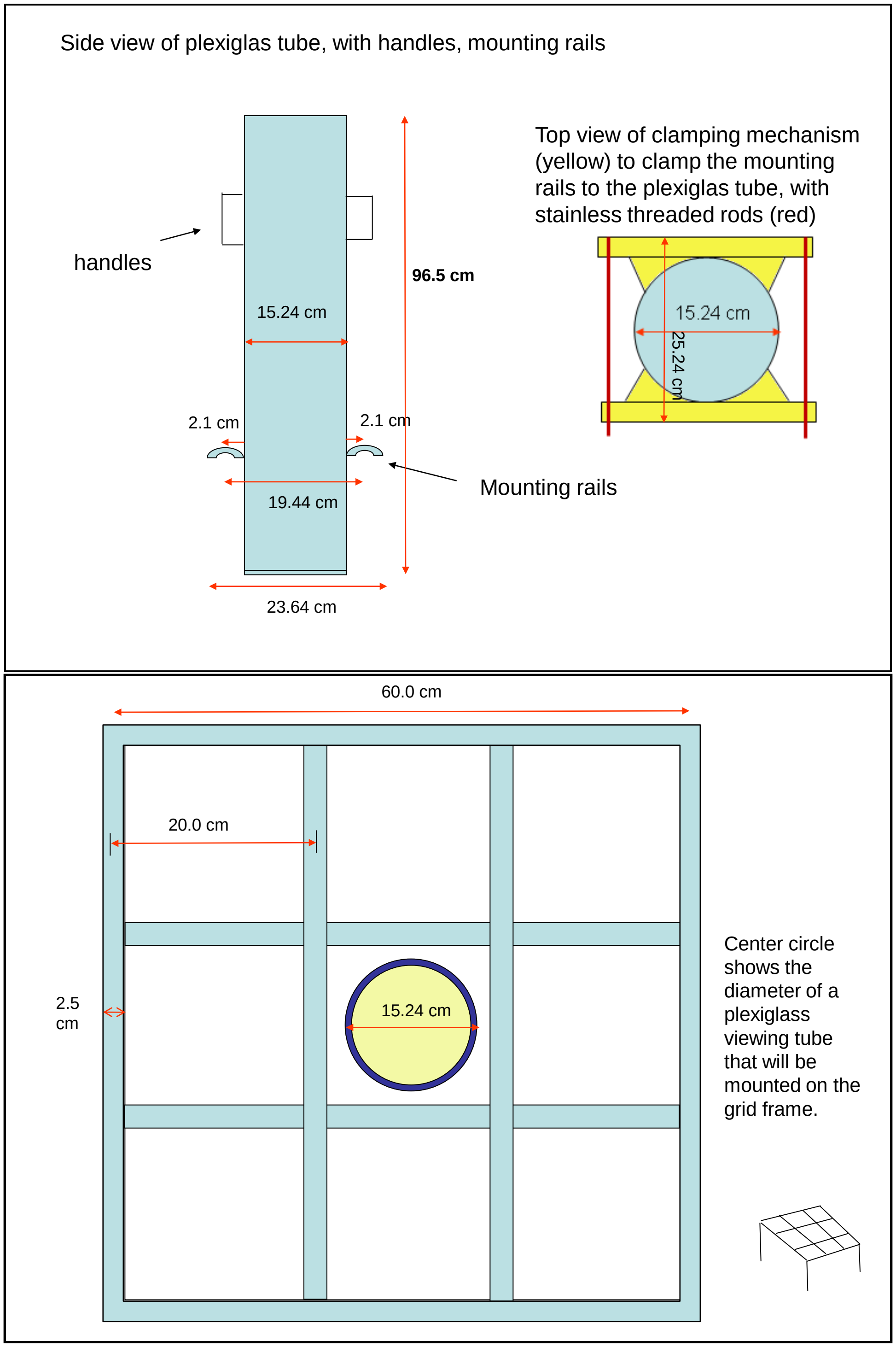

Figure 2. Diagram of the underwater viewing scope (top) and sampling grid frame (bottom) used to collect surface sediment particles.

with the scope, they were removed by hand and measured along their median axis using a standard US SAH-97 gravelometer.

With standard surface pebble count procedures, pebbles along a transect or within a grid are selected by lowering one's hand to a predefined location on the bed surface (i.e. center of grid intersections or intervals along a transect) and selecting the first particle that is touched (Wolman 1954, Bunte and Abt 2001a). Researchers in fluvial geomorphology and stream ecology have commonly acknowledged that these standard pebble count procedures are not very accurate for sampling particles less than about 4mm (Kondolf et al. 2003, Fripp and Diplas 1993). To reduce potential bias associated with standard pebble count methods, we incorporated the underwater viewing scope to pinpoint the position of the center particle and increase the likelihood of incorporating finer particles in the sample.

We began sampling in the mainstem Grande Ronde River above Five Points Creek, where we selected 10 equally spaced transects within a run-type habitat unit with relatively homogenous substrate composition. The distance between transects was approximately two grid widths (i.e., 1.2m). We divided each transect into four quadrants, and placed the grid in the center of each quadrant, measuring a total of 369 particles at the Grande Ronde site (Table 2). The additional 9 particles likely resulted from recording error. Compared with the Grande Ronde site, the area of potential spawning habitat at the other sampling sites was much smaller and more sparsely distributed, making it impossible to collect all sediment particles from a single patch of spawning gravels. In these cases, the sampling grid was placed randomly within patches of available spawning habitat, usually located within pool tail or run habitats. In addition, we reduced the level of effort at these sites due to time constraints, but maintained a minimum sample size of 100 particles as is typically called for in studies of sediment size composition (Table 2; Wolman 1954).

Table 2. Number of surface sediment particles retained for each size class at three sites in the Grande Ronde River basin in summer, 2009.

Size (mm)	Grande Ronde	Fly	Meadow
2	1	10	5
3.35	21	3	1
6.3	2	1	0
8	13	1	3
11	18	2	11
16	33	0	16
22.6	39	8	22
32	70	16	31
45	61	17	40
64	46	20	21
90	37	9	18
128	26	10	8
180	1	3	3
250	1	0	0
Total	369	100	179

The proportion of particles retained in each size class p_r was estimated as:

$$p_r = \frac{X}{n},$$

where X is the number of particles retained in each size class, and n is the total number of particles in the sample. The standard error for p_r in each size class was calculated using a standard formula for a binomial distribution (Zar 1999):

$$s_{p_r} = \sqrt{\frac{p_{r(1-p_r)}}{n-1}}.$$

The 95% confidence limits for the p_r were computed using a relationship between the F distribution and the binomial distribution as described in Zar (1999). The lower confidence limit for p_r is:

$$L_1 = \frac{X}{X + (n - X + 1)F_{a(2),v_1,v_2}},$$

where $v_1 = 2(n - X + 1)$, and $v_2 = 2X$.

The upper confidence limit for p_r is:

$$L_2 = \frac{(X+1)F_{a(2),v_1',v_2'}}{n-X+(X+1)F_{a(2),v_1',v_2'}},$$

where $v_1' = 2(X + 1)$, and $v_2' = 2(n - X)$.

This method for estimating standard error and confidence intervals relies on the assumption that the frequencies within individual size classes are binomially distributed, and that frequencies among size classes are completely independent. These assumptions are not technically accurate because the frequency data collected for multiple size classes are actually multinomially distributed and some degree of covariance between size classes is expected. To account for this, we also computed proportions for each size class and associated standard errors assuming multinomially distributed frequency data using a maximum likelihood approach. We compared the difference between these two approaches using the data from the Grande Ronde above Five Points Creek and found that the standard error for p_r differed by less than $2X10^{-5}$ on average across all size classes. Because the difference was essentially negligible, we proceeded with calculations based on a binomial distribution for ease of calculation.

Cumulative size frequency distributions and associated confidence intervals were calculated for each site by summing the p_r and confidence limits from all smaller size classes. The proportion of particles finer than a given size class p_f was then calculated by simply lagging the size class by one. For example, p_r for size class 2mm becomes p_f for size class 3.35mm.

The percentage of fine sediment particles less than 3.35, 6.3, and 9.5mm were estimated for each site because these metrics are commonly used to evaluate effects of fine sediment on egg-to-fry survival of salmonid fishes (Chapman and McLeod 1987). Additionally, we estimated

percentile values D5, D16, D50, D84, and D95 for each site, which are often used as descriptive statistics to compare two or more particle size distributions. Percentile values were estimated using logarithmic interpolation, which means that the mm size classes were log transformed prior to linear interpolation (Bunte and Abt 2001b). For example, the particle size of a desired percentile *x* was computed from:

$$D_x = e^{\left((\ln(x_2)-\ln(x_1))*\left(\frac{y_x-y_1}{y_2-y_1}\right)+\ln(x_1)\right)},$$

where y_1 and y_2 are the cumulative percent frequencies just below and above the desired cumulative frequency y_x, and x_1 and x_2 are the particle sizes in mm corresponding with the cumulative frequencies y_1 and y_2.

One of the key objectives of this pilot study was to evaluate sample size requirements to detect statistically significant differences in quantities of fine sediment over time, or from one area to another. To do this, we used an approach outlined in Bevenger and King (1995), which is based on a 2X2 contingency table analysis. In their example, the proportion of fine sediment is compared between two pebble counts, one conducted in a *reference* reach and the other in a *study* reach. The *reference* reach can be considered to represent the unimpaired or background condition, while the *study* reach represents the altered condition. Assuming equal sample sizes at both *reference* and *study* sites, the required sample size (i.e., number of particles in a pebble count) is dependent upon three factors, including: 1) percentage of fines in the *reference* site p_{ref}; 2) the minimum detectable difference between p_{ref} and the percentage of fines in the study site p_s; and 3) acceptable risk in terms of Type I error (α) and Type II error (β).

The minimum sample size for the pebble count at the study site n_s is given by:

$$n_s = \frac{n'}{4}\left(1+\frac{4}{n'\cdot|p_s-p_{ref}|}\right)^2,$$

where $$n' = \frac{\left(Z_\alpha\sqrt{p_{ref}+p_s\cdot\left(1-\frac{p_{ref}+p_s}{2}\right)}-Z_{1-\beta}\sqrt{p_{ref}\cdot(1-p_{ref})+p_s\cdot(1-p_s)}\right)^2}{(p_s-p_{ref})^2},$$

and Z_α and Z_β refer to the ordinates of the standard normal distribution for specified values of Type I and Type II error respectively. In this analysis, we selected an α value of 0.05 and a β value of 0.20 (i.e., power = 1 – β = 0.80). We selected initial values for p_{ref} based on the percentage of sediment particles less than 6.3mm observed at the three study sites. Resulting sample size requirements were evaluated for a range of detectable differences from 1 to 10%.

In addition to the Bevenger and King (1995) method for estimating sample size requirements, we used a bootstrap approach to examine the relationship between sample size and coefficient of variation (CV) for estimates of percentage of fines. In this approach, we simulated random samples of varying sample sizes ranging from 20 to 1000 using estimated proportions for each size class from the observed field data and assuming the counts for each size class were multinomially distributed. Random samples for each sample size were replicated 1000 times, and the resulting particle count for each size class was averaged across the 1000 bootstrap replicates. The average particle count in each size class was then used to calculate the proportion finer p_f.and the associated standard deviation s_{p_f} using the binomial formulas described above. The CV was then calculated by dividing s_{p_f} by p_f and multiplying by 100. The relationship between sample size and CV was calculated separately for each of the three sample sites.

Subsurface sediment sampling

We collected five subsurface bulk sediment samples at each of five sites within the upper Grande Ronde River basin using a modified McNeil sampler (Table 1; Figure 1). Core dimensions on the sampler were 20 cm diameter by 20 cm height, producing bulk samples ranging in mass from 5 to 10.5 kg (mean = 7.9 kg) (Figure 3). At the Grande Ronde site, the location for bulk samples was determined using a systematic random sampling technique. Using the same transects that were used for surface sediment sampling, we randomly selected the starting transect between 1 and 2 by tossing a coin. After the starting transect was selected, every other transect was sampled until a total of 5 transects were sampled. The location of the bulk sample along each transect was

determined by randomly selecting a quadrant between 1 and 4, and collecting the sample in the center of the quadrant. Because of the patchy distribution of available spawning gravels in the other four sites, the selection of sampling locations at these sites was less systematic. Essentially, one bulk sample was collected at each patch of potential spawning habitat until a total of five was attained. Although an attempt was made to collect bulk samples in a pseudo-random fashion, the exact location of the sample within each patch was not technically random.

Bulk samples were transported to the lab where they were dried in a drying oven at approximately 110°C. After returning samples to room temperature, they were sorted using an automatic sieve shaker for a period of 10 minutes. Sieve sizes included 0.125, 0.355, 0.85, 2, 3.35, 4, 6.3, 8, 11.2, 16, 31.5, and 63 mm. The mass of particles in each size class was weighed to the nearest 0.1 grams, and the sorted sediment was saved for use in fine sediment infiltration studies. A small subset of the samples were processed using fewer sieve sizes, resulting in size composition data that was not directly comparable with the majority of the samples which used the full suite of sieve sizes. Consequently, these samples were excluded from the analysis, resulting in only four samples at the Grande Ronde, Meadow Creek, and Sheep Creek sites.

Using methods similar to those previously described for surface sediment sampling, we calculated cumulative sediment size distribution curves for each bulk sample and computed an average cumulative distribution curve for each site. The percentage of sediment particles finer than 0.85, 3.35, 6.3, and 9.5 mm was estimated for each site using the full dataset as well as a truncated dataset. For the truncated dataset, all sediment particles > 31.5mm were excluded from the sample to correspond as closely as possible with a study of sediment effects on salmonid embryo survival by Tappel and Bjornn (1983), who truncated their samples at 25.4 mm. Figures of cumulative size distributions for each site were generated from the non-truncated dataset. Similarly, we estimated percentile values D5, D16, D50, D84, and D95 for each site using the non-truncated data using logarithmic interpolation as described previously.

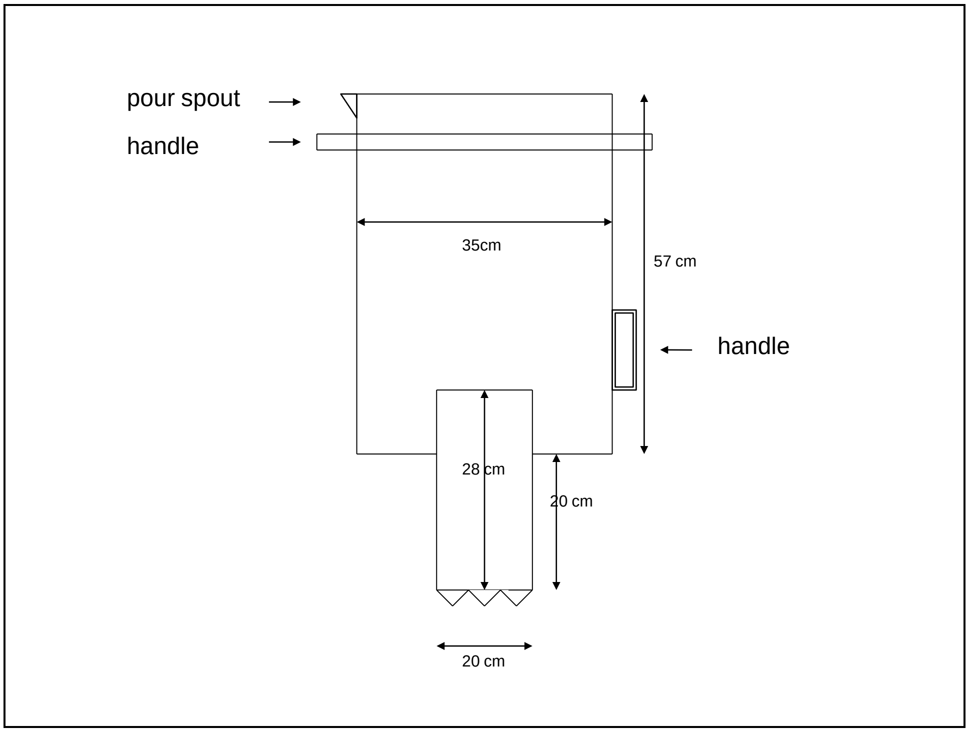

Figure 3. Diagram of modified stainless steel McNeil sediment sampler.

Confidence intervals for the proportion of sediment particles finer than a given size criteria p_f and percentile values (e.g., D5) were calculated using the standard formula for the confidence interval of a mean (Zar 1999):

$$\bar{X} \pm t_{\alpha(2),\nu} s_{\bar{X}},$$

where
$$s_{\bar{x}} = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n(n-1)}}.$$

In this case, values of p_f or percentile were substituted for X_i in the above formula. We selected an α value of 0.05 for computation of 95% confidence intervals.

The minimum number of bulk samples n required to detect a statistically significant difference of magnitude δ between the mean proportion of fines p_f between two populations was given by:

$$n = 2\sigma^2 \left(\frac{t_{\alpha/2} + t_\beta}{\delta}\right)^2,$$

where σ is the standard deviation for p_f, and $t_{\alpha/2}$ and t_β are the ordinates for the t distribution (which approximates the standard normal distribution at large sample sizes) for Type I and Type II error rates respectively. This formula is commonly applied using ordinates from the standard normal distribution (i.e., $Z_{\alpha/2}$ and Z_β) (Kuehl 2000), but given the relatively small number of samples typically collected in sediment studies, it is more conservative to substitute ordinates from the t distribution. Because t is dependent on n, it is necessary to iteratively solve for n as described in Bunte and Abt (2001b). This formula was applied in a similar study of spawning gravel composition to evaluate sample size requirements (McBain and Trush 2000). In this case, the difference δ may refer to the expected change in mean p_f among sites, or the temporal changes within a single site.

To estimate σ, we used the pooled standard deviation estimated from an Analysis of Variance (ANOVA) comparing the proportion of fines across all sites as was done by McBain and Trush (2000). Specifically, σ was calculated as the square root of the mean square error (MSE) from the ANOVA. Thus, σ represents the amount of unexplained variance in p_f after the variability among sites was accounted for. Because several different sediment size criteria have been used historically to evaluate the effects of fine sediment on survival of salmonid embryos (Chapman and McLeod 1987), we used a range of different size criteria to estimate p_f and to evaluate sample size requirements. Specifically, we calculated the proportion of fines less than 0.85, 6.3, and 9.5 mm for each sample, and used the p_f values and associated standard deviations for each size criteria to evaluate sample size requirements.

We examined the potential implications of observed levels of subsurface fine sediment on Chinook egg-to-fry survival using predictive formulas developed from laboratory studies. Perhaps

the most thorough evaluation of the effects of fine sediment on salmonid survival to emergence was done by Tappel and Bjornn (1983), who evaluated the survival impacts of different combinations of fine sediment including particles less than 0.85 and 9.5 mm. The proportion of fine sediment in the spawning gravels explained approximately 93% of the variability in Chinook survival to emergence. The relationship relating fine sediment to percent survival to emergence s_e was given by:

$$s_e = 93.4 - 0.171 p_{9.5} \cdot p_{0.85} + 3.87 p_{0.85},$$

where $p_{9.5}$ and $p_{0.85}$ denote the percentage of sediment particles in the spawning gravel that is less than 9.5 and 0.85 mm respectively. Note that the spawning gravels used in the study by Tappel and Bjornn (1983) were limited to particles less than 25.4 mm, so it was necessary to truncate our sediment data to exclude particles exceeding this size criteria to ensure comparability with their study results.

We also used an alternative relationship developed by Irving and Bjornn (1984) based on the same data as Tappel and Bjornn (1983) to compare survival estimates based on different size criteria. In this study, the authors developed a relationship between survival to emergence and the percentage of sediment particles smaller than 6.35 mm $p_{6.35}$:

$$s_e = \frac{96.0}{1 + e^{-8.1 + 0.2 p_{6.35}}}.$$

Confidence intervals for survival estimates were computed by inputting the 95% confidence intervals for p9.5, p0.85, and p6.35 estimated from the sediment data into the survival formulas above. The resulting 95% confidence intervals for the survival estimates do not incorporate variability in the predictive relationships from Tappel and Bjornn (1983) and Irving and Bjornn (1984), and as a result, they likely underestimate the amount of variation in predicted survival rates.

Results

Surface Sediment

The percentage of fine sediment (i.e., < 6.3 mm) in surface samples ranged from 3.4 to 13% (mean across sites = 7.5%), with Fly Creek having the highest fine sediment loading of the three sites evaluated (Table 3). The size frequency distribution of streambed particles appeared to be bimodal, with a relatively small peak in particle frequencies occurring between 3.35 and 6.3, and a second larger peak occurring between 45 and 90 mm (Figures 4-6). The fifth percentile, or D5 of the cumulative sediment size distribution, ranged from 2.6 to 10.9 mm (mean across sites = 6.4 mm), with Meadow Creek having largest D5 value (Table 4). Inspection of the cumulative size distribution curves confirms that the surface sediment in the Meadow Creek site had a relatively small proportion of fines (particles < 11 mm) compared with the other two sites (Figures 4-6). Median particle size, or D50 ranged from 42.3 to 54.2 mm (mean across sites = 47.3), with Fly Creek having the largest dominant particle size. Dominant substrate size (i.e., D50) at all three sites met the minimum size criteria of 8-128 mm defined by Schuett-Hames et al. (1999) for identification of usable spawning habitat.

The minimum number of particles in a surface sediment sample required to detect a significant difference in percent fines varied tremendously depending on the proportion of fines (< 6.3 mm) used to represent the *reference* condition p_{ref} and the magnitude of the detectable difference between *reference* and *study* conditions. The minimum sample size necessary to detect a difference of 10% ranged from 113 for the Meadow Creek site (p_{ref} = 3.4%) to 201 for the Fly Creek site (p_{ref} = 13%) (Table 5). In contrast, the sample size required to detect a difference of 1% ranged from 4,831 for the Meadow Creek site to as much as 14,638 for Fly Creek.

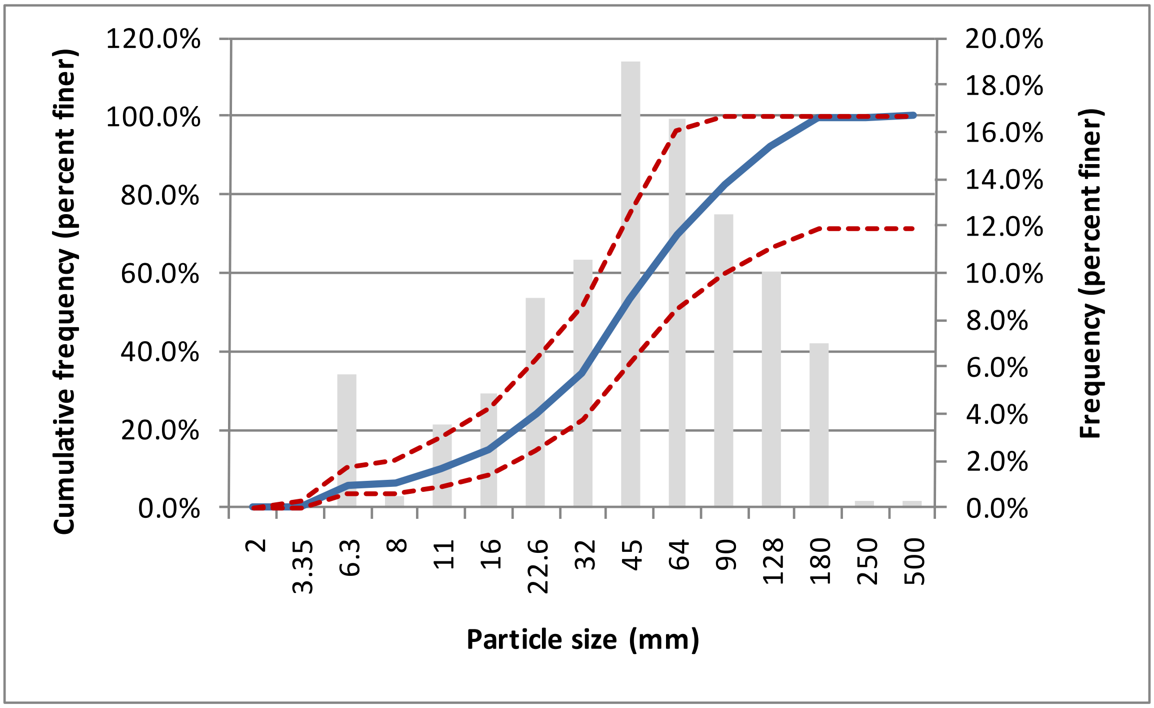

Figure 4. Surface sediment size distribution for the Grande Ronde River upstream of Five Points Creek, summer 2009. Dashed lines denote the 95% confidence interval for the cumulative distribution.

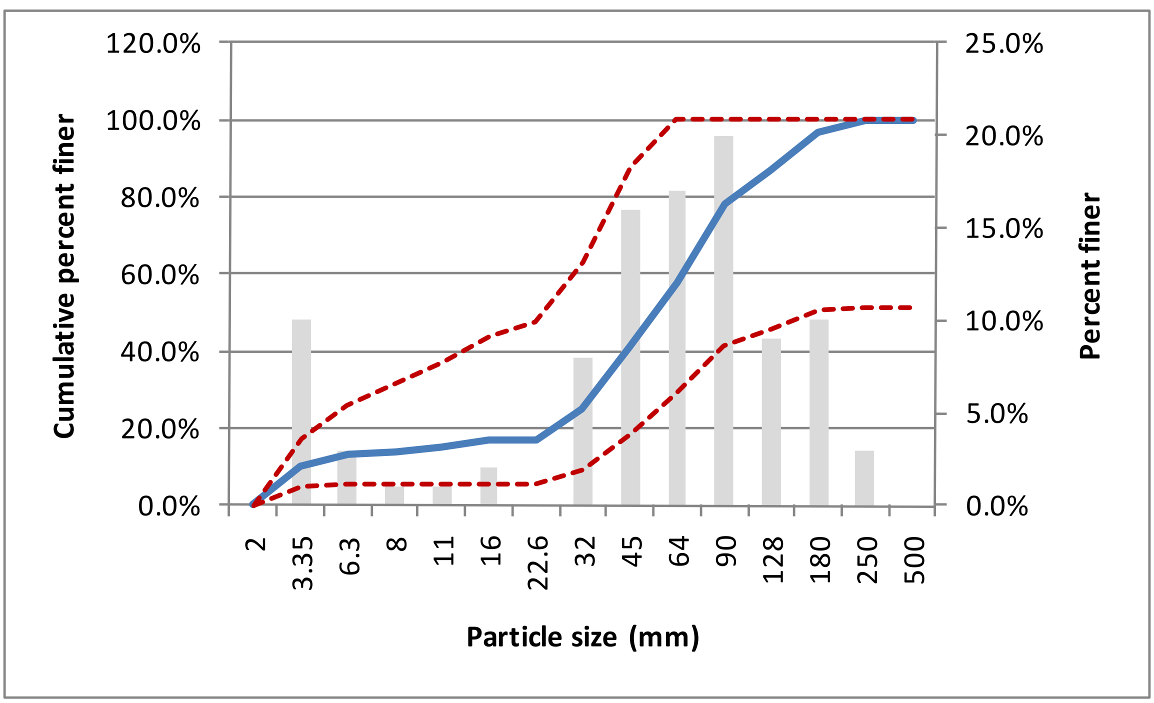

Figure 5. Surface sediment size distribution for Fly Creek at the mouth, summer 2009. Dashed lines denote the 95% confidence interval for the cumulative distribution.

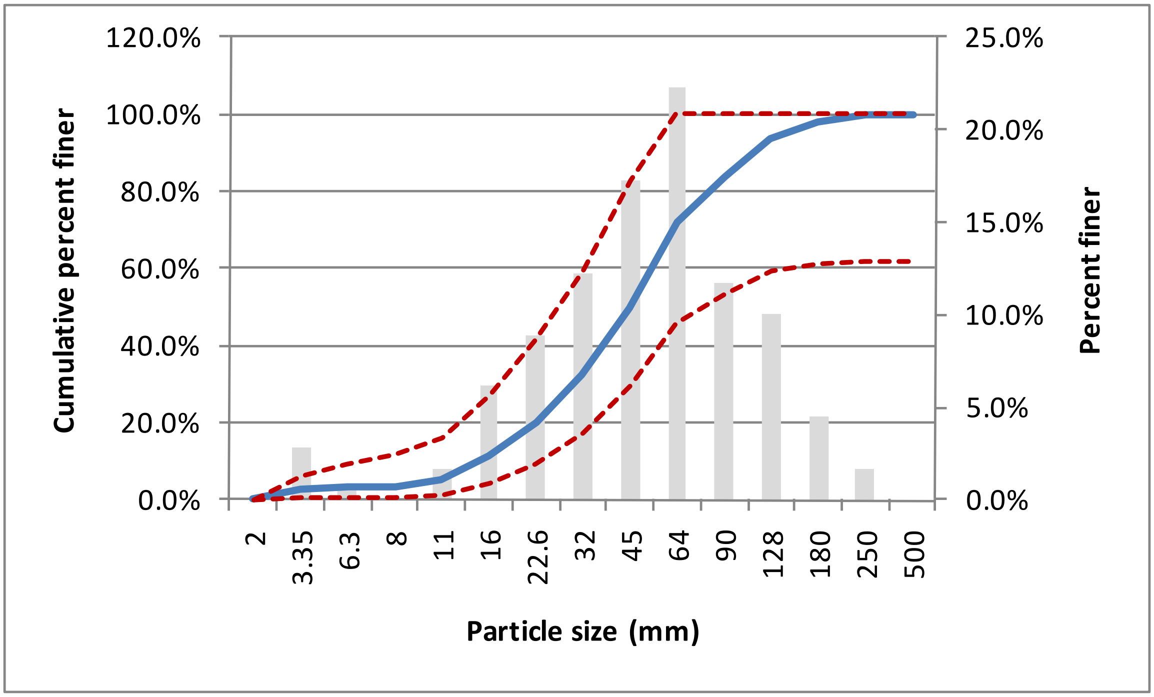

Figure 6. Surface sediment size distribution for Meadow Creek below Bear Creek, summer 2009. Dashed lines denote the 95% confidence interval for the cumulative distribution.

Table 3. Percentage of surface fine sediment measured at three sites in the Grande Ronde River basin in summer, 2009. Calculations of percent finer are provided for three commonly used particle size criteria including 3.35, 6.3, and 9.5 mm.

		95% Confidence Interval	
Particle Size (mm)	Percent Finer	Lower	Upper
Grande Ronde above Five Points Creek			
3.35	0.3	0.0	1.5
6.3	6.0	3.6	10.1
9.5	8.4	4.6	15.2
Fly Creek at mouth			
3.35	10.0	4.9	17.6
6.3	13.0	5.5	26.1
9.5	14.5	5.6	34.5
Meadow Creek below Bear Creek			
3.35	2.8	0.9	6.4
6.3	3.4	0.9	9.5
9.5	4.3	1.1	14.1

Table 4. Percentile values for surface fine sediment particle size (mm) measured at three sites in the Grande Ronde River basin in summer, 2009. Summary statistics across sites include the mean, standard deviation (SD) and coefficient of variation (CV= 100* S.D./mean).

Percentile	Grande Ronde	Fly	Meadow	Average	SD	CV (%)
D5	5.7	2.6	10.9	6.4	4.2	66.0
D16	16.7	13.3	19.3	16.4	3.0	18.4
D50	42.3	54.2	45.2	47.3	6.2	13.1
D84	95.3	113.8	90.6	99.9	12.3	12.3
D95	145.1	168.1	139.7	151.0	15.1	10.0

To establish sample size goals for future sediment work in the Grande Ronde River basin, we selected an absolute detectable difference of 10%. We believe this magnitude of change in fine sediment would have important biological implications for the early life history of spring Chinook salmon in the basin. To be conservative in our assessment of sample size requirements, we used the percentage of fines < 6.3 mm observed at Fly Creek (p_{ref} = 13%), resulting in a sample size goal of approximately 200 (Table 5, gray shading).

According to the bootstrap analysis of the relationship between sample size and CV for each of the three sites, a sample size of 200 would produce estimates of the percentage of particles finer than 6.3 mm with a CV of less than 40% on average (range = 18 – 38%) (Figure 7). Of course, given the limited number of sites that this analysis is based on, and the relatively small number of particles collected at each site, it is reasonable to expect that the CV will exceed 40% at some sites. However, these data represent the best available information to determine sample size goals, and appear to indicate that a sample size of 200 would provide a reasonable tradeoff between precision and time/cost required for data collection and processing.

Table 5. Number of particles in a surface sediment sample required to detect a significant difference in percent fines at α=0.05 and β=0.20 (power = 0.80). Sample size requirements were evaluated for three different reference values for percent fines based on the percentage of fines < 6.3mm observed at Meadow Creek, Grande Ronde, and Fly Creek study sites.

Detectable difference (%)	Meadow Creek p_{ref} = 3.4%	Grande Ronde p_{ref} = 6%	Fly Creek p_{ref} = 13%
1	4831	7713	14638
2	1397	2110	3820
3	704	1018	1768
4	442	617	1034
5	312	423	686
6	237	313	493
7	189	244	375
8	155	197	296
9	131	164	241
10	113	139	201

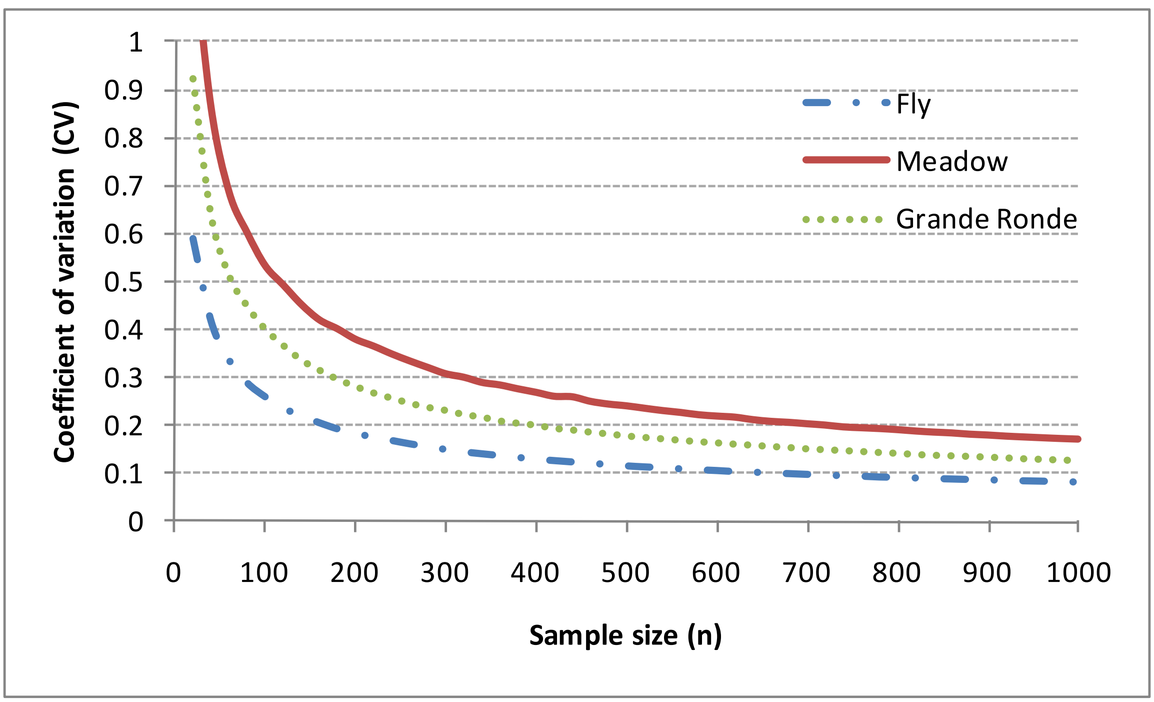

Figure 7. Relationship between sample size and average coefficient of variation (CV) of percent fine sediment < 6.3 mm from 1000 bootstrap replicates. Data for each bootstrap replicate was simulated using estimated proportions for each size class from the observed field data and assuming the counts for each size class were multinomially distributed.

Subsurface sediment

The percentage of fine sediment (i.e., < 6.3 mm) in subsurface samples was generally higher and more consistent across sites than in surface samples with values ranging from 20.5% at Limber Jim Creek to 28.8% at Sheep Creek (mean across sites = 22.9%) (Table 6; Figure 8). As expected, percent fines < 6.3 mm were generally higher using the truncated dataset, with values ranging from 35.5% at Meadow Creek to 42.5% at Sheep Creek (mean across sites = 39.4%) (Table 7). The average D5 in the subsurface ranged from 0.7 mm at Sheep Creek to 1.8 mm at Fly Creek (mean across sites = 1.3 mm) (Table 8). Similarly, median particle size (D50) ranged from 17.3 mm at Sheep Creek to 30.6 mm at Fly Creek (mean across sites = 25.2).

Similar to the surface sediment distributions, the frequency distributions of subsurface particles appeared to have a bimodal distribution with the smaller peak occurring around 2 mm, and the second larger peak occurring around 63 to 90 mm (Figure 9, 11, 13, 15, and 17). Sediment size composition was generally very consistent across individual samples as evidenced by the tight clustering of cumulative distribution curves (Figures 12, 16, and 18), with the exception of Fly Creek (Figure 14) and a single outlier sample in Limber Jim Creek (Figure 10).

The number of subsurface bulk samples required at each site to detect a 10% change in mean percent fines ranged from 3 to 9, depending on the size criteria used to calculate percent fines. Because all three size criteria (i.e., 0.85, 6.3, and 9.5 mm) are potentially useful for evaluating impacts of fine sediment on Chinook survival, we used 9.5 mm as the basis for sample size calculations to be most conservative. Thus, a minimum of 9 bulk samples per site should be collected in future subsurface sampling work to ensure sufficient replication to assess important changes in sediment conditions.

Predicted egg-to-fry survival rates based on sediment size criteria of 0.85 and 9.5 mm (Tappel and Bjornn 1983) ranged from 44.6% for Sheep Creek to 78.5% for Meadow Creek (mean across sites = 62.2%) (Table 10, Figure 19). Using a size criteria of 6.3 mm to define fine sediment

(Irving and Bjornn 1983), predicted survival rates ranged from 38.3% for Sheep Creek to 70.3% for Meadow Creek (mean across sites = 52.8%). Survival rates based on the Tappel and Bjornn (1983) formula were generally higher than estimates from the Irving and Bjornn (1984) formula. In addition, 95% confidence intervals were generally narrower using the Tappel and Bjornn (1983) formula, with the exception of Sheep Creek, which had a confidence interval of 0 to 77.7%. This wide confidence interval for the Sheep Creek resulted from a relatively large amount of variability in the percent fines < 0.85 mm.

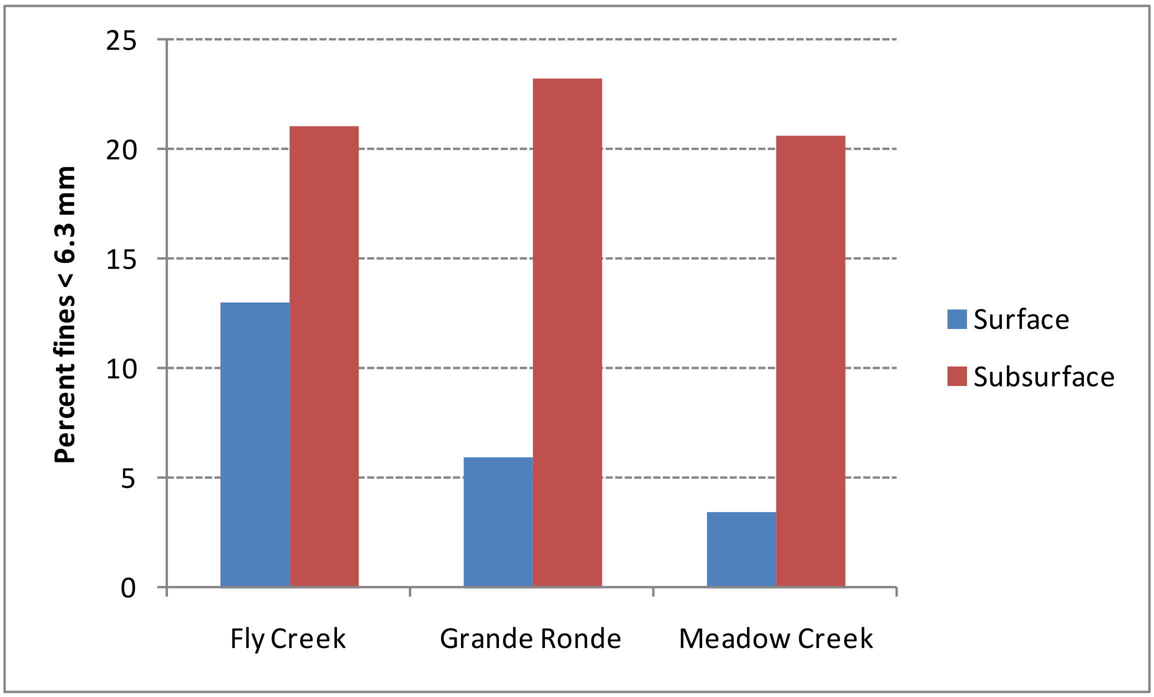

Figure 8. Comparison of percent fines < 6.3 mm between surface and subsurface sediment samples for three sites in the Upper Grande Ronde Basin, summer 2009.

Table 6. Percentage of fine sediment in subsurface bulk samples (non-truncated data) measured at five sites in the Grande Ronde River basin in summer, 2009. Calculations of percent finer are provided for four commonly used particle size criteria including 0.85, 3.35, 6.3, and 9.5 mm. Summary statistics at each site include the mean percent finer, sample size (n), standard deviation (SD), standard error (SE), coefficient of variation (CV= 100* S.D./mean) and 95% confidence intervals.

						95% Confidence Interval	
Particle Size (mm)	Avg. percent finer	n	SD	SE	CV	Lower	Upper
Fly Creek at Mouth							
0.85	2.3	5	1.1	0.5	46.6	1.0	3.6
3.35	13.7	5	6.8	3.0	49.2	5.3	22.1
6.3	21.1	5	9.5	4.2	44.9	9.3	32.9
9.5	27.1	5	11.4	5.1	42.2	12.9	41.3
Grande Ronde River above Five Points Creek							
0.85	3.8	4	1.5	0.8	41.1	1.3	6.2
3.35	15.3	4	4.5	2.2	29.3	8.2	22.4
6.3	23.3	4	5.3	2.6	22.7	14.8	31.7
9.5	30.6	4	5.4	2.7	17.8	21.9	39.2
Limber Jim Creek at Mouth							
0.85	4.7	5	1.7	0.8	37.4	2.5	6.8
3.35	14.6	5	6.0	2.7	41.2	7.1	22.1
6.3	20.5	5	8.5	3.8	41.2	10.0	31.0
9.5	25.6	5	10.1	4.5	39.3	13.1	38.2
Meadow Creek above Bear Creek							
0.85	2.1	4	0.8	0.4	39.5	0.8	3.4
3.35	13.3	4	3.1	1.5	22.9	8.5	18.2
6.3	20.7	4	3.9	2.0	19.0	14.4	26.9
9.5	27.4	4	5.0	2.5	18.3	19.4	35.4
Sheep Creek at Road Junction							
0.85	6.0	4	2.1	1.0	34.4	2.7	9.3
3.35	19.2	4	1.2	0.6	6.1	17.3	21.0
6.3	28.8	4	2.4	1.2	8.3	25.0	32.6
9.5	36.9	4	3.3	1.6	8.9	31.6	42.1
Average							
0.85	3.8	4.4	1.4	0.7	39.8	1.7	5.9
3.35	15.2	4.4	4.3	2.0	29.7	9.3	21.2
6.3	22.9	4.4	5.9	2.8	27.2	14.7	31.0
9.5	29.5	4.4	7.1	3.3	25.3	19.8	39.2

Table 7. Percentage of fine sediment in subsurface bulk samples (truncated data[a]) measured at five sites in the Grande Ronde River basin in summer, 2009. Calculations of percent finer are provided for four commonly used particle size criteria including 0.85, 3.35, 6.3, and 9.5 mm. Summary statistics at each site include the mean percent finer, sample size (n), standard deviation (SD), standard error (SE), coefficient of variation (CV= 100* S.D./mean) and 95% confidence intervals.

						95% Confidence Interval	
Particle Size (mm)	Avg. percent finer	n	SD	SE	CV	Lower	Upper
Fly Creek at Mouth							
0.85	4.5	5	0.8	0.4	18.6	3.4	5.5
3.35	26.5	5	7.3	3.3	27.5	17.4	35.5
6.3	41.2	5	8.2	3.7	19.8	31.1	51.4
9.5	53.5	5	8.0	3.6	14.9	43.6	63.4
Grande Ronde River above Five Points Creek							
0.85	6.7	4	2.3	1.2	34.7	3.0	10.3
3.35	27.3	4	6.1	3.0	22.3	17.6	37.0
6.3	41.7	4	6.1	3.1	14.6	32.0	51.5
9.5	55.0	4	4.9	2.5	9.0	47.2	62.9
Limber Jim Creek at Mouth							
0.85	8.3	5	1.5	0.7	17.8	6.5	10.2
3.35	25.4	5	5.6	2.5	22.0	18.4	32.3
6.3	35.8	5	8.0	3.6	22.2	25.9	45.7
9.5	45.0	5	8.5	3.8	19.0	34.4	55.6
Meadow Creek above Bear Creek							
0.85	3.6	4	1.2	0.6	32.6	1.7	5.4
3.35	22.8	4	3.5	1.7	15.3	17.3	28.4
6.3	35.5	4	3.4	1.7	9.5	30.1	40.8
9.5	47.0	4	3.0	1.5	6.3	42.3	51.8
Sheep Creek at Road Junction							
0.85	9.0	4	3.3	1.7	37.2	3.7	14.3
3.35	28.3	4	0.7	0.4	2.5	27.2	29.5
6.3	42.5	4	3.2	1.6	7.5	37.5	47.6
9.5	54.5	4	4.2	2.1	7.8	47.7	61.3
Average							
0.85	6.4	4.4	1.8	0.9	28.2	3.7	9.1
3.35	26.1	4.4	4.6	2.2	17.9	19.6	32.5
6.3	39.4	4.4	5.8	2.7	14.7	31.3	47.4
9.5	51.0	4.4	5.7	2.7	11.4	43.0	59.0

[a]Data were truncated at 31.5mm (i.e., all particles > 31.5mm were excluded from the sample) to correspond as closely as possible with a study by Tappel and Bjornn (1983), who truncated their samples at 25.4 mm.

Table 8. Percentile values for sediment particle size distributions from subsurface bulk samples (non-truncated data) measured at five sites in the Grande Ronde River basin in summer, 2009.

						95% Confidence Interval	
Percentile	Avg. Particle Size (mm)	n	SD	SE	CV	Lower	Upper
Fly Creek at Mouth							
D5	1.8	5	1.2	0.5	69.4	0.2	3.3
D16	5.8	5	4.4	2.0	75.5	0.4	11.3
D50	30.6	5	14.6	6.5	47.8	12.4	48.7
D84	69.9	5	8.7	3.9	12.4	59.1	80.7
D95	83.2	5	3.1	1.4	3.7	79.3	87.0
Grande Ronde River above Five Points Creek							
D5	1.1	4	0.4	0.2	36.3	0.5	1.7
D16	3.8	4	1.8	0.9	46.1	1.0	6.6
D50	24.7	4	6.5	3.3	26.5	14.2	35.1
D84	63.2	4	8.5	4.2	13.4	49.8	76.7
D95	79.7	4	4.3	2.1	5.4	72.9	86.5
Limber Jim Creek at Mouth							
D5	1.4	5	1.4	0.6	97.7	0.0	3.1
D16	6.0	5	6.5	2.9	107.3	0.0	14.1
D50	28.1	5	13.8	6.2	49.0	11.0	45.2
D84	59.5	5	15.5	6.9	26.1	40.2	78.8
D95	72.4	5	14.9	6.6	20.5	53.9	90.8
Meadow Creek above Bear Creek							
D5	1.4	4	0.4	0.2	28.8	0.8	2.1
D16	4.5	4	1.6	0.8	35.5	2.0	7.0
D50	25.1	4	7.2	3.6	28.7	13.7	36.6
D84	60.3	4	11.5	5.8	19.1	42.0	78.7
D95	75.3	4	12.5	6.3	16.6	55.4	95.2
Sheep Creek at Road Junction							
D5	0.7	4	0.2	0.1	31.5	0.4	1.1
D16	2.6	4	0.2	0.1	9.2	2.2	3.0
D50	17.3	4	2.5	1.3	14.7	13.3	21.4
D84	53.9	4	7.7	3.9	14.4	41.6	66.2
D95	73.2	4	11.6	5.8	15.8	54.7	91.6
Average							
D5	1.3	4.4	0.7	0.3	52.7	0.4	2.3
D16	4.6	4.5	2.9	1.3	54.8	1.1	8.4
D50	25.2	4.5	8.9	4.2	33.3	12.9	37.4
D84	61.4	4.5	10.4	4.9	17.1	46.5	76.2
D95	76.7	4.5	9.3	4.4	12.4	63.3	90.2

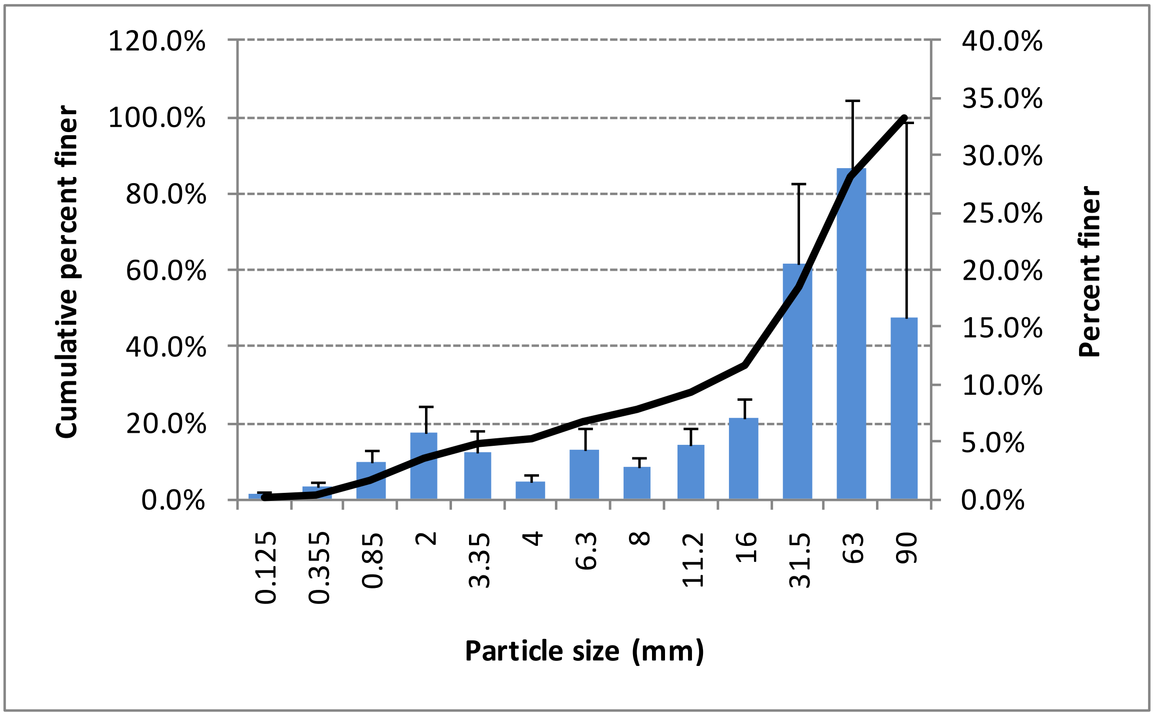

Figure 9. Average sediment size distribution from subsurface bulk samples collected in Limber Jim Creek near the mouth, summer 2009. Error bars denote the standard deviation of the percent finer for each size class.

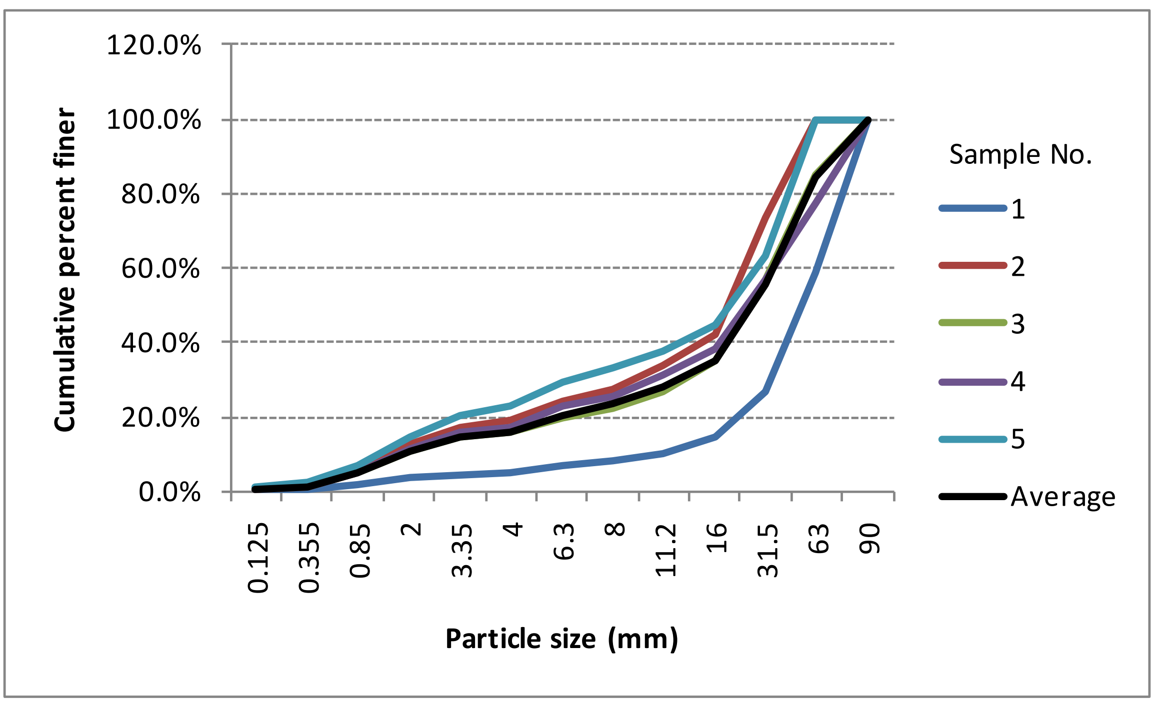

Figure 10. Cumulative sediment size distribution from individual subsurface bulk samples collected in Limber Jim Creek near the mouth, summer 2009.

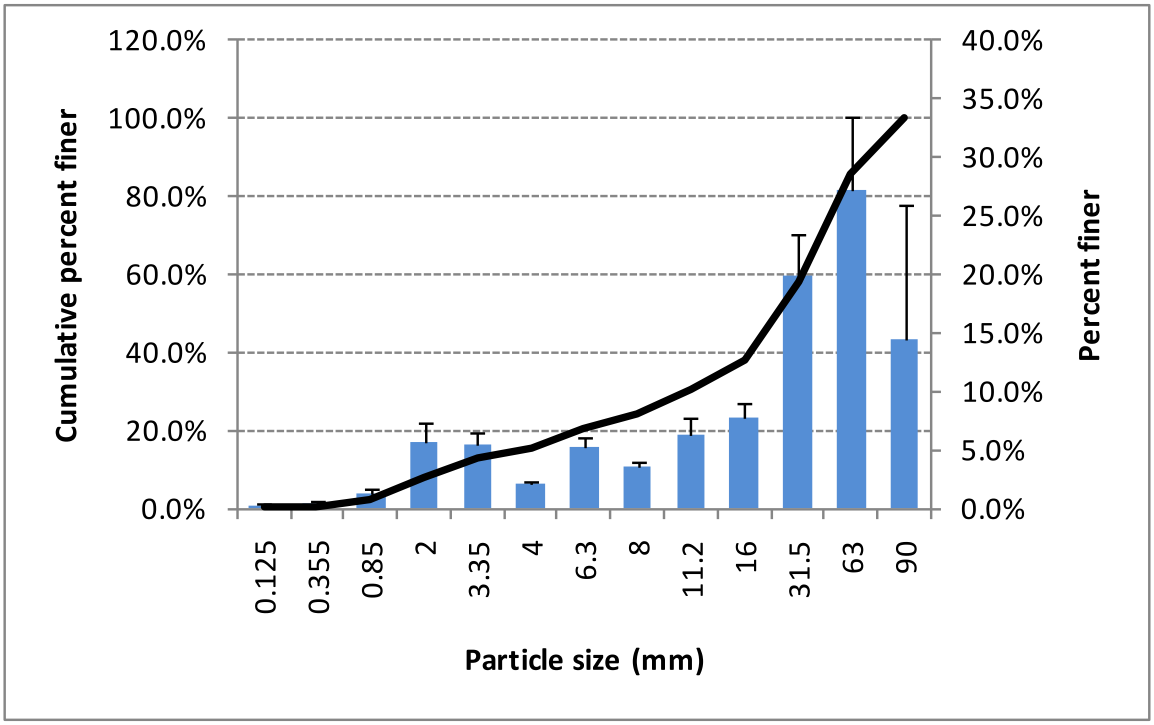

Figure 11. Average sediment size distribution from subsurface bulk samples collected in Meadow Creek below Bear Creek, summer 2009. Error bars denote the standard deviation of the percent finer for each size class.

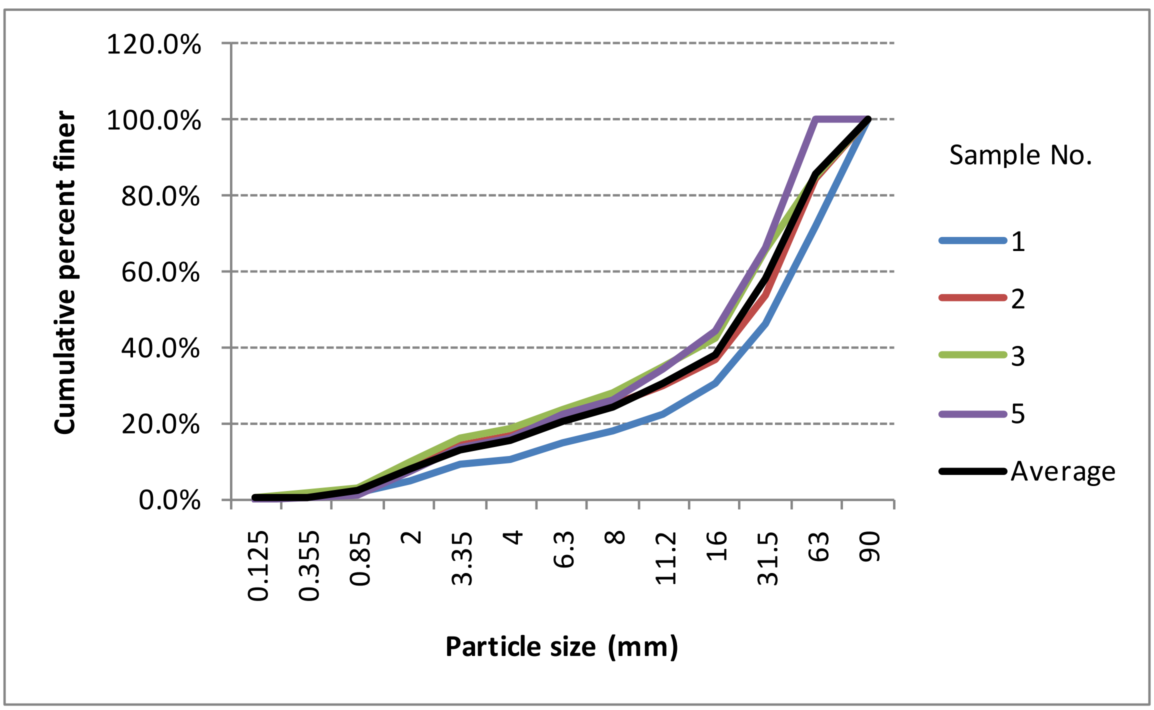

Figure 12. Cumulative sediment size distribution from individual subsurface bulk samples collected in Meadow Creek below Bear Creek, summer 2009.

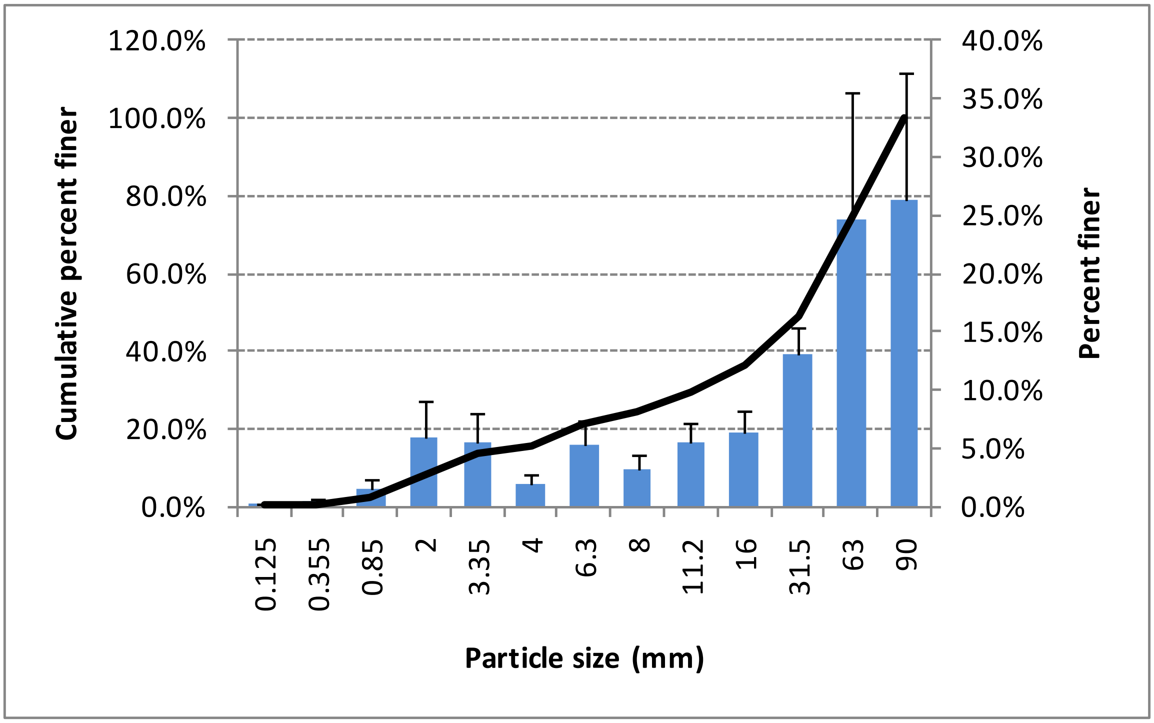

Figure 13. Average sediment size distribution from subsurface bulk samples collected in Fly Creek near the mouth, summer 2009. Error bars denote the standard deviation of the percent finer for each size class.

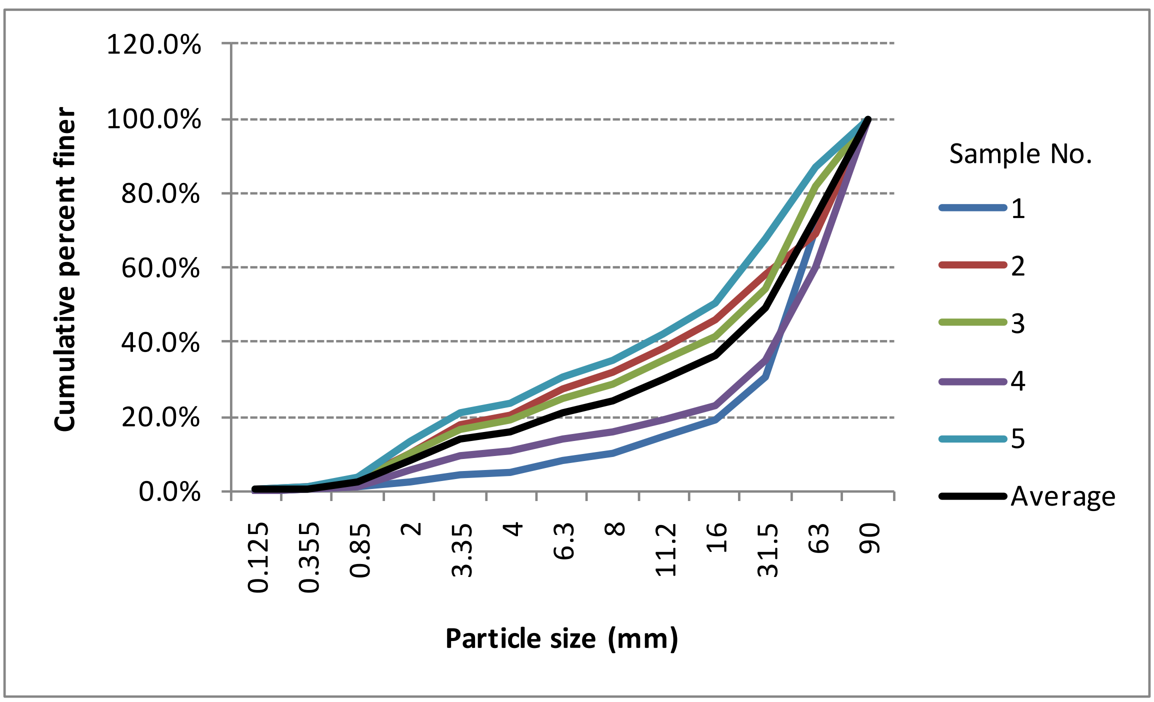

Figure 14. Cumulative sediment size distribution from individual subsurface bulk samples collected in Fly Creek near the mouth, summer 2009.

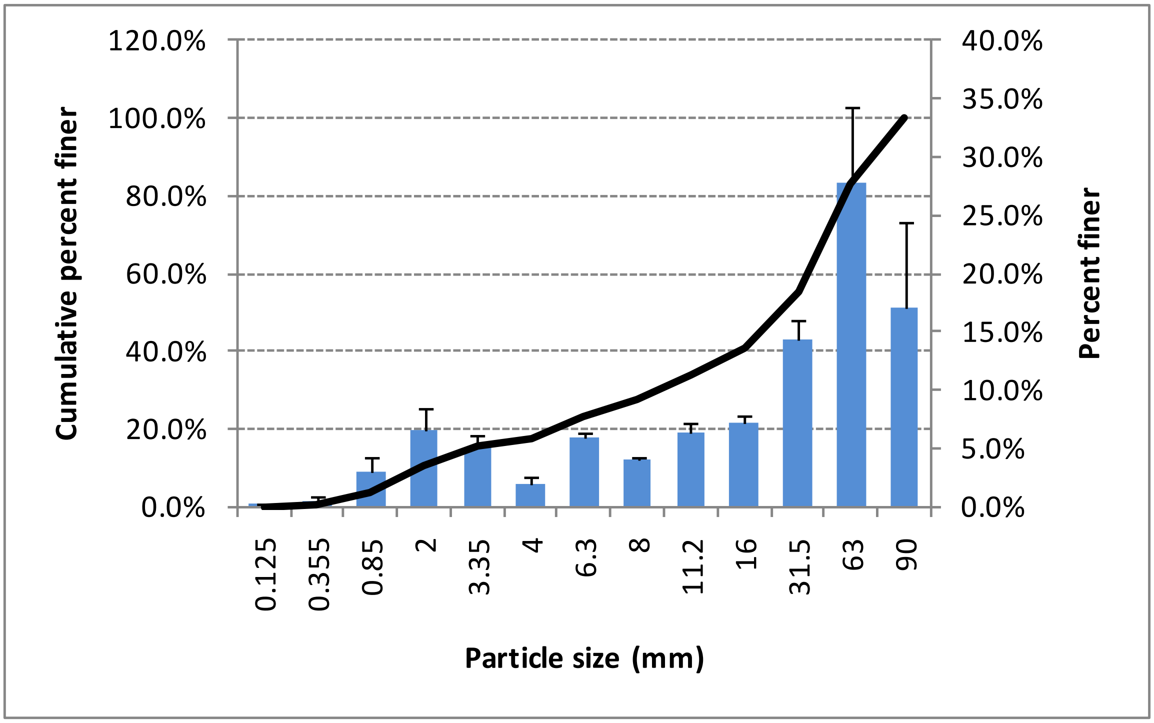

Figure 15. Average sediment size distribution from subsurface bulk samples collected in the Grande Ronde River above Five Points Creek, summer 2009. Error bars denote the standard deviation of the percent finer for each size class.

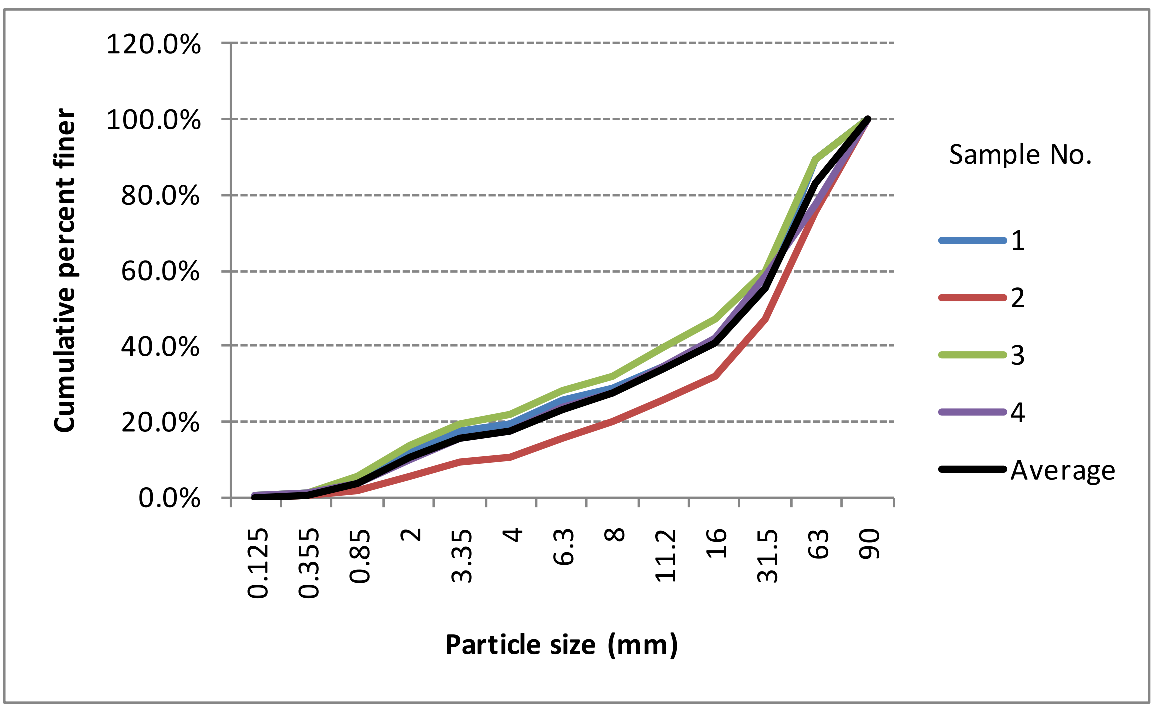

Figure 16. Cumulative sediment size distribution from individual subsurface bulk samples collected in the Grande Ronde River above Five Points Creek, summer 2009.

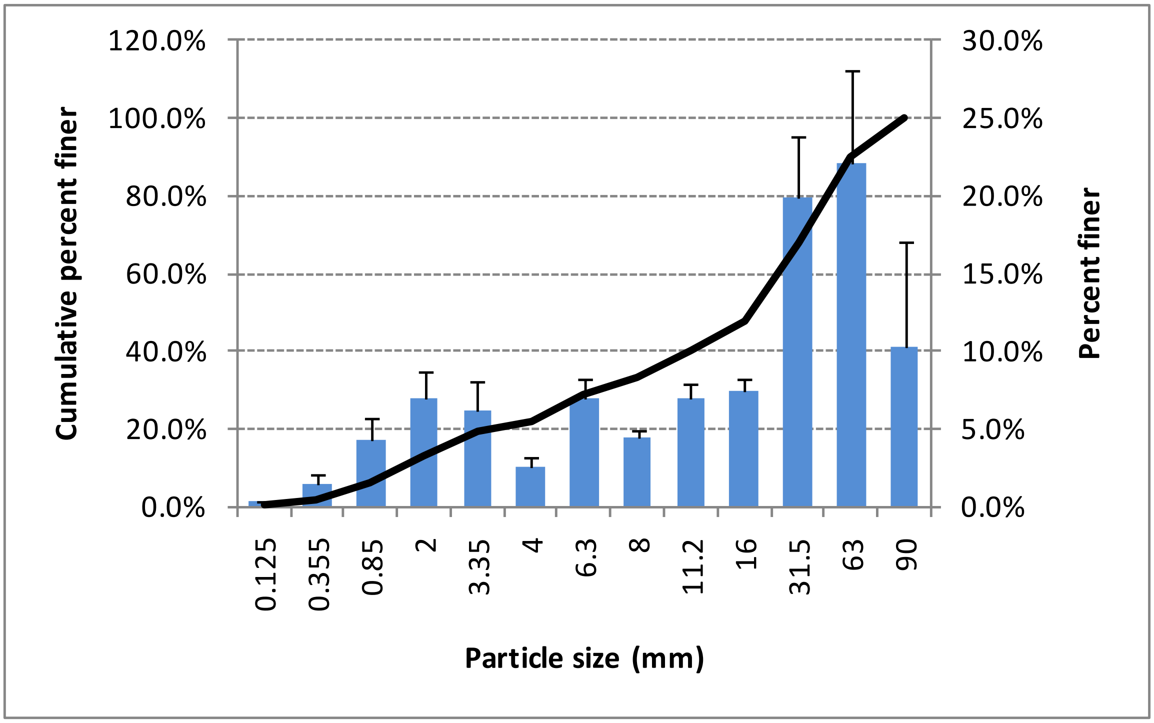

Figure 17. Average sediment size distribution from subsurface bulk samples collected in Sheep Creek at the road junction, summer 2009. Error bars denote the standard deviation of the percent finer for each size class.

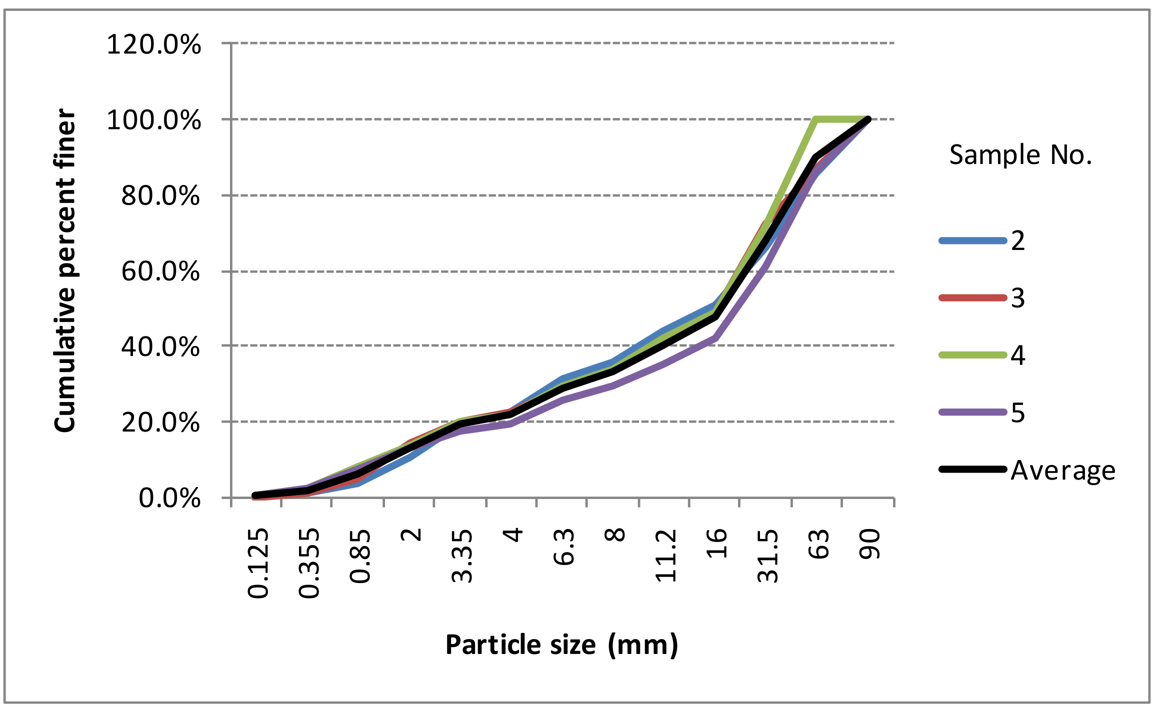

Figure 18. Cumulative sediment size distribution from individual subsurface bulk samples collected in Sheep Creek at the road junction, summer 2009.

Table 9. Number of subsurface bulk samples required per site to detect a significant difference in mean percent fines at α=0.05 and β=0.20 (power = 0.80) based on the mean and variance of particle sizes less than 0.85, 6.3, and 9.5mm.

Detectable difference	p < 0.85 mm	p < 6.3 mm	p < 9.5 mm
1.0%	62	644	648
2.0%	17	163	164
3.0%	9	73	74
4.0%	6	42	42
5.0%	5	28	28
6.0%	4	20	20
7.0%	4	15	15
8.0%	3	12	12
9.0%	3	10	10
10.0%	3	9	9

Table 10. Predicted egg-to-fry survival and associated 95% confidence intervals for five sites in the Grande Ronde River basin using two different predictive formulas.

		95% Confidence Interval	
Site	Survival est.	Lower	Upper
p_f < 0.85 and 9.5mm (Tappel and Bjornn 1983)			
Limber Jim	61.6	36.2	80.4
Meadow	78.5	66.4	87.6
Fly	69.7	54.9	81.0
Grande Ronde	56.5	22.2	80.9
Sheep	44.6	0.0	77.7
p_f < 6.3 mm (Irving and Bjornn 1983)			
Limber Jim	69.0	25.1	91.1
Meadow	70.3	46.5	85.3
Fly	44.5	9.8	83.3
Grande Ronde	42.1	9.7	81.2
Sheep	38.3	18.7	62.0

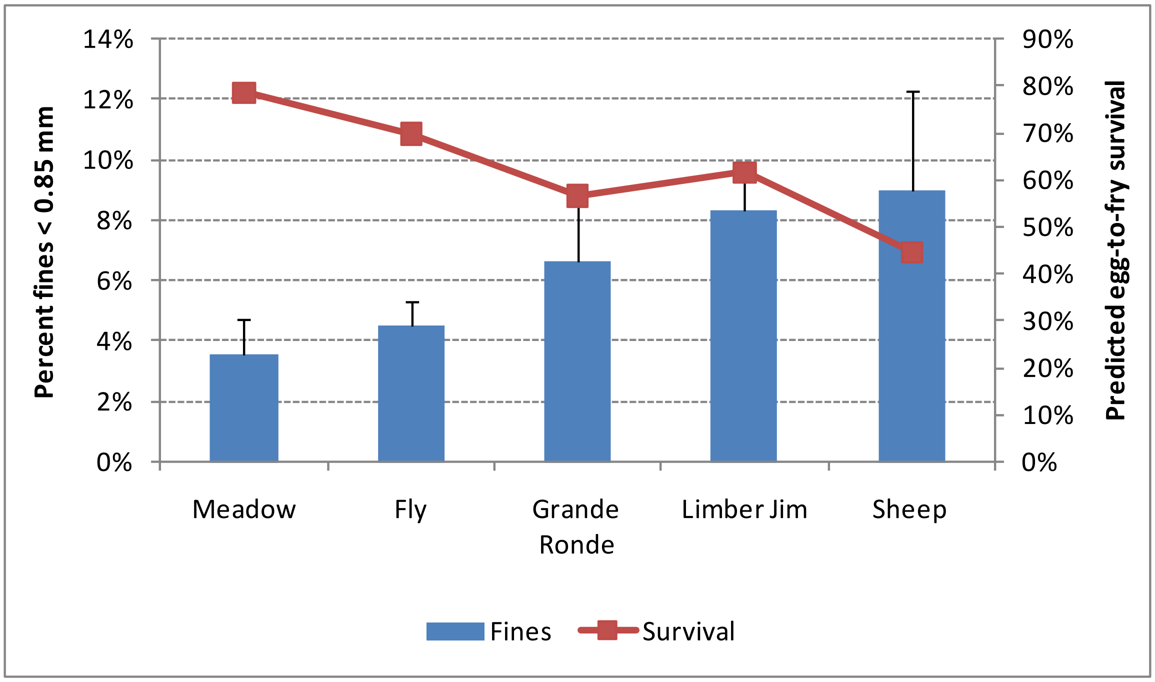

Figure 19. Average percent fines < 0.85mm in subsurface bulk samples and predicted egg-to-fry survival for five sites in the Grande Ronde River basin. Survival estimates are based on results from Tappel and Bjornn (1983).

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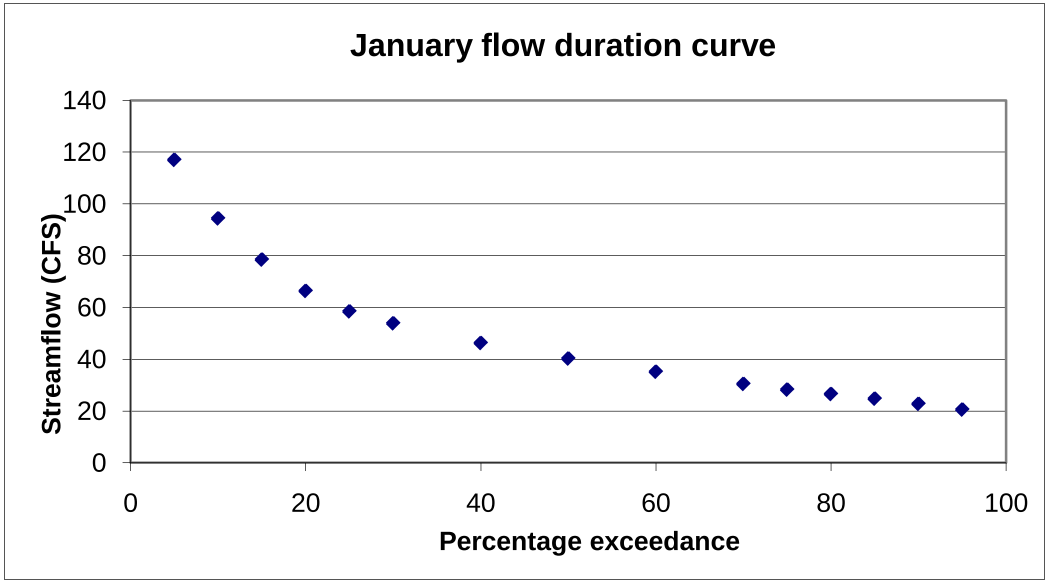
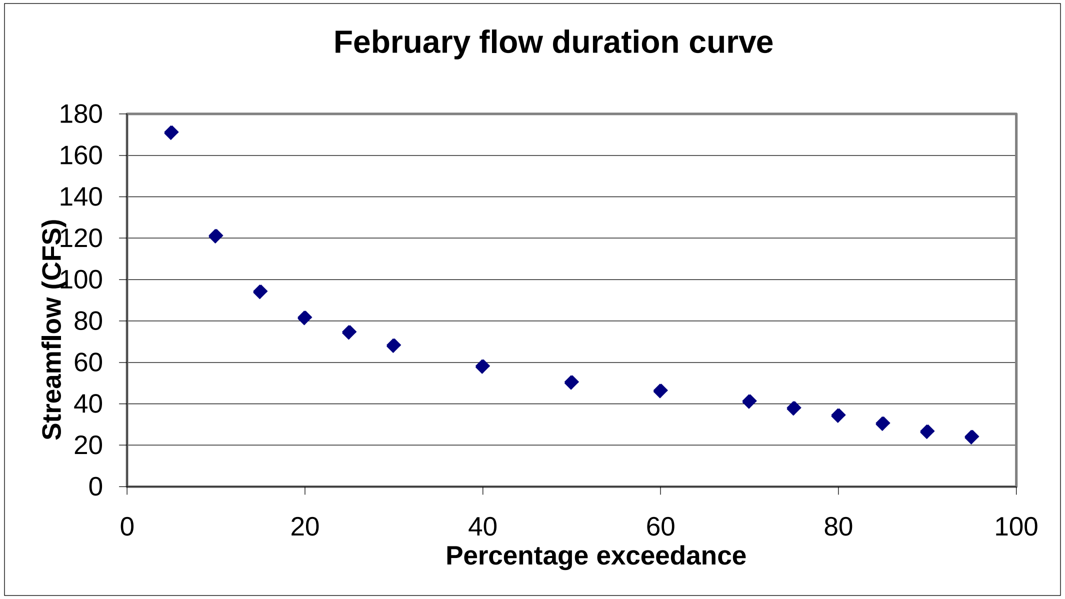
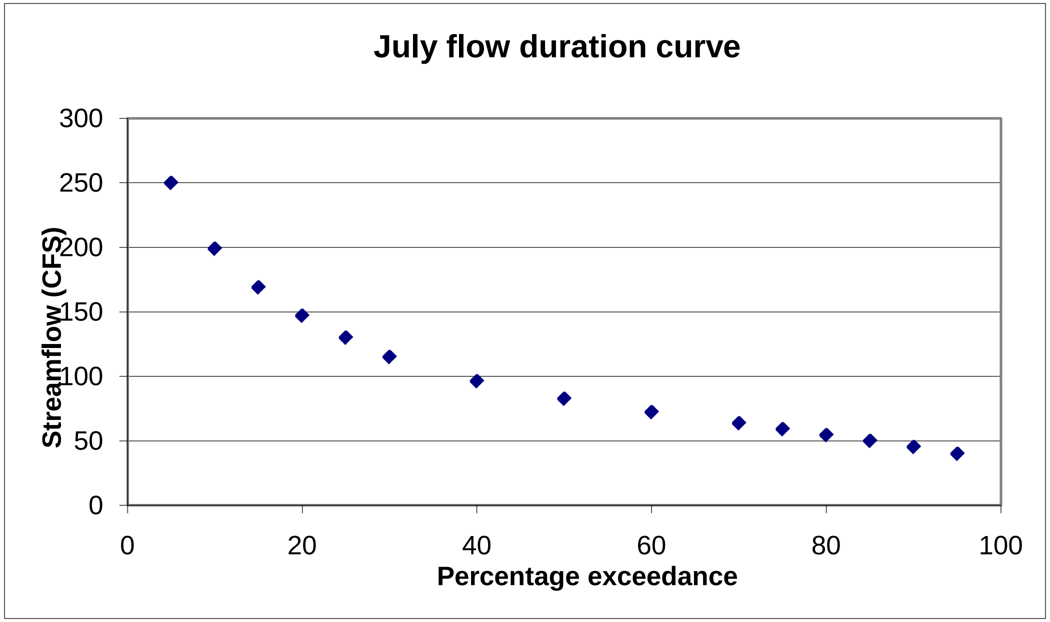
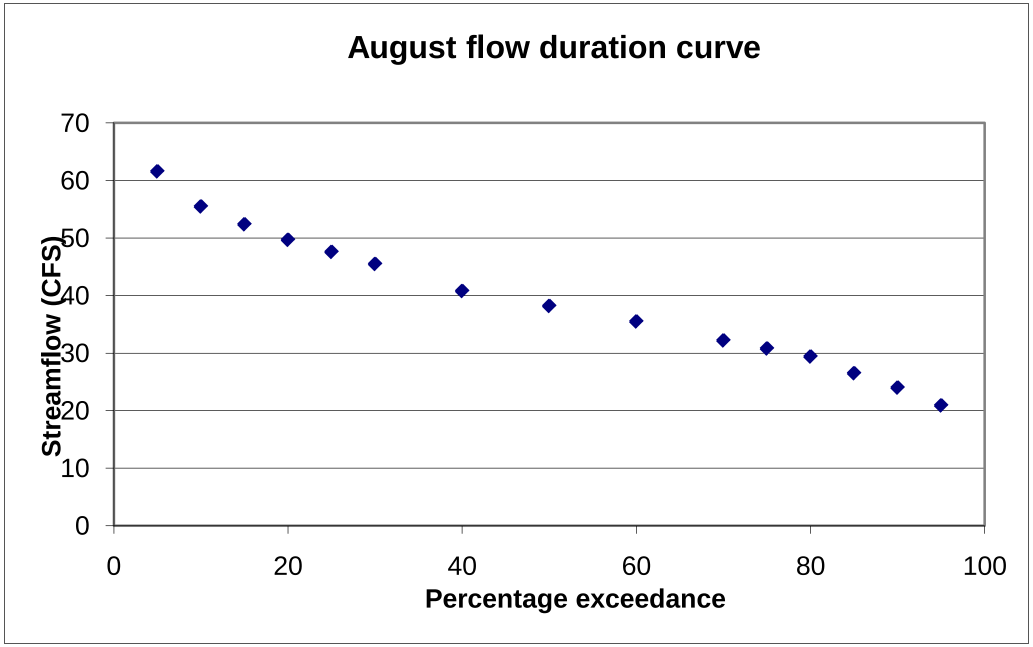
Appendix I

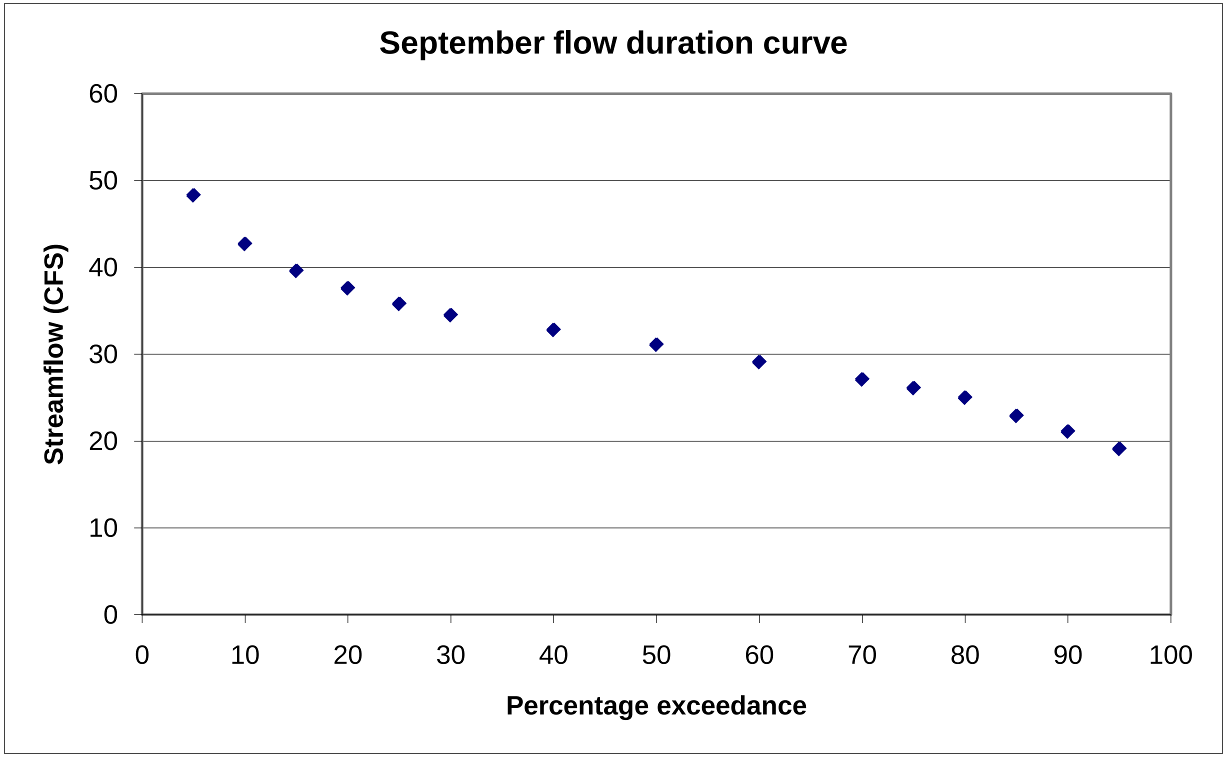
Preliminary Analysis of Data from Oregon Water Resources Department


January flow duration curve
Streamflow (CFS)
0
20
40
60
80
100
120
140
0
20
40
60
80
100
Percentage exceedance


February flow duration curve
Streamflow (CFS)
0
20
40
60
80
100
120
140
160
180
0
20
40
60
80
100
Percentage exceedance


July flow duration curve
Streamflow (CFS)
300
250
200
150
100
50
0
0
20
40
60
80
100
Percentage exceedance


August flow duration curve
Streamflow (CFS)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Percentage exceedance


September flow duration curve
Streamflow (CFS)
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90
100
Percentage exceedance

MONTHLY FLOW DURATION CURVES
CATHERINE CR NR UNION, OR
13320000

Mth	95	90	85	80	50
10	20	21.7	23.3	24.6	29.5
11	21.3	23.7	25.3	26.7	34
12	20.2	22.9	24.3	25.6	36.8
1	20.6	22.8	24.8	26.6	40.3
2	23.9	26.5	30.4	34.3	50.3
3	26.6	35.6	42.4	47.9	76
4	70.8	86.2	97.5	108	175
5	137	183	217	240	351
6	88.6	114	148	175	307
7	39.9	45.2	49.9	54.4	82.6
8	20.9	24	26.5	29.4	38.2
9	19.1	21.1	22.9	25	31.1

Compare ratios of monthly flow statistics between Catherine Cr. and GR at Hilgard

95/80	95/50	80/50
0.813	0.678	0.834
0.798	0.626	0.785
0.789	0.549	0.696
0.774	0.511	0.660
0.697	0.475	0.682
0.555	0.350	0.630
0.656	0.405	0.617
0.571	0.390	0.684
0.506	0.289	0.570
0.733	0.483	0.659
0.711	0.547	0.770
0.764	0.614	0.804

Grande Ronde nr Hilgard (copied from spreadsheet: Grande Ronde nr Hilgard OR-flow duration.xls

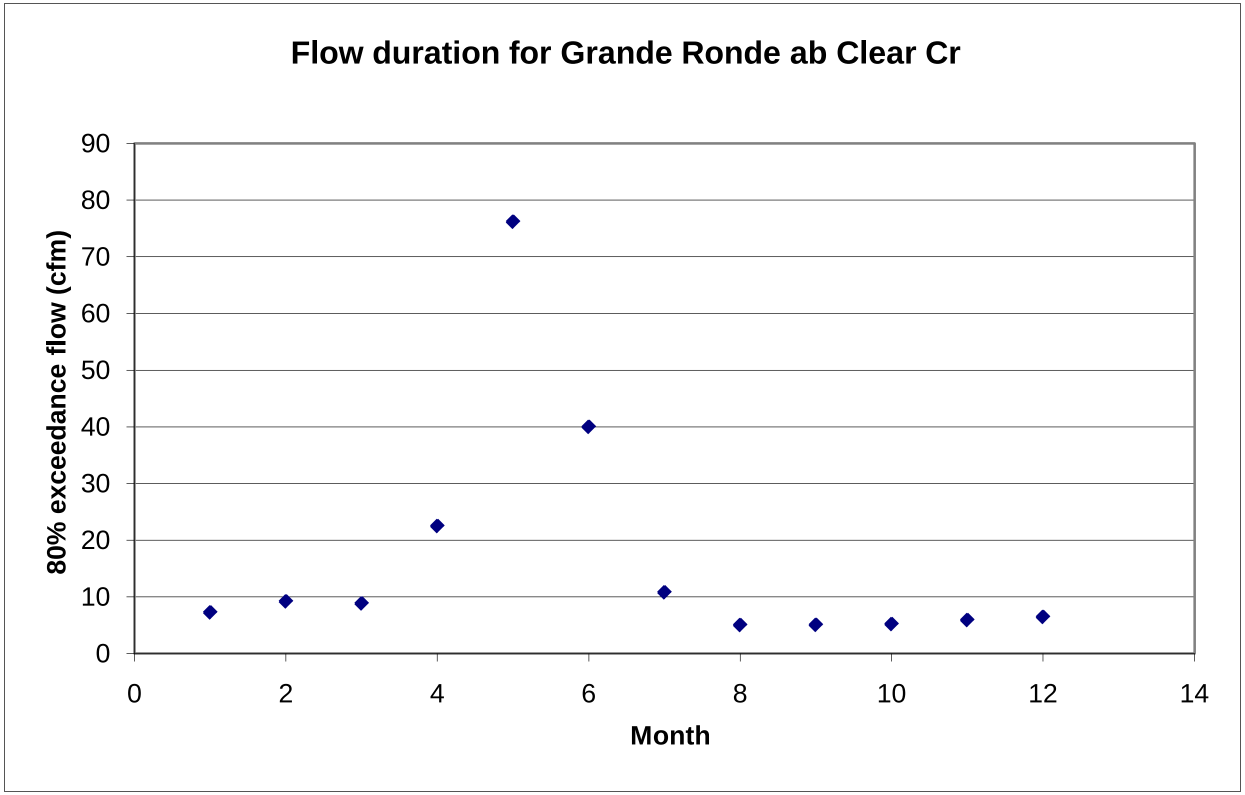
95/50	95/80	80/50
0.544	0.780	0.697
0.503	0.759	0.663
0.336	0.602	0.558
0.372	0.683	0.545
0.231	0.614	0.376
0.234	0.490	0.477
0.355	0.563	0.630
0.311	0.510	0.609
0.277	0.567	0.488
0.345	0.607	0.568
0.509	0.722	0.706
0.584	0.799	0.730

Grande Ronde above Clear Creek

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
1	7.26	0.26	3.6	0	0	0	0	0	0	2.1
2	9.20	0.33	4.5	0	0	0	0	0	0	3.2
3	8.84	0.32	4.4	0	0	0	0	0	0	7.46
4	22.50	0.81	11.1	0	0	0	0	0	0	16.4
5	76.20	2.75	37.6	0	0	0	0	0	0	38.8
6	40.00	1.45	19.8	0	0	0	0	0	0	45.8
7	10.80	0.39	5.3	0	0	0	0	0	0	5
8	5.03	0.18	2.5	0	0	0	0	0	0	2.37
9	5.06	0.18	2.5	0	0	0	0	0	0	1.3
10	5.20	0.19	2.6	0	0	0	0	0	0	2.11
11	5.91	0.21	2.9	0	0	0	0	0	0	3.76
12	6.46	0.23	3.2	0	0	0	0	0	0	4.04

Stream:	GRANDE	RONDE	R	>	SNAKE	R	-	AB	CLEAR	CR	
WAB	ID	#:	30810415#		WABS	ABOVE:		0			

Area	27.67		0	0			
Relief	3000		0	0			
Slope	15.6		0	0			
Elevation	6130		0	0			
MAP	42.2		0	0			
Jan	Min	T		8.96	0	0	
Jul	Min	T		38	0	0	
Yield	19.61		0	0			



Flow duration for Grande Ronde ab Clear Cr
80% exceedance flow (cfm)
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
Month

Grande Ronde above Clear Creek

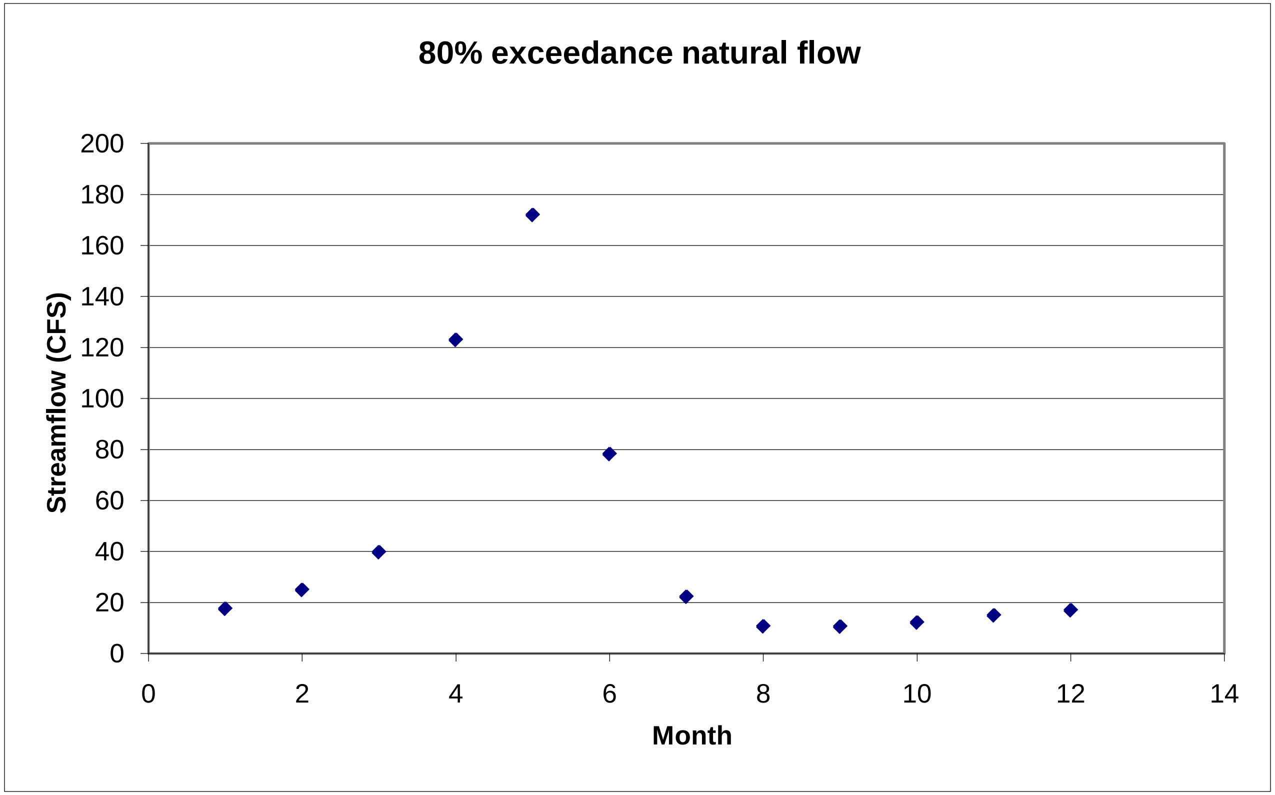
	ft3	m3
1	7.26	0.21
2	9.2	0.26
3	8.84	0.25
4	22.5	0.64
5	76.2	2.16
6	40	1.13
7	10.8	0.31
8	5.03	0.14
9	5.06	0.14
10	5.2	0.15
11	5.91	0.17
12	6.46	0.18

Grande Ronde ab Fly Cr-natural flow-80% duration.xls

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
Stream:	GRANDE	RONDE	R	>	SNAKE	R	-	AB	FLY	CR
WAB	ID	#:	30810414#		WABS	ABOVE:		4		
1	17.5	0.1	3.2	16.9	0.2	3.5	0.6	0.0	0.9	14.3
2	24.9	0.2	4.6	20.9	0.2	4.3	4.0	0.1	6.4	27.4
3	39.7	0.3	7.3	30.7	0.3	6.4	9.0	0.3	14.5	41.9
4	123.0	0.8	22.7	97.0	0.9	20.2	26.0	0.8	42.0	63.0
5	172.0	1.2	31.7	160.0	1.4	33.3	11.9	0.4	19.2	100.0
6	78.2	0.5	14.4	76.0	0.7	15.8	2.2	0.1	3.6	81.8
7	22.2	0.2	4.1	21.9	0.2	4.6	0.3	0.0	0.5	15.1
8	10.6	0.1	2.0	10.6	0.1	2.2	0.0	0.0	0.0	6.0
9	10.5	0.1	1.9	9.9	0.1	2.1	0.6	0.0	1.0	4.1
10	12.1	0.1	2.2	10.3	0.1	2.1	1.8	0.1	2.9	4.6
11	14.9	0.1	2.8	11.8	0.1	2.5	3.1	0.1	5.0	7.3
12	16.9	0.1	3.1	14.5	0.1	3.0	2.4	0.1	3.9	10.4

Area		145.7	113.9	31.78		
Relief		4000********	********			
Slope		15.1	14.3	17.8		
Elevation		5360	5520	4800		
MAP		34.4	35.7	30		
Jan	Min	T		11	10.5	12.9
Jul	Min	T		40.2	39.6	42.2
Yield		12.25	13.39	7.36		

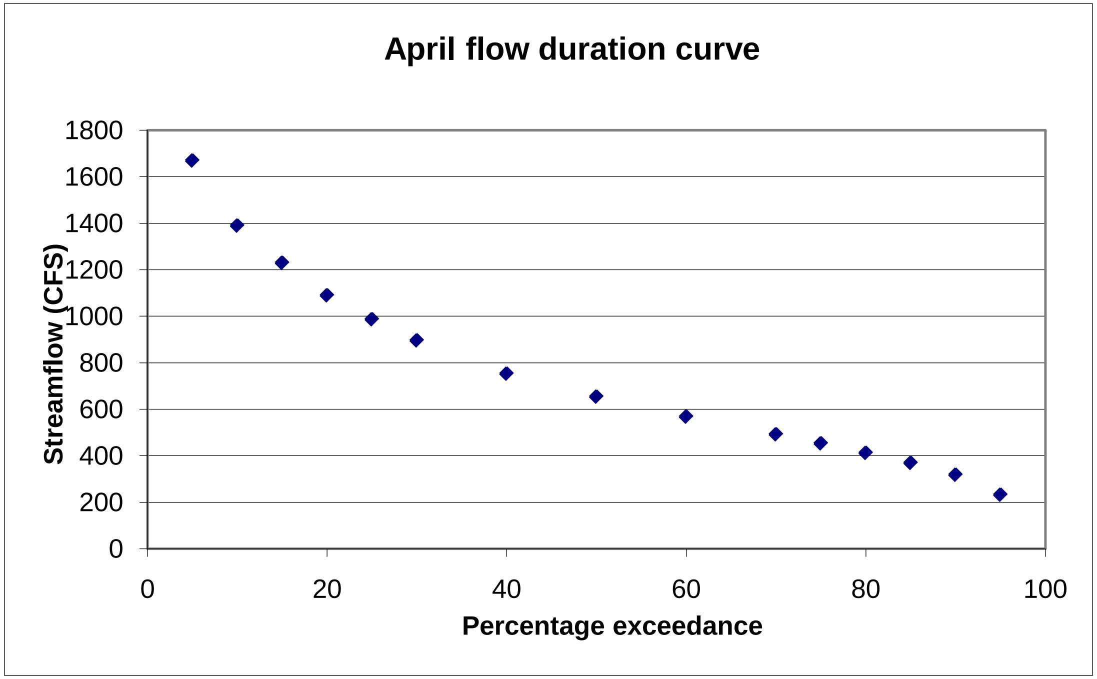
Grande Ronde ab Fly Cr-natural flow-80% duration.xls

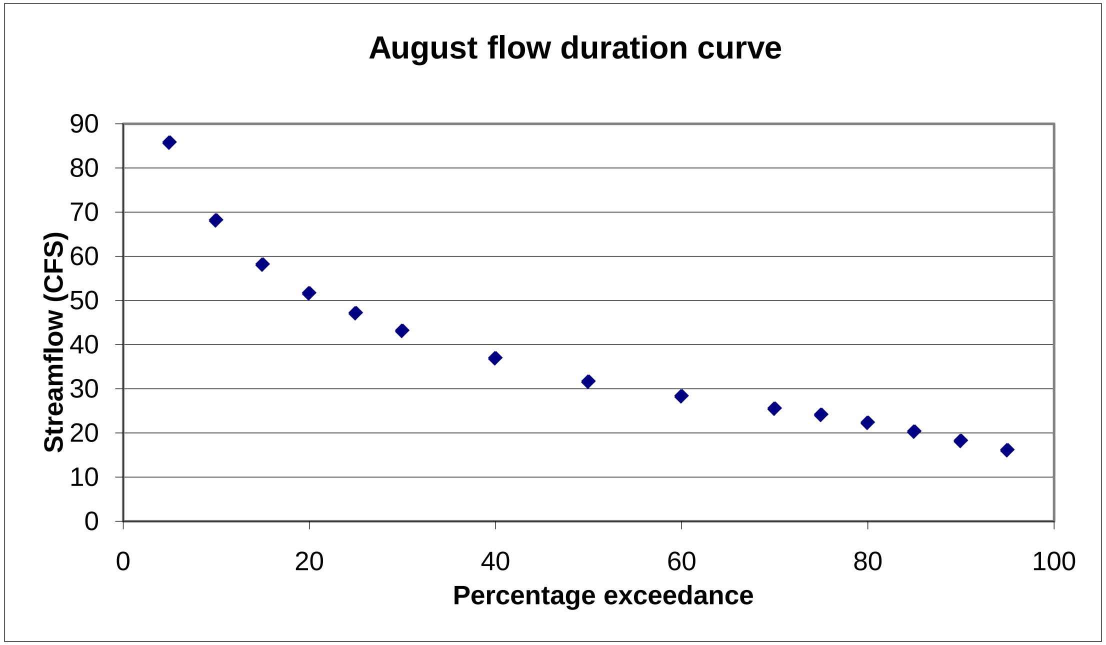


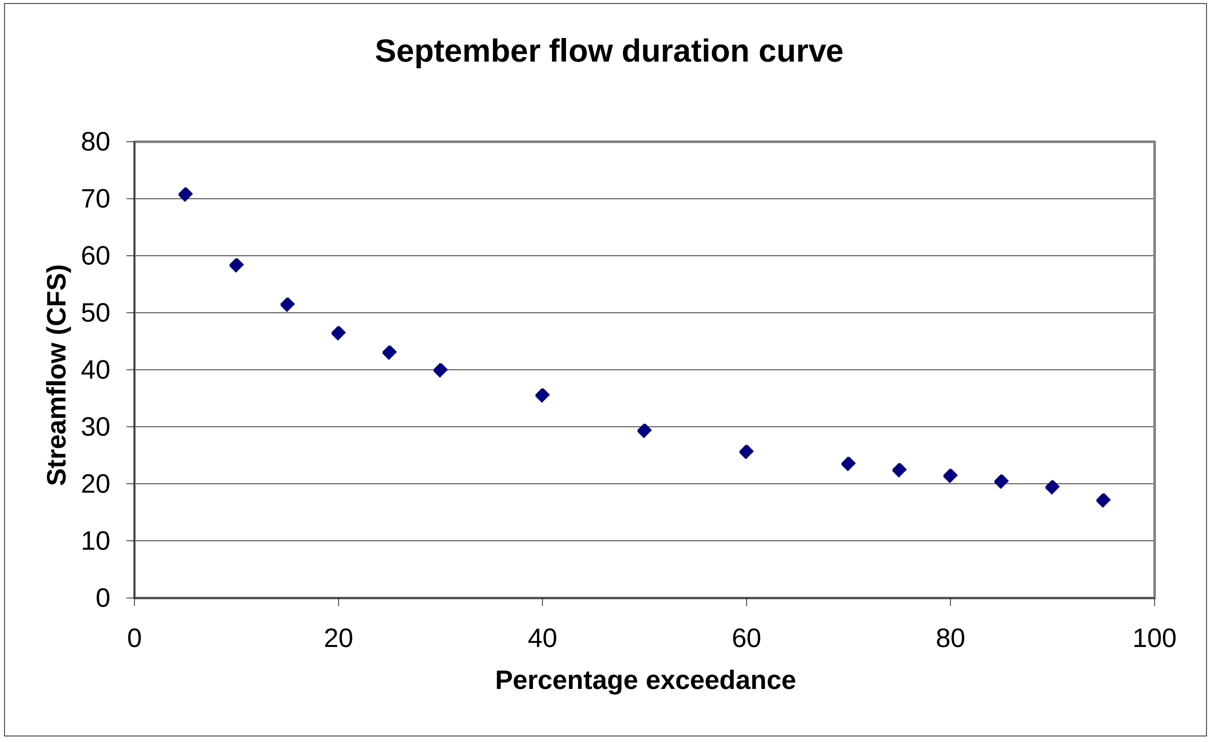
Grande Ronde nr Hilgard OR-flow duration.xls

95	90	85	80	75	70	60	50	40	30	25	20	15	10	5
19.9	21.6	23.3	25.5	27.9	29.9	33.8	36.6	39.6	44.2	47.6	52.1	59.3	71.6	89.9
25.5	29.3	31.4	33.6	36.1	38.6	44.3	50.7	58.5	71.2	82.3	101.0	125.0	151.0	201.0
24.0	30.5	35.2	39.9	44.6	49.4	60.8	71.5	87.3	120.0	152.0	191.0	236.0	295.0	462.0
31.6	36.5	41.5	46.3	50.9	56.3	69.5	85.0	106.0	197.0	232.0	278.0	352.0	472.0	-1.0
43.4	54.9	63.4	70.7	86.9	106.0	148.0	188.0	247.0	303.0	341.0	404.0	491.0	627.0	910.0
81.8	119.0	144.0	167.0	187.0	213.0	273.0	350.0	455.0	608.0	696.0	792.0	926.0	1120.0	1510.0
232.0	318.0	369.0	412.0	453.0	492.0	568.0	654.0	753.0	896.0	987.0	1090.0	1230.0	1390.0	1670.0
223.0	299.0	381.0	437.0	480.0	521.0	613.0	718.0	827.0	967.0	1030.0	1100.0	1180.0	1290.0	1450.0
82.8	105.0	125.0	146.0	167.0	186.0	241.0	299.0	366.0	448.0	512.0	582.0	644.0	759.0	953.0
24.2	33.2	36.8	39.9	44.4	49.0	59.3	70.2	81.6	101.0	112.0	127.0	150.0	180.0	251.0
16.1	18.2	20.3	22.3	24.1	25.5	28.3	31.6	36.9	43.1	47.1	51.6	58.1	68.1	85.7
17.1	19.4	20.4	21.4	22.4	23.5	25.6	29.3	35.5	39.9	43.0	46.4	51.4	58.3	70.7

95/50	95/80	80/50
0.544	0.780	0.697
0.503	0.759	0.663
0.336	0.602	0.558
0.372	0.683	0.545
0.231	0.614	0.376
0.234	0.490	0.477
0.355	0.563	0.630
0.311	0.510	0.609
0.277	0.567	0.488
0.345	0.607	0.568
0.509	0.722	0.706
0.584	0.799	0.730


April flow duration curve
Streamflow (CFS)
1800
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
Percentage exceedance


August flow duration curve
Streamflow (CFS)
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Percentage exceedance


September flow duration curve
Streamflow (CFS)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Percentage exceedance

Little Catherine Cr-at mouth-80% flow duration data.xls

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
1	1.99	0.11	3.1	0	0	0	0	0	0	1.78
2	3.29	0.19	5.1	0	0	0	0	0	0	2.11
3	5.73	0.33	8.9	0	0	0	0	0	0	4.27
4	12.4	0.71	19.1	0	0	0	0	0	0	12.2
5	20.4	1.18	31.5	0	0	0	0	0	0	11.3
6	10.7	0.62	16.5	0	0	0	0	0	0	8.2
7	3.32	0.19	5.1	0	0	0	0	0	0	1.36
8	1	0.06	1.5	0	0	0	0	0	0	1.1
9	1.06	0.06	1.6	0	0	0	0	0	0	0.74
10	1.08	0.06	1.7	0	0	0	0	0	0	0.85
11	1.94	0.11	3	0	0	0	0	0	0	0.83
12	1.87	0.11	2.9	0	0	0	0	0	0	1.17

Stream: LITTLE CATHERINE CR > CATHERINE CR - AT MOUTH

WAB ID #: 71681# WABS ABOVE: 0

MO WAB ID # 71681Sum Upstream WABs Difference Difference

Flow CSM % Ann Flow CSM % Ann Flow CSM % Ann With 50%Flow

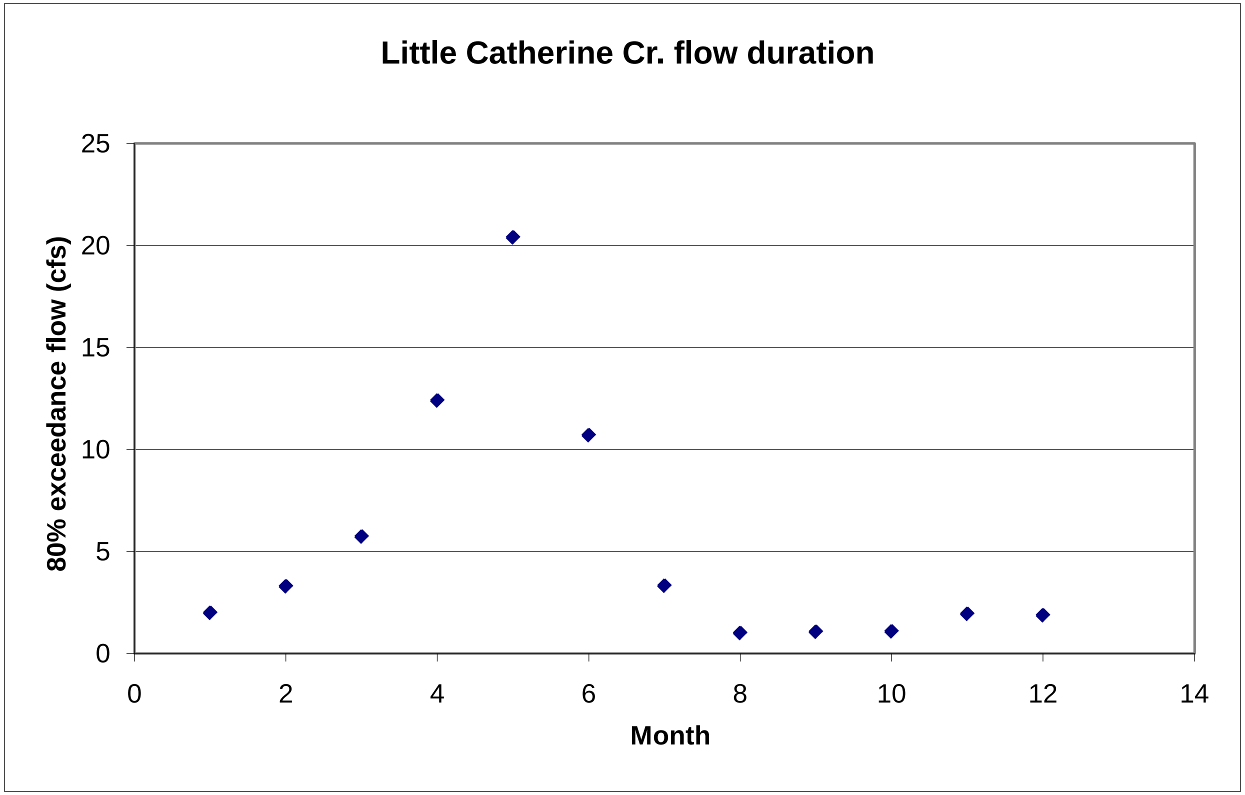
Page 49of Natural Streamflow Check File Total Pages: 49

Stream: LITTLE CATHERINE CR > CATHERINE CR - AT MOUTH

WAB ID #: 71681# WABS ABOVE: 0

Area	17.36	0	0		
Relief	3420	0	0		
Slope	16.4	0	0		
Elevation	5100	0	0		
MAP	39.1	0	0		
Jan Min T			11.6	0	0
Jul Min T			42	0	0
Yield	10.82	0	0		

Data from file: Grande Ronde-naturalstreamflow for selected watersheds-80%.pdf


Little Catherine Cr. flow duration
80% exceedance flow (cfs)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
Month

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
1	21.7	0.64	3.3	0	0	0	0	0	0	0
2	25	0.73	3.8	0	0	0	0	0	0	0
3	31.5	0.93	4.7	0	0	0	0	0	0	0
4	65.9	1.94	9.9	0	0	0	0	0	0	0
5	195	5.73	29.4	0	0	0	0	0	0	0
6	183	5.38	27.6	0	0	0	0	0	0	0
7	46	1.35	6.9	0	0	0	0	0	0	0
8	21.3	0.63	3.2	0	0	0	0	0	0	0
9	17.9	0.53	2.7	0	0	0	0	0	0	0
10	16.5	0.48	2.5	0	0	0	0	0	0	0
11	18.8	0.55	2.8	0	0	0	0	0	0	0
12	21.3	0.63	3.2	0	0	0	0	0	0	0

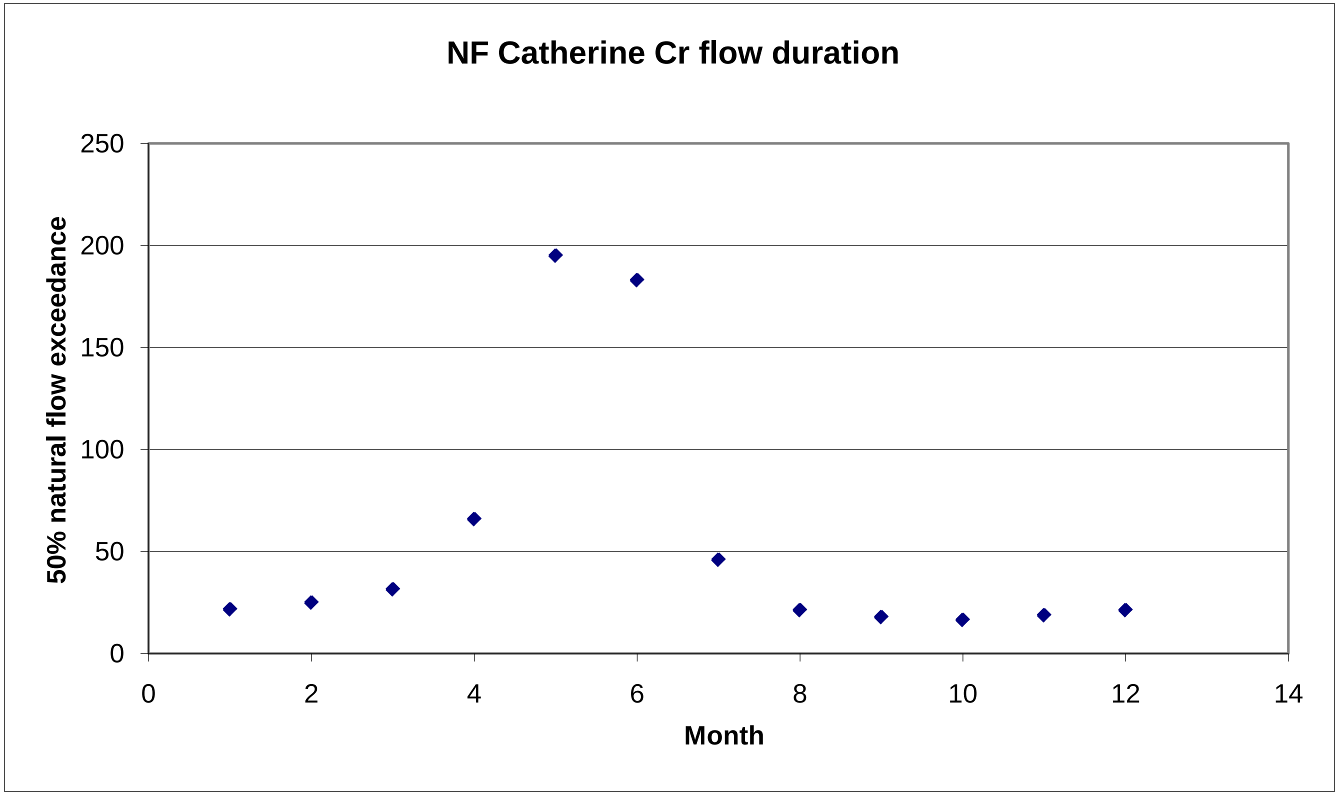
Stream: N FK CATHERINE CR > CATHERINE CR - AT MOUTH

WAB ID #: 70865# WABS ABOVE: 0

MO WAB ID # 70865Sum Upstream WABs Difference Difference

Flow CSM % Ann Flow CSM % Ann Flow CSM % Ann With 50%Flow

Area	34.02	0	0
Relief	4600	0	0
Slope	25.9	0	0
Elevation	5960	0	0
MAP	54	0	0
Jan Min T	9.25	0	0
Jul Min T	39.4	0	0
Yield	40.87	0	0


NF Catherine Cr flow duration
50% natural flow exceedance
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Month

NF Catherine Cr-80% flow duration data.xls

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
1	15.6	0.46	3.5	0	0	0	0	0	0	6.1
2	18.4	0.54	4.1	0	0	0	0	0	0	6.6
3	21	0.62	4.7	0	0	0	0	0	0	10.5
4	48.7	1.43	10.8	0	0	0	0	0	0	17.2
5	134	3.94	29.8	0	0	0	0	0	0	61
6	101	2.97	22.5	0	0	0	0	0	0	82
7	28.7	0.84	6.4	0	0	0	0	0	0	17.3
8	20.2	0.59	4.5	0	0	0	0	0	0	1.1
9	16.3	0.48	3.6	0	0	0	0	0	0	1.6
10	15.3	0.45	3.4	0	0	0	0	0	0	1.2
11	15.1	0.44	3.4	0	0	0	0	0	0	3.7
12	15.5	0.46	3.5	0	0	0	0	0	0	5.8

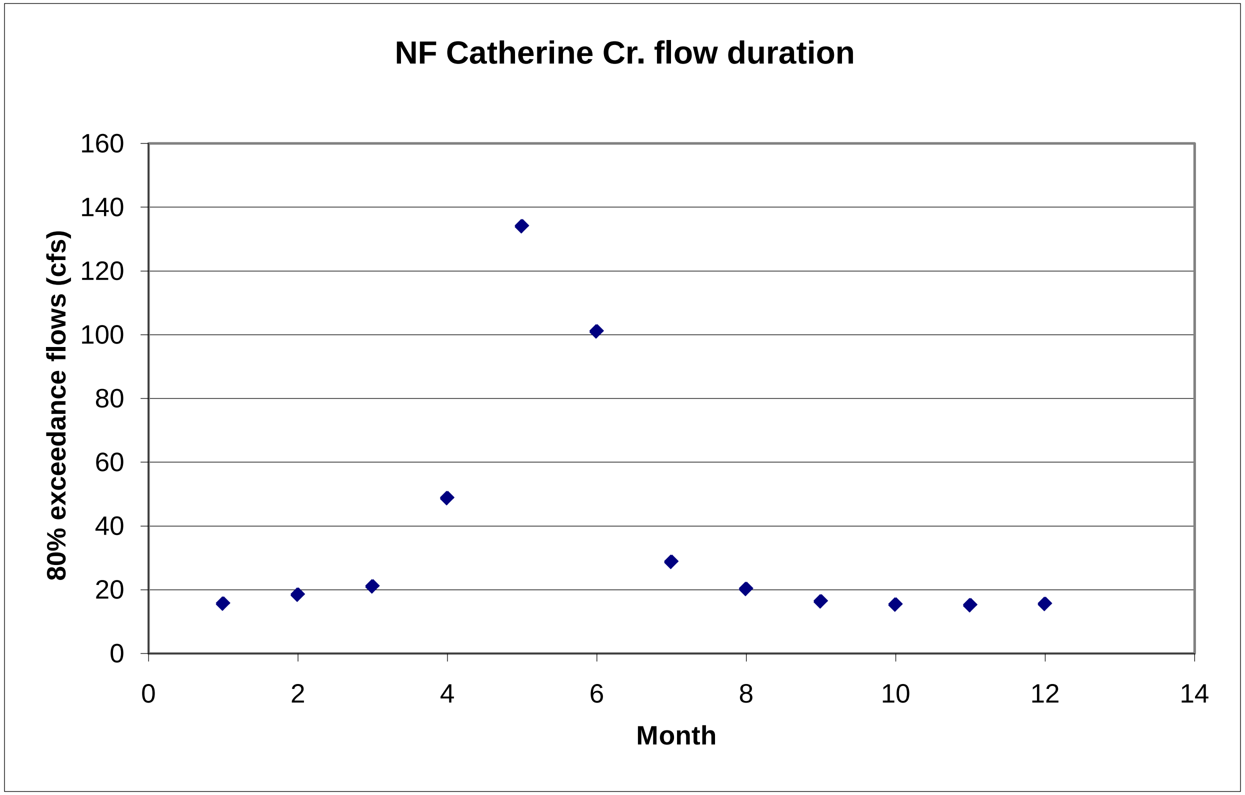
Stream: N FK CATHERINE CR > CATHERINE CR - AT MOUTH

WAB ID #: 70865# WABS ABOVE: 0

MO WAB ID # 70865Sum Upstream WABs Difference Difference

Flow CSM % Ann Flow CSM % Ann Flow CSM % Ann With 50%Flow

Area		34.02	0	0		
Relief		4600	0	0		
Slope		25.9	0	0		
Elevation		5960	0	0		
MAP		54	0	0		
Jan	Min	T		9.25	0	0
Jul	Min	T		39.4	0	0
Yield		27.69	0	0		



NF Catherine Cr. flow duration
80% exceedance flows (cfs)
0
20
40
60
80
100
120
140
160
0
2
4
6
8
10
12
14
Month

SF Catherine Cr-80% natural exceedance flows.xls

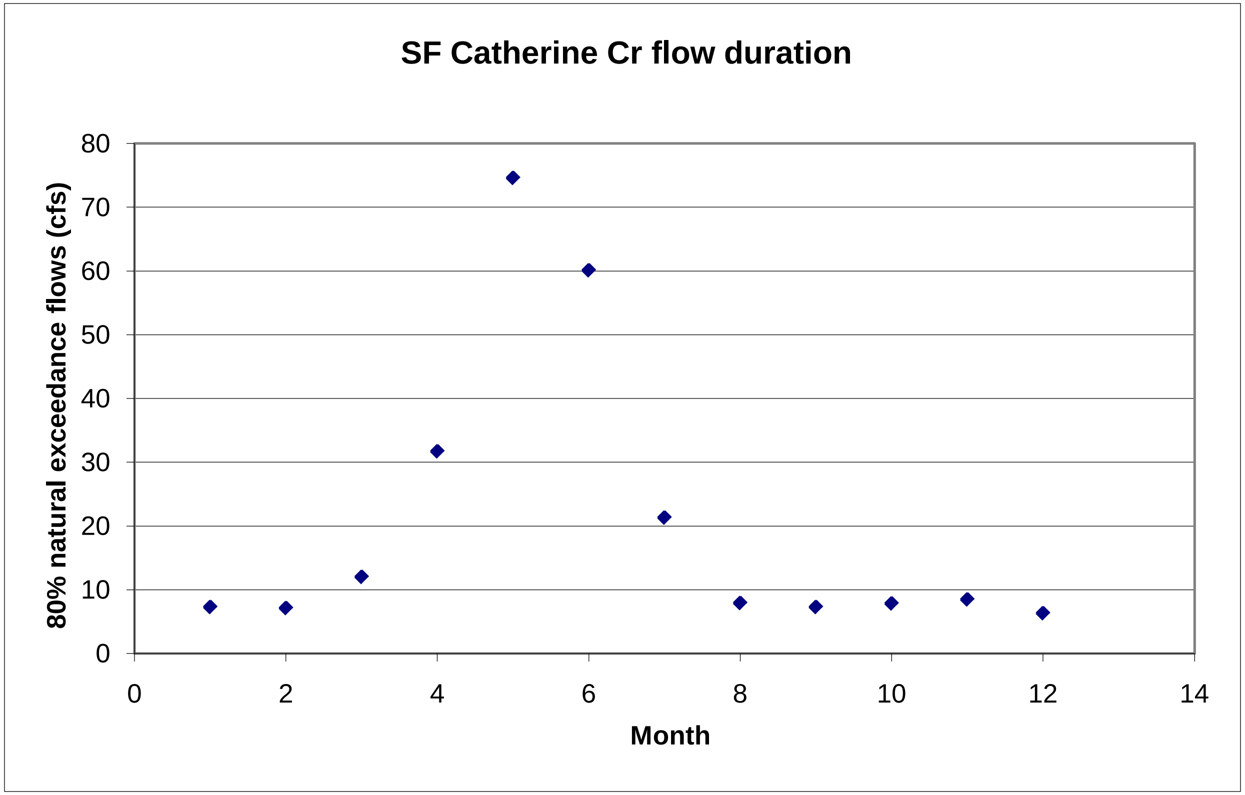
Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow
1	7.27	0.3	2.9	0	0	0	0	0	0	1.68
2	7.11	0.3	2.8	0	0	0	0	0	0	3.39
3	12	0.5	4.8	0	0	0	0	0	0	5.8
4	31.7	1.32	12.6	0	0	0	0	0	0	20.9
5	74.6	3.12	29.6	0	0	0	0	0	0	31.4
6	60.1	2.51	23.9	0	0	0	0	0	0	39
7	21.3	0.89	8.5	0	0	0	0	0	0	9.2
8	7.9	0.33	3.1	0	0	0	0	0	0	6.2
9	7.27	0.3	2.9	0	0	0	0	0	0	3.43
10	7.83	0.33	3.1	0	0	0	0	0	0	2.27
11	8.46	0.35	3.4	0	0	0	0	0	0	1.94
12	6.3	0.26	2.5	0	0	0	0	0	0	2.27
			100.1							

Page 50of Natural Streamflow Check File Total Pages: 50

Stream: S FK CATHERINE CR > CATHERINE CR - AT MOUTH
WAB ID #: 70862# WABS ABOVE: 0

MO WAB ID # 70862Sum Upstream WABs Difference Difference
Flow CSM % Ann Flow CSM % Ann Flow CSM % Ann With 50%Flow

Area	23.94	0	0		
Relief	4600	0	0		
Slope	20.1	0	0		
Elevation	5730	0	0		
MAP	59.4	0	0		
Jan Min	T		9.5	0	0
Jul Min	T		39.8	0	0
Yield	20.06	0	0		

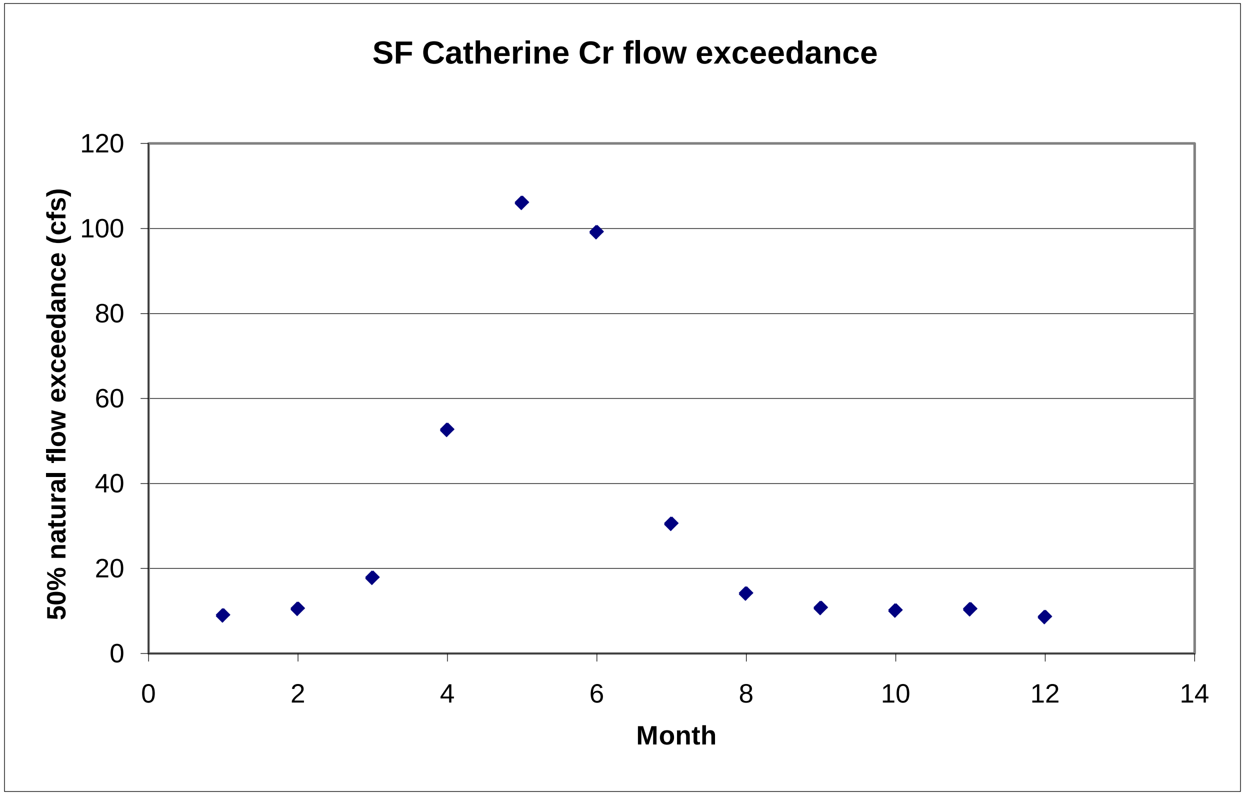


SF Catherine Cr flow duration
80% natural exceedance flows (cfs)
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
Month

SF Catherine Cr 50% flow exceedance data.xls

Month	WAB ID # 30810414			Sum Upstream WABs			Difference			Difference	
	Flow	CSM	% Ann	Flow	CSM	% Ann	Flow	CSM	% Ann	with 50% flow	
1	8.95	0.37	2.4	0	0	0	0	0	0	0	
2	10.5	0.44	2.8	0	0	0	0	0	0	0	
3	17.8	0.74	4.7	0	0	0	0	0	0	0	
4	52.6	2.2	13.9	0	0	0	0	0	0	0	
5	106	4.43	27.9	0	0	0	0	0	0	0	
6	99.1	4.14	26.1	0	0	0	0	0	0	0	
7	30.5	1.27	8	0	0	0	0	0	0	0	
8	14.1	0.59	3.7	0	0	0	0	0	0	0	
9	10.7	0.45	2.8	0	0	0	0	0	0	0	
10	10.1	0.42	2.7	0	0	0	0	0	0	0	
11	10.4	0.43	2.7	0	0	0	0	0	0	0	
12	8.57	0.36	2.3	0	0	0	0	0	0	0	

MO	WAB	ID	#	70862Sum		Upstream WABs		DifferenceDifference						
Flow	CSM	%	Ann	Flow	CSM	%	Ann	Flow	CSM	%	Ann	With		50%Flow
Area	23.94		0	0										
Relief	4600		0	0										
Slope	20.1		0	0										
Elevation	5730		0	0										
MAP	59.4		0	0										
Jan	Min	T		9.5	0	0								
Jul	Min	T		39.8	0	0								
Yield	30.21		0	0										
				Streamflo										
Page	50of		Natural	w	Check	File	Total	Pages:	50					
			CATHERI			CATHERI								
Stream:	S	FK	NE	CR	>	NE	CR	-	AT	MOUTH				
WAB	ID	#:	70862#		WABS	ABOVE:		0						
			Ronde-	streamflo										
from	file:	Grande	natural	w	for	selected	watersheds.pdf							

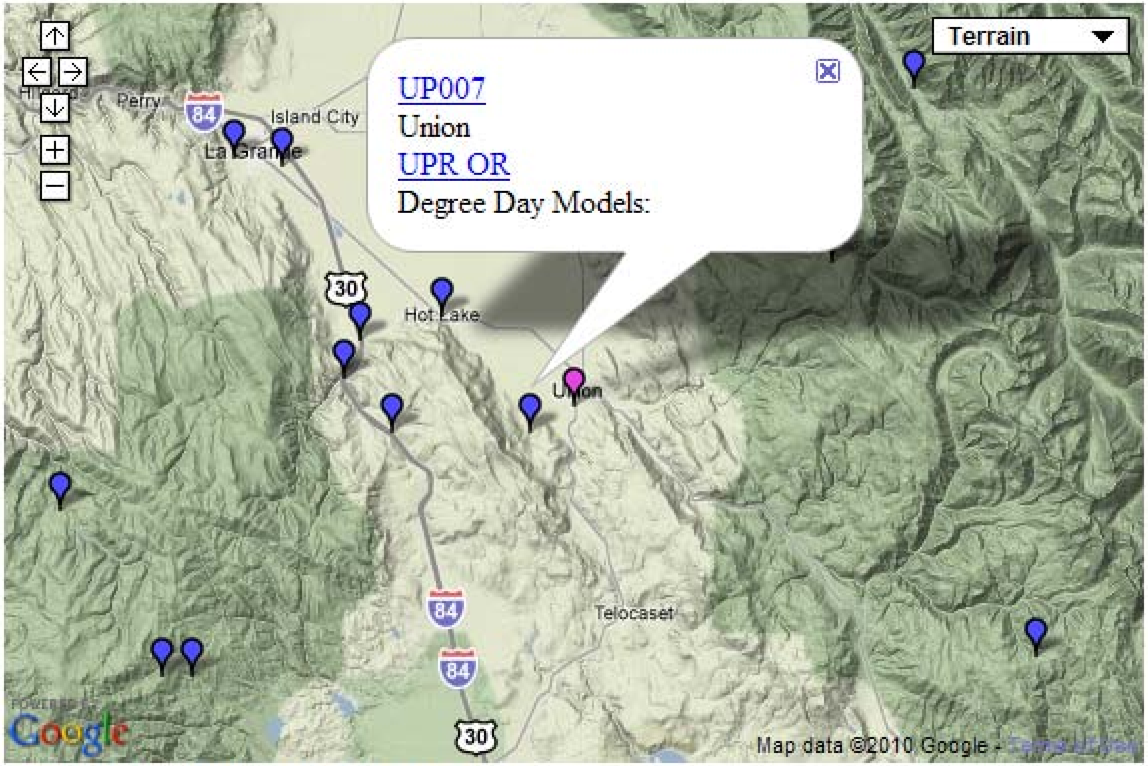


SF Catherine Cr flow exceedance
50% natural flow exceedance (cfs)
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
Month

Appendix J

Local Stations having Hourly Air Temperature, Relative Humidity, and Precipitation Data

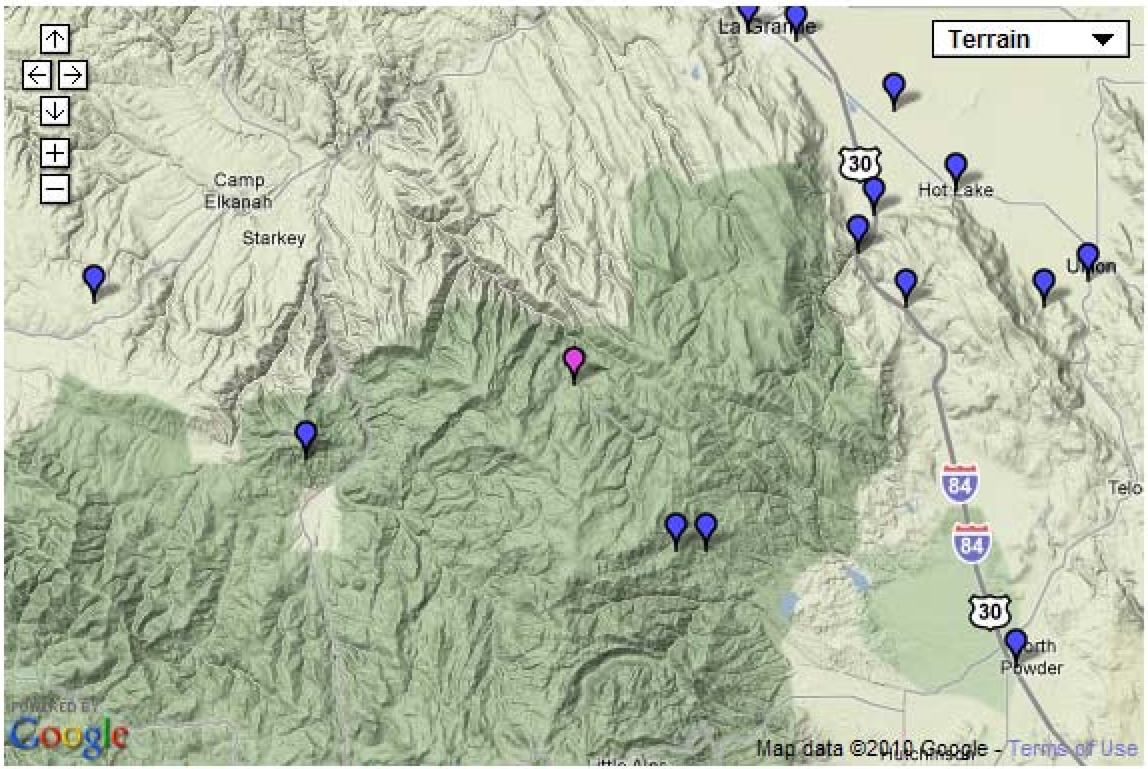
Locations where hourly air temperature, relative humidity, and precipitation are available. Data source: http://upest.org/risk/models



UNIO3 COOP 45.2000 -117.8667
UNIONEXPERIMENTSTAM OR 2765 elevation

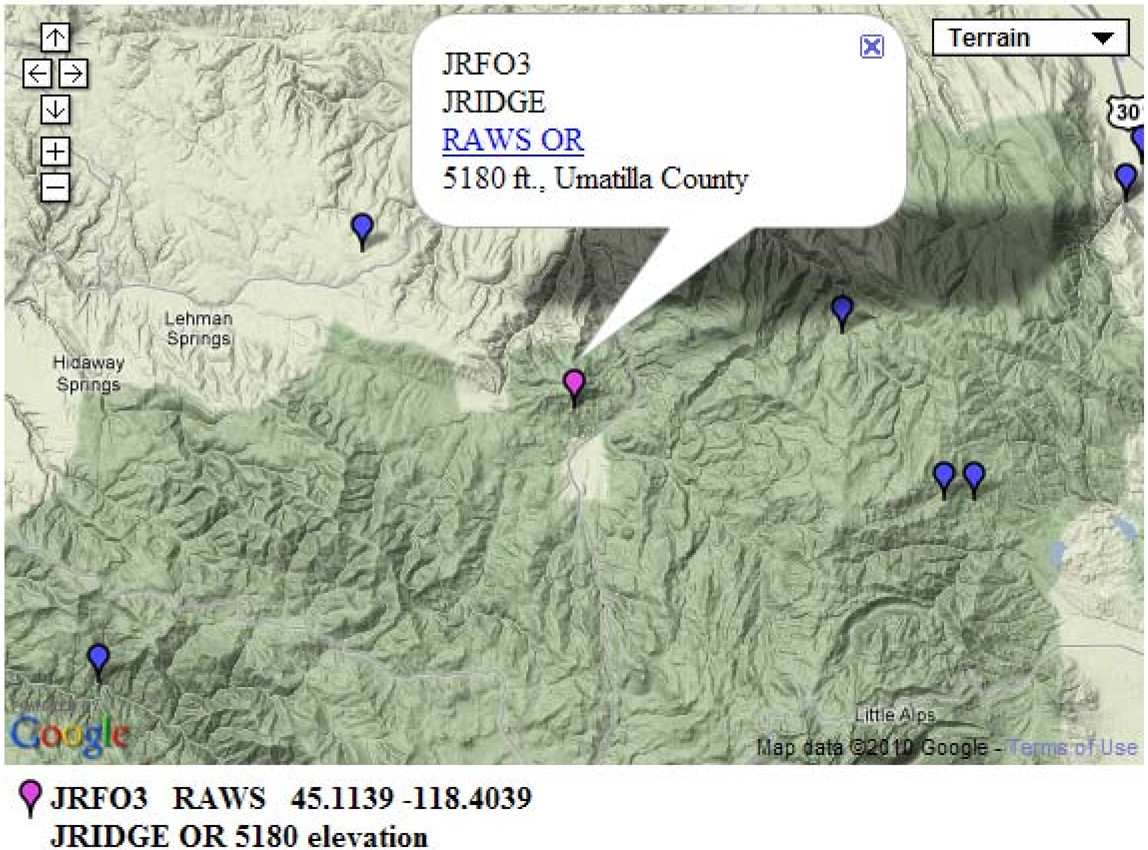
UP007 UPR 45.1883 -117.8967
Union OR 2816 elevation

http://uspest.org/risk/models

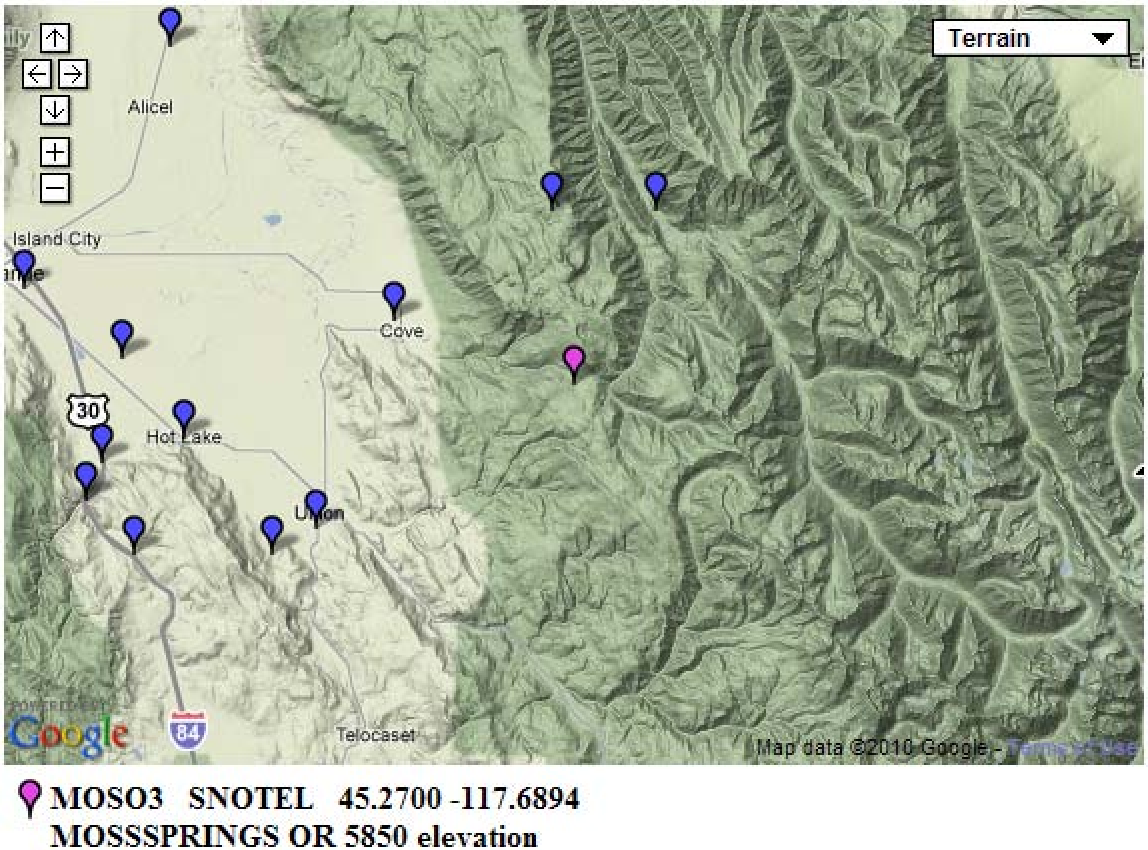


BVRO3 SNOTEL 45.1500 -118.2194
BEAVERRESERVOIR OR 5150 elevation

BVRO3 SNOTEL 45.1500 -118.2194
BEAVERRESERVOIR OR 5150 elevation



JRFO3 RAWS 45.1139 -118.4039
JRIDGE OR 5180 elevation



MOSO3 SNOTEL 45.2700 -117.6894
MOSSSPRINGS OR 5850 elevation

Appendix K

Survey Design

Survey Design

Monitoring sites within the Upper Grande Ronde River and Catherine Creek basins will be selected using a generalized random-tessellation stratified design (GRTS) (Steven and Olsen 2004). GRTS has been applied frequently in the Pacific Northwest to assess trends in stream habitat conditions over large spatial scales (Stevens 2002, Larsen et al. 2004, Kauffman et al. 1999, Heitke et al. 2008). This method utilizes a quadrant recursive function to map two-dimensional space into one-dimensional space, thereby creating an ordered spatial address. A technique known as hierarchical randomization is then used to randomly order the address. Finally, systematic sampling is used to select sample points along the randomly ordered line, thereby ensuring a well-balanced spatial distribution of sample points.

After reviewing the merits of various probabilistic sampling designs including GRTS, stratified random sampling, systematic sampling, and simple random sampling (Thompson 2002), we concluded that GRTS was best suited for our project objectives and provided unique advantages over alternative designs. One important feature of GRTS is that it produces samples with a higher degree of spatial balance than traditional sampling designs such as simple random sampling and stratified random sampling (Stevens and Olsen 2004). Because stream habitat conditions and associated biological communities often vary in a continuous fashion from headwaters to mouth (Vannote et al. 1980), it is important that monitoring sites are regularly distributed throughout the stream network such that all available habitat conditions within the population of interest are well represented.

An additional advantage of GRTS is that it allows for selection of replacement samples (i.e., over samples) in the event that original sample points can't be included in the sample due to issues such as landowner denial or unsafe conditions. Lack of access to sites due to landowner denial is likely to be a significant problem in the Grande Ronde Basin, where approximately 65% of potential spawning habitat for spring Chinook salmon is located on private land. Although this feature of GRTS does not eliminate the potential bias of inference to the inaccessible areas of the population, it does allow for a randomized and efficient method for selecting replacement sites, which is not easily achieved with other sampling designs like systematic random sampling. Finally, the variance estimator for GRTS samples is generally more precise than that of simple random and systematic samples. In a study of water quality in various streams in Indiana, Stevens and Olsen (2004) found that the local neighborhood variance for mean water quality indices estimated using GRTS was approximately 38% smaller than the variance achieved with simple random sampling.

Because a primary objective of our study is to evaluate both status and trends in habitat conditions, it was important to design our study such that the temporal distribution of sampling effort provided sufficient statistical power to detect trends, while maintaining adequate spatial distribution for assessing status. We evaluated five alternative survey designs representing a range of potential tradeoffs between power to detect trend and ability to accurately describe status (Table 1). We set total sample size within a year to 50 for all survey designs based on the maximum number of sites that we could feasibly visit within a year. The duration of the study was set at 9 years, consistent with our study contract.

The ability of a monitoring program to detect trends depends on four sources of variation including: 1) site variation (i.e., differences among stream reaches such as stream size, gradient, and valley form); 2) year variation (i.e., inter-annual variation due to broad-scale effects of climate or other types of disturbance); 3) interaction variation (i.e., independent, unsynchronized variation between sites and years); and 4) residual variation (i.e., short term temporal variation within years, measurement error, and observer error) (Larsen et al. 2004). A well designed monitoring plan will allow researchers to separately estimate each of these components of variation and will include measures to reduce certain components of variation.

If unaccounted for, site variation is often the largest component of variation in stream habitat attributes. However, if a portion of the sites are revisited through time, the effect of site-to-site differences on trend detection is essentially eliminated (Larsen et al. 2004). Residual variation can be reduced by using precise and careful measurement techniques and by increasing the number of total sites in the survey. The year component of variation can comprise a substantial portion of the total variation, and detection of regional trends is particularly sensitive to this “year effect” (Urquhart and Kincaid 1999, Larsen et al. 2004). The best solution to reducing the effect of year variation is to increase the duration of the study (Larsen et al. 2001). Additionally, the year effect can be reduced by identifying and modeling the factors controlling the year effect such as regional climate patterns.

Sampling designs in which the same set of sites is revisited annually (Table 1, Design 1) typically has the greatest power to detect trends (Urquhart and Kincaid 1999). However, owing to their relatively small sample size and limited spatial distribution, such designs have a limited ability to describe status and evaluate spatial patterns in habitat conditions. Panel designs that include sampling in different groups of sites each year allow for data collection across a much larger number of sites over the same time frame, allowing for finer resolution in evaluation of spatial patterns in habitat conditions at the cost of reduced power to detect trends. An extreme example of this type of panel design is Design 2 (Table 1), in which 50 new sites are visited each year. Such a design would maximize our ability to describe status and examine spatial patterns in habitat conditions, but would provide no power to detect temporal trends.

Augmented serially alternating panel designs like Designs 3 through 4 represent survey designs that strike a balance between power for trend detection and status assessment. Studies have shown that well balanced panel designs are nearly as powerful as annual repeat surveys at detecting trends, with the added benefit of increased spatial resolution (Larsen et al. 2004, Urquhart and Kincaid 1999). For alternating panel designs, we selected a 3-year alternating schedule to correspond with the average life cycle of spring Chinook salmon as in Stevens et al. (2002). Design 3 is more heavily weighted towards trend detection, with the majority of sites being revisited each year and a total sample size of 70. In contrast, Design 5 is weighted towards status assessment, with a greater portion of new sites being visited each year and a larger total sample size of 130. Design 4 is a balanced panel design in which equal portions of annual sites and 3-year alternating sites are visited each year for a total sample size of 100.

We conducted a preliminary analysis to test the utility and feasibility of the GRTS sampling methodology and to evaluate the spatial distribution of sampling points for various panel designs. Methods used to stratify habitat and specific panel designs evaluated will likely change prior to commencement of field sampling as new classification methods are developed and sampling strategies are refined. We generated stratified GRTS samples for each of the five survey designs using the *SPSURVEY* analysis package in program R developed by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP, Messer et al. 1991). We divided the Upper Grande Ronde River and Catherine Creek basins into relatively homogenous strata based on the Interior Columbia Technical Recovery Team (ICTRT) intrinsic potential ratings. Strata values were defined as 0 = lowest potential, 1 = low potential, 2 = medium potential and 3 = high potential. Sample sizes within each stratum were allocated in proportion to the total length of stream in each stratum as described in Thompson (2002) (Table 2). Thirty oversamples were selected for each stratum for all five panel designs. GRTS samples for each panel design were imported into Arc GIS and the distribution of sample points were compared visually.

GRTS samples were generally well distributed across the landscape, although some degree of clustering was evident. Examination of the spatial distribution of sample points from Design 1 illustrated an important point. Namely, 50 sites spread throughout the Upper Grande Ronde River and Catherine Creek Basins is a small sample size compared to the size of the target population, and doesn't appear to provide adequate spatial representation in all areas of interest. Specifically, no sample points were selected in the heavily used spawning habitat in the Upper Grande Ronde River upstream of Vey Meadows or in the high quality habitat in Sheep Creek (Figure 1). In contrast, Design 5 provided considerably better spatial representation, with a much larger number of sample points distributed throughout the basin (Figure 2).

The next step in development of a robust sampling design for the Upper Grande Ronde Basin is to use our newly developed habitat classification system to stratify the basin into homogenous reaches. This will ensure that our sampling effort is well-distributed among all potential habitat types and that the variance in estimates of average habitat conditions is minimized. Additionally, we intend to conduct a simulation analysis to compare different panel designs and sampling methods (i.e., GRTS vs. stratified random sampling vs. systematic sampling) with respect to their power to detect trends in physical habitat variables.

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Table 1. Alternative panel designs for stream habitat monitoring in the Grande Ronde basin. Numbers refer to sample sizes.

	Year								
Panel	1	2	3	4	5	6	7	8	9
Design 1: Always revisit									
1	50	50	50	50	50	50	50	50	50
Unique samples	***50***								
Design 2: Never revisit									
1	50								
2		50							
3			50						
4				50					
5					50				
6						50			
7							50		
8								50	
9									50
Unique samples	***450***								
Design 3: Augmented serially alternating (trend weighted)									
1	40	40	40	40	40	40	40	40	40
2	10			10			10		
3		10			10			10	
4			10			10			10
Unique samples	***70***								
Design 4: Augmented serially alternating (balanced)									
1	25	25	25	25	25	25	25	25	25
2	25			25			25		
3		25			25			25	
4			25			25			25
Unique samples	***100***								
Design 5: Augmented serially alternating (status weighted)									
1	10	10	10	10	10	10	10	10	10
2	40			40			40		
3		40			40			40	
4			40			40			40
Unique samples	***130***								

Table 2. Sample allocation for stratified panel designs with strata designated by ICTRT intrinsic potential ratings.

	Strata				
Panel	lowest	low	medium	high	Sum
Design 1: Always revisit					
OverSamp	30	30	30	30	120
Panel1	13	10	11	16	50
Sum Total	43	40	41	46	170
Design 2: Never revisit					
OverSamp	30	30	30	30	120
Panel1	13	10	11	16	50
Panel2	13	10	11	16	50
Panel3	13	10	11	16	50
Panel4	13	10	11	16	50
Panel5	13	10	11	16	50
Panel6	13	10	11	16	50
Panel7	13	10	11	16	50
Panel8	13	10	11	16	50
Panel9	13	10	11	16	50
Sum Panels	117	90	99	144	450
Sum Total	147	120	129	174	570
Design 3: Augmented serially alternating (trend weighted)					
OverSamp	30	30	30	30	120
Panel1	10	8	9	13	40
Panel2	3	2	2	3	10
Panel3	3	2	2	3	10
Panel4	3	2	2	3	10
Sum Panels	19	14	15	22	70
Sum Total	49	44	45	52	190
Design 4: Augmented serially alternating (balanced)					
OverSamp	30	30	30	30	120
Panel1	6	5	6	8	25
Panel2	6	5	6	8	25
Panel3	6	5	6	8	25
Panel4	6	5	6	8	25
Sum Panels	24	20	24	32	100
Sum Total	54	50	54	62	220
Design 5: Augmented serially alternating (status weighted)					
OverSamp	30	30	30	30	120
Panel1	3	2	2	3	10
Panel2	10	8	9	13	40
Panel3	10	8	9	13	40
Panel4	10	8	9	13	40
Sum Panels	33	26	29	42	130
Sum Total	63	56	59	72	250

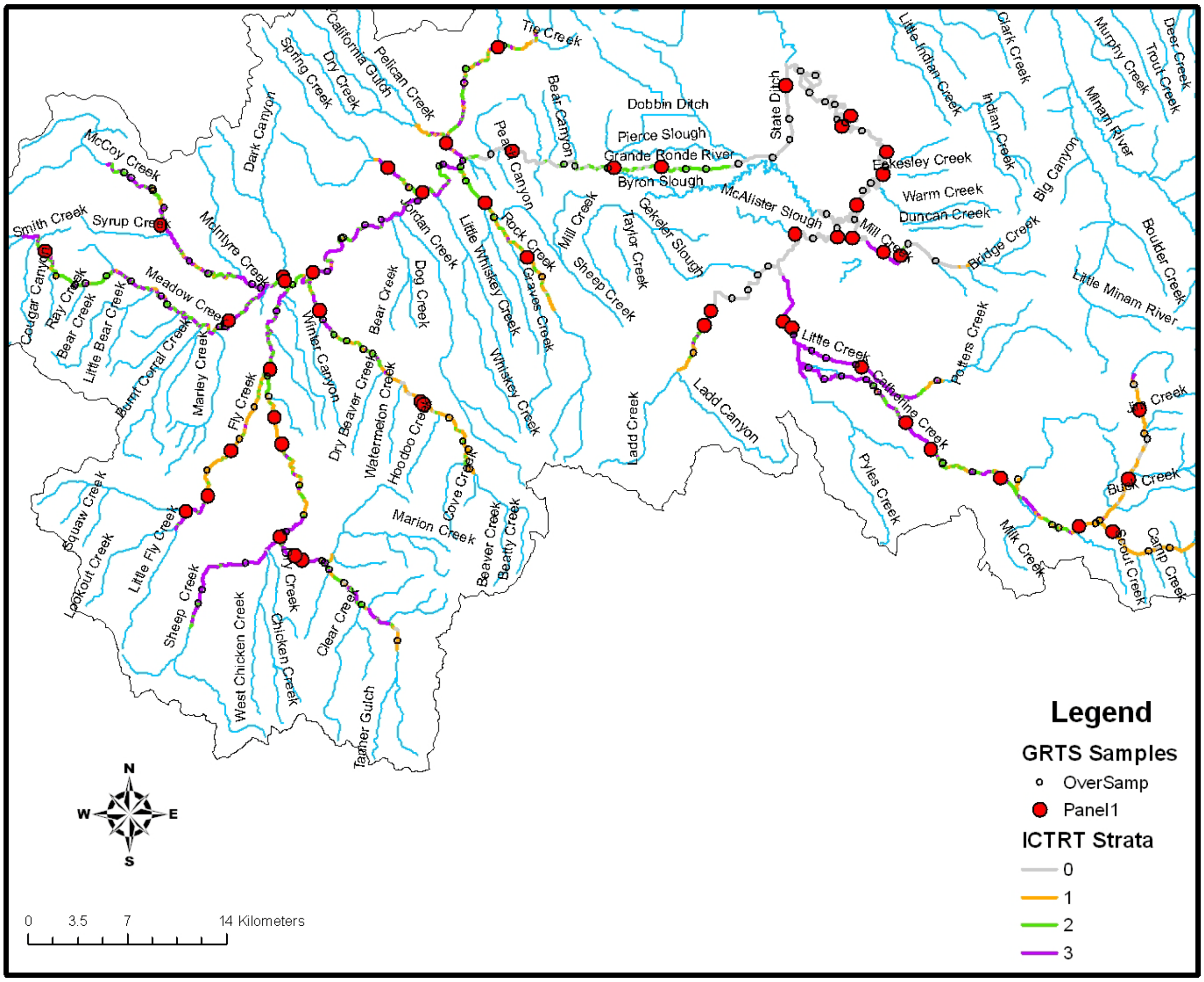

Figure 1. Stratified GRTS survey design using ICTRT intrinsic potential ratings as strata and the "Design 1" panel structure (i.e., sites are revisited every year). The total sample size for this survey design is 50. Strata values are defined as 0 = lowest potential, 1 = low potential, 2 = medium potential, 3 = high potential.

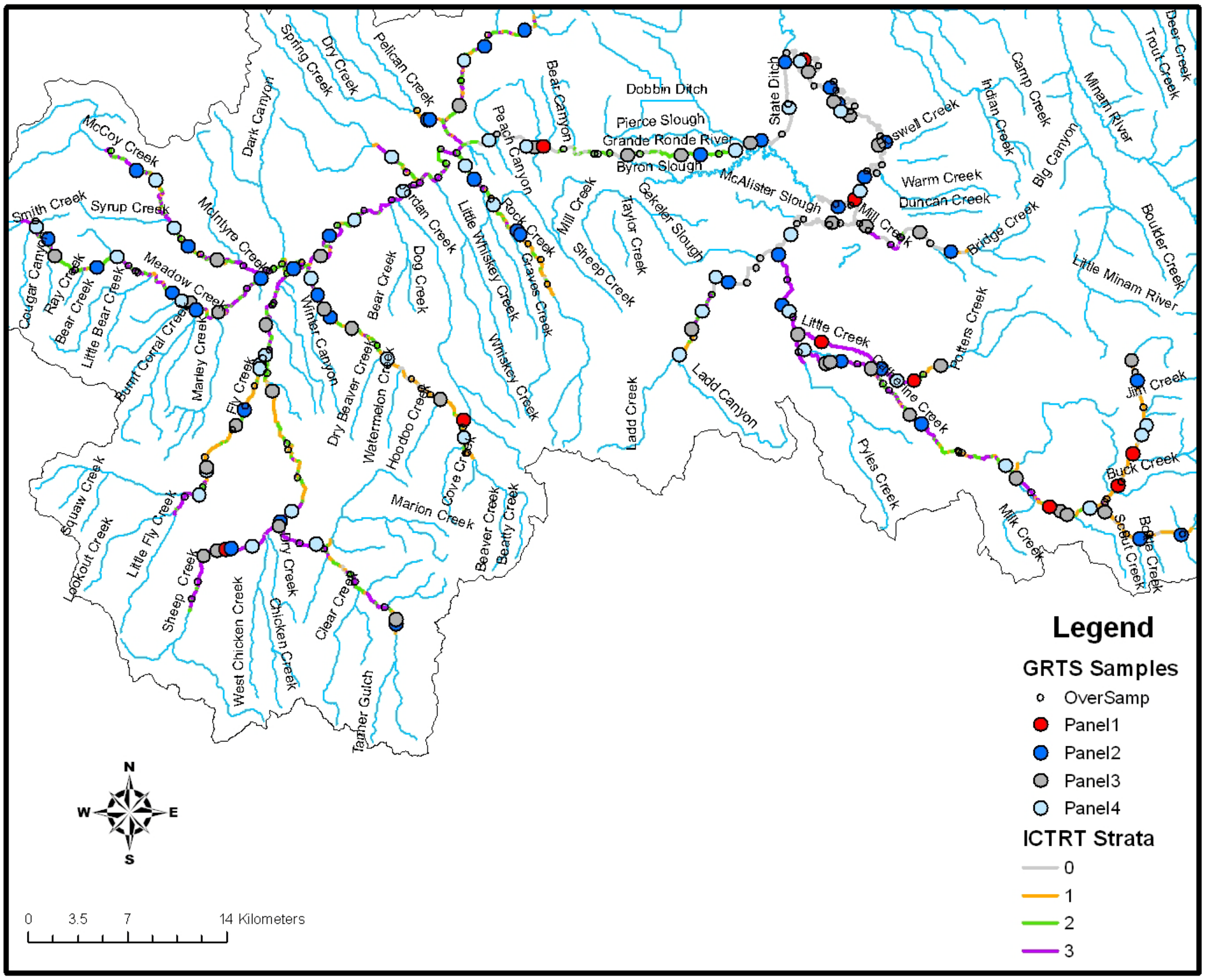

Figure 2. Stratified GRTS survey design using ICTRT intrinsic potential ratings as strata and the "Design 5" panel structure (i.e., augmented serially alternating (status weighted)). The total sample size for this survey design is 130. Strata values are defined as 0 = lowest potential, 1 = low potential, 2 = medium potential, 3 = high potential.

Appendix L

Preliminary Field Manual for CRITFC Accord Habitat Monitoring

Preliminary Field Manual for CRITFC Accord Habitat Monitoring

Substrate Composition

Surface fine sediment

<u>Procedure</u>

1. Visual estimates of *Fines <0.635 mm*

The commonly cited method of surface fine sediment estimation by Platts et al. (1983) is a visually-based estimation. Measures of embeddedness, correlated with percentage surface fines, are also commonly estimated by visual methods (Sylte and Fischenich 2002). Visual surface fine estimates by the Platts et al. method are made by stretching a measuring tape across a transect and estimating the dominant particle size class for each 1 ft-increment on the transect line. For example, if the 1 ft of stream bottom contained "4 inches rubble, 6 inches gravel, and 2 inches fine sediment," it "would be classified as 1 ft of gravel. All 1-ft increments are combined to derive the overall substrate composition. Using such a process, it is conceivable that each 1-ft increment could have a substantial amount of fine sediment, but if a larger size class were predominant, fines would not be recorded at all. For this reason, we favor a visual method that attempts to integrate conditions over the entire transect and that was based on evaluation on an areal basis rather than a linear one.

Visual estimates of surface fines will be made at each of 5 transects established in each study reach for which surface and subsurface fine sediment will be measured. By imagining a 1-m wide band across the stream at each transect, the percentage material <6.35 mm diameter was estimated visually as percentage of surface area occupied. This size class is referred to as fine gravel in the American Geophysical Union (AGU) sediment classification system (USACE 1995). These estimates occasionally involve integrating several patches of different particle size distribution, where some patches were largely comprised of fine sediments. More commonly, the visual integration involved estimation of the percentage surface area covered by particles <6.35 mm within the entire band where the fine particles were more uniformly distributed among larger framework particles.

Ocular estimates will be made by having two observers visually estimate the percentage of surface area occupied by substrate surface particles in a transect 1-m wide at the transect locations where overwinter samples were taken. This estimate is an integration of the entire band transect surface area. Percentages in the following diameter categories will b estimated: <0.635 cm, 0.635-1 cm, 1- 3, 3-6, 6-13, 13-25, 25-50, 50-100, and >100 cm. These particle size classes approximate those corresponding to standard sieve sizes and gravelometer classes, but are simplified for purposes of visual assessment. In these streams no bedrock or boulders >200 cm were detected. After independently recording the observations of two field staff, discrepancies between observers are discussed. If totals did not sum to 100% (note: deviation from 100% by 1- 5% often occurred with unconstrained visual estimation), size fractions that most likely accounted for discrepancies in totals are discussed and adjusted if warranted. Otherwise, duplicate estimates per size fraction are averaged and no further attempt is made to adjust totals to 100%. That is, it

is assumed that the relative percentages among size classes represents what is observed. Averaged observations per size class for each transect is then multiplied by a factor that would adjust each size fraction by an equal percentage so that totals equaled 100%.

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Infiltration

To measure overwinter sedimentation, artificial "redds" were created in the channel substrate in late summer of each year of the study, which was immediately prior to spawning. This method has been used successfully to monitor fine sediment accumulation in channel substrate in northern California (Lisle 1989) and provides an indication of the ultimate sediment conditions in salmonid redds (Lisle and Eads 1991). Lisle and Eads (1991) discussed the relative merits and precision of this method of sampling fine sediment accumulation. We used a particle diameter of <6.35 mm to define the fine sediment fraction detrimental to salmon survival, after Stowell et al. (1983), although many descriptors of fine sediment sizes and distribution have been used to characterize substrate and effects on salmonid survival (Young et al. 1991). The percentage by weight of overwinter sedimentation by particles <6.35 mm in the collected containers was determined using standard particle size analysis methods. Fines deposited in artificial redds were sorted and reported in size classes <0.85 mm, 0.85-2.0 mm, and 2.0-6.35 mm, and also summarized as all material <6.35 mm. These size categories correspond to clays to coarse sand, coarse to very coarse sands, and very coarse sand to fine gravel on the AGU sediment classification system (USACE 1995).

The simulated redds were constructed by embedding plastic buckets filled with cleaned substrate material (1-3 inches or 2.5-7.5 cm diameter) in the channel substrate of riffle areas known to be used by spring Chinook spawners of each of the four study streams beginning in August 1998. Artificial redds were intended to mimic the attributes of salmon redds, based on the data in Bjornn and Reiser (1991). Other more recent studies validated the use of this particle size range as representative of spawning gravel. Schuett-Hames and Pleus (1996) defined particle sizes of salmonid spawning gravels as 0.8 to 12.8 cm diameter. A survey of 135 spawning gravels for a variety of salmonid species revealed that the range in median values of d50s ranging from 2.2- 7.8 cm (Kondolf and Wolman 1993). Of the entire set of d50 values, 50% occurred between 1.5 and 3.5 cm (Kondolf and Wolman 1993).

The solid-walled containers are tapered cylinders with a diameter of 0.18 m at the opening, a bottom diameter of 0.16 m, and a height of 0.185 m. The bucket volume is 6 L. The depth of the containers ensured that the bottoms of the containers were within the range of depths where egg centrums within natural redds are typically encountered, according to Chapman (1988) and Bjornn and Reiser (1991). These sample containers will be retrieved in the spring (April-May) after the date of fry emergence. New buckets will be placed in the streams in August-September prior to spawning. Five “redds” were excavated in each stream monitored. Two containers of cleaned gravel were buried in each “redd,” except for two “redds” each in the Grande Ronde River and Catherine Creek, which had three containers, so that one of the three at each site could be collected during mid-winter to provide some indication of the rate of sedimentation during the incubation period. The Grande Ronde River and Catherine Creek are reasonably accessible during the winter period. Although mid-winter sampling or serial sampling during the winter period would be desirable to track the progression of infiltration during incubation, this is not feasible. During the winter, there is a risk of disturbing incubating eggs of listed species during sampling in the incubation season.

McCullough and Green (2006) found that even if redd material has a rock framework consisting of particles 2.5-7.5 cm diameter, the voids in this framework can be totally filled even at 23.9% fines (<6.35 mm) or less, depending on degree of framework compaction, and this condition can be generated at mean surface fine levels less than 20% in some samples. Carling and Glaister (1987) and Church et al. (1987)(as cited by Milan et al. 2000) indicated that framework material is filled by fine sediment matrix at a concentration of 32%. Wilcock and Kenworthy (2002) indicated that filling of voids by sand can be complete at 10 to 30%, depending upon the ability of bridging of the framework material to occur. Beschta and Jackson (1979), studying infiltration of fines into sand-gravel mixtures of average diameter of 1.5 cm (range 0.01 to 5.0 cm), found that complete filling of voids occurred when fines equaled 25% of the total sample. Diplas and Sutherland (1988)(as cited by Dalecky 2001) stated that fluvial sediments typically have a porosity of 33.3%. Knowledge of the initial void volume provides a measure of the potential for fine sediment infiltration. However, even if fines fully infiltrate initial void space, there is still a void volume remaining attributable to sediment porosity.

Implanting of artificial redds

Five buckets of artificial spawning gravel will be implanted in each of two spawning reaches in the Upper Grande Ronde mainstem and Catherine Creek. This will compromise a total of 20 buckets for measuring infiltration. Buckets will be implanted in selected pool tailouts that provide optimal habitat conditions for Chinook spawning. Buckets will be filled with an artificial mixture of spawning gravels simulating the composition of gravels typically found in high quality Chinook spawning habitat. The substrate material was collected from spawning habitats in the Upper Grande Ronde and Catherine Creek from McNeil core samples that were dried and sieved. The size fractions from processing McNeil core samples were retained in 5-gallon buckets so that known initial mixtures could be created. The purpose of creating a gravel mixture of known composition where fines are omitted is so that the potential for particle bridging exists. Small gravel particles larger than the size class considered to be the upper limit for fine sediment (i.e., 6.35 mm) enhance the ability of the substrate to exhibit particle bridging at the surface. Bridging would tend to limit the downward infiltration of fine sediments in transport downstream. If only coarse particles were placed into buckets, leaving large interstitial spaces, the potential for complete infiltration

of the gravel mixture is greater than if a more complete range of particles is present in the artificial mixture.

After filling buckets with the artificial gravel mixture, measure the amount of water that is required to fill all void spaces and cover all particles. Water volume should be measured with a 500-ml graduated cylinder. Note the volume required to fill all void spaces. Continue adding water to determine the volume needed to fill the bucket to its rim. Make this determination by observing the point at which the water level just meets a straightedge ruler placed across the bucket top. The void space represents the total volume that could be filled with fine sediment size fractions.

The excavated "redd" should be about 6 m^2 and should be located at pool tailouts to the extent possible (see Bjornn and Reiser 1991, Burner 1951). Place the filled buckets into a hole excavated into the streambed and make sure that the tops of the buckets are level with the channel floor. Secure the buckets with rocks and make sure that the bucket handles are up for removal. If necessary, tie the bucket handles to an object on the bank or a stake in the bank. Concurrently, water depth, channel width, distance from the bank should be measured. The distances to flagged markers from the buckets should also be measured and recorded on the data form, along with GPS coordinates. The markers, distances, and redds should be included in sketches for the reach. Discharge should be estimated and recorded on the form. Take photos of the implanted buckets to facilitate relocation. Notes should include general observations and particles size conditions with depth in the "redd."

Measurement of fine sediment in overwinter sample buckets

Overwinter fine sediment samples will be retrieved by extracting buckets simulating redds from study streams in the spring after spring Chinook emergence has occurred. Buckets will be returned intact to the laboratory with all sediments. The unfilled volume of the bucket above the sediment level will be measured. Contents of each bucket will be transferred to large trays for air-drying. Large pieces of organic matter will be removed by hand to the extent feasible but samples will not be ashed. Framework rocks will be brushed to remove dry, clinging sediment particles. Dry sediments will be sorted into particles of >6.35 mm (considered to be non-fines or framework) and three categories of fines (2.0-6.5 mm, 0.85-2.0 mm, and <0.85 mm) using a standard sieve set (Gilson). Each size fraction will be weighed to the nearest 0.1 g. Percentage fines of any size category will be calculated as percentage dry weight of the category relative to the total dry weight of the entire sample (framework plus fines).

Process the sediment samples in the buckets in the same manner that is used to process McNeil core samples to determine dry weights of the size fractions. However, after sieving, measure the dry volume and displacement volumes of each of the fine sediment size fractions in addition to their dry weights. Calculate particle density from the mass and volumes. Calculate the percentages of the original and final void volumes that were filled by fines. Return the original framework particle fractions to the bucket and thoroughly mix them in the same way that was done to create the artificial mixture initially. Again, measure the volume of void space available and the volume from the surface of the particles to the top of the buckets. The difference between the void volume of the framework particles and the dry volume of the fines is the void volume that could be filled by additional fines.

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Sub-surface fine sediment

Procedure

1. Identify stream reaches that provide intrinsic potential (IP) spawning according to a classification procedure. See methodology for channel and habitat unit classification adopted. Spawning potential is based on Interior Columbia Technical Recovery Team protocol, which relies on channel gradient classes and valley width combinations to rate potential. (ref). Channel unit classification and mapping is drawn from Schuett-Hames and Pleus (1996), Schuett-Hames et al. (1999), Hawkins et al. (1992).
2. Use a GRTS procedure (R-GRTS) to select a series of sampling points within the strata defined by our classification criteria (intrinsic potential of stream reaches based on channel gradient classes and valley width). GRTS sample points fall within the population of all 200-m sample reaches defined by IP (high, medium, and low potential for spawning). When a sample of 200-m reaches is selected, map the channel units within this reach. Visual mapping would segregate features such as channel margins, side channels, alcoves, depositional zones, aggregations of LWD, boulder clusters, spawning zones, and distinctly map the locations of riffles, glides, and pools. The potential spawning areas would be mapped and classified according to depth, velocity, and dominant or d_{90} substrate particle size. Area of available spawning substrate (quantity) and particle size distribution (quality) of the substrate will be determined only with the streambed classified as having spawning potential. If a portion of the streambed in a reach considered to have spawning potential was formerly spawning habitat (i.e., had velocity, depth, and dominant substrate conditions matching those of spawning habitat) but is not currently suitable, this information is documented in terms of percentage spawning area currently available. A change in quantity of spawning area is a key piece of information denoting habitat improvement in conjunction with average quality of the spawning area.
3. Access to sites with spawning potential is frequently limited by private landowner permission. Granting of permission reduces the potential sampling universe of spawning reaches. Within the population of sample spawning reaches stratified by IP, draw a random sample of points.
4. Spawning reaches of a given IP class may vary in length or homogeneity of substrate conditions. Homogeneity can be visually classified by conventional habitat unit mapping (Schuett-Hames et al. 19xx). See habitat unit mapping protocol. Heterogeneity is introduced into a reach by presence of features such as LWD or boulders. Using aerial color photos of the sampling reach, superimpose polygons on this image delineating channel units. Units of homogeneous substrate condition within a channel unit specify patch sizes suitable for spawning.
5. If boulder clusters within a pool tailout occupy a significant area, it would be misleading to include this substrate size in measures of the surface substrate size of material available for

spawning. Only the patches that provide suitable spawning characteristics within the IP class should be measured.

6. Conduct a visual estimate of surface particle size in the area that will be sampled for sub-surface material. Also, use the grid frame to estimate the surface particle size distribution. This is a 2-stage sampling design that takes advantage of the more time consuming grid frame method to reduce sample variance and derive a more accurate estimate.
7. If the spawning area has a uniform distribution of spawning gravels (i.e., one with a uniform distribution of substrate particles and a particle distribution meeting the size distribution usable by Chinook as determined by visual and grid-based methods), select a random location for the first transect. Collect 9 samples in the defined reach, with 2 samples per transect. The samples should be taken from the center of the left, middle, or right thirds of the channel cross-section. Randomly assign samples to these L, M, or R segments of the transect. There would be 3 transects per spawning reach. If the 200-m reach is uniform in surface materials for this length, the starting transect in the mainstem can be randomly selected by identifying the downstream 65 m (for a 200-m reach). The starting transect would then be identified as a random number between 0 and 65, representing the number of meters from the downstream boundary. The other 2 transects would then be spaced at 65-m intervals upstream of the lower transect. Three samples would be taken on each transect in the center of the L, M, and R equal segments of the transect identified as a potential spawning zone. If the channel margins are depositional areas, this portion of the transect would not be considered as spawnable. If the 200-m reach is more diverse in channel unit distribution and may have some longitudinal trend in surface particle distribution, the samples should be spread out across the 200-m reach in a balanced manner. Subdivide the reach into 200/9 or 22.2-m segments. Within each segment locate a sample point randomly. If spawning occurs only in small patches of appropriately sized spawning gravels in a reach, samples should be taken only in patches meeting minimum size requirements (i.e., $\geq 5\ m^2$). Patches can then be selected by identifying the lower boundary of the 200-m spawning reach and measuring upstream 22.2 m; then identifying all qualifying patches within this segment and randomly selecting one as the initial sample. If ≥ 1 patch is found in the first segment (22.2 m), there is a possibility that 1 patch per segment can be randomly selected from each segment. Then 9 samples will be taken by randomly selecting a patch from each successive 22.2-m segment. This method provides a spatially-balanced distribution of sample points for reach segments of 22.2-m length. If patch distribution is such that there is not a patch ($\geq 5\ m^2$) in every segment but there are ≥ 2 patches for every segment of 44.4 m, select 2 patches in a random manner from segments of this length. However, if within the 200-m reach the spawning units are highly aggregated, sample points should be distributed randomly in relation to area of spawning habitat. If the 200-m segment is divided into 4 subsegments of 50-m length and the percentage of the available spawning habitat is 0, 10, 20, and 70% by subsegment, the number of samples assigned to this distribution might be 0, 1, 2, and 6 with a total of 9 samples.
8. Samples will be taken with a McNeil core sampler. See diagram and photo of the sampler designed for our project. The device is rotated back and forth to force it straight down into the substrate to the maximum depth allowable by the sampler design. This depth is approximately 20 cm depth, which is the average Chinook egg pocket depth. Given the diameter of the coring tube, the entire sample collected to the bottom of the core can be transferred to a plastic bucket (6L) for return to the laboratory. Transfer to the plastic bucket is done using hands to retrieve larger

particles; stainless steel scoop to transfer finer material. Preliminary testing revealed that it was not necessary to pump superfine material (< 300 um) because this did not comprise a significant portion of bed material.

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Temperature

Procedure

Water temperature thermistors (U22-001-HOBO Pro v2 water temperature data logger) were deployed in locations specified by Watershed Sciences, Inc. See map of temperature sample points. These locations were identified as points needed to make the Heat Source temperature model work efficiently. Points were typically above nodes or mouths of tributaries entering a mainstem where the tributary contributed $\geq$ 5% of the mainstem flow occurring below the tributary junction. This percentage contribution was judged based upon the relative areas of the watersheds of the tributary and mainstem above the junction.

Temperature loggers were deployed according to specifications found in the Oregon Plan (cite 20xx). All loggers were calibrated in the laboratory in an ice water bath prior to transfer to the field using a NIST-traceable electronic thermometer (Omega Engineering, HH42 handheld thermistor thermometer). All loggers are also re-calibrated after returning the units to the laboratory for data downloading. Time recorded by the units is also checked to insure that time stamps for temperature recordings are accurate. Each logger carries a unique serial number so that its calibration factor can be associated with the unit.

Loggers are attached to a rebar stake driven into the substrate. Attachment is either using two nylon zip ties or using 1/16th inch stainless steel braided cable with aluminum crimps. Steel stakes are either ½ inch rebar (2 or 3 ft lengths) or 2 ft lengths of concrete form stakes, which have holes serving as convenient means of attachment of the stainless cable. We believe that the latter type of stake is provides are greater security in attaching loggers because they cannot be pulled upward off the stake as can happen with rebar where the cable is simply looped around the rebar. Rebar was located generally behind large boulders in the swift flow in the channel. When large boulders are not available for protection of the rebar and logger, the logger was positioned closer to a streambank, but still in a location where water depth is sufficient to maintain water flow over the logger under September flows and where flows represent the well mixed flow of the main channel and is not subject to eddying or margin effects. Loggers were placed into sections of steel pipe for protection from substrate movement and to shield them from direct sunlight. Rebar locations were predominantly in positions where they received shading from streambanks or riparian vegetation or the boulder itself.

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Streamflow

Surface streamflow measurements at cross sections

Procedure

Gauging Stations. We plan to measure streamflow at gauging stations using an Onset U20-001-04 HOBO 30-foot depth data logger. There will be two gauging stations selected—one cross section in the upper Grande Ronde and one in Catherine Creek. Our tentative site locations are the South Fork Catherine Creek in the Catherine Creek Drainage and Sheep Creek in the UGR. These were assessed after obtaining all current gauge locations for the USGS , USFS, and Grande Ronde Model Watershed. There are no gauges currently on these streams. We intend to install gauges on these streams at points above which the landowner is USFS. This insures that there are no stream diversions or irrigation above gauge sites.

At each of the two gauge sites we will measure streamflows at the cross sections incorporating the depth gauge. We will install a permanent benchmark as a point for measuring relative elevation so that we can assess changes in water stage height against streamflow (m^3/sec) over time. Because the Onset depth data logger is unvented, it will be necessary to acquire barometric pressure concurrently with depth measurements in order to correct pressure readings. We will use a single pressure logger to correct each of the loggers deployed in-river.

Gauge sites will be located at sites where there is no downstream backwater effect. Sites will have a uniform gradient with uniform channel morphology. No channel constrictions above or below the site will be present to affect stage-discharge relationships. Channels will have cross sections at the point of deployment of the pressure transducer that are free of large boulders and can provide a cross section not highly subject to displacement at high flows. Sites selected may not provide access to allow measurement of the highest flows (e.g., a site with cable over the stream, or a bridge site). However, the Sheep Creek site may offer this opportunity where there is a large culvert coveying the entire streamflow nearby.

Streamflow will be measured at the gauge sites during the period from June-October to define the stage-discharge relationship. As recommended by Carter and Davidian (1968) approximately 20-30 flow measurements will be made across a cross-section. On the mainstem Grande Ronde this can be accomplished by taking readings at approximately 0.5-m intervals. Where the channel is very wide and the substrate is highly uniform and there are minor variations in readings among sample points, it appears adequate to sample at 1-m intervals. At each vertical the following observations are made : (1) distance to the bank, (2) current velocity, (3) water depth at 0.6 m depth from the water surface. Streamflow is then computer using a program such as FlowPro or by Excel spreadsheet in which velocities are multiplied by mean depth and the sum of half the distances to adjacent verticals (Carter and Davidian (1968).

In stable cross sections, one streamflow measurement taken per month is generally sufficient to describe the relationship (Carter and Davidian 1968).

When it becomes feasible to access sites during the high flow period, peak flows will be measured primarily by the slope-area method (Dalrymple and Benson 1967). This method relies on the Manning equation: $Q = \frac{1.486}{n} AR^{2/3}S^{1/2}$

Where

Q = discharge
A= cross-sectional area
R=hydraulic radius

S=friction slope
n=roughness coefficient

The Manning equation should work well in channels with uniform flow where the water surface profile is parallel to the streambed. The reach should be straight if possible with a trapezoidal channel cross-section. If a straight reach is not possible, a contracting reach is preferable to an expanding reach. The slope-area reach should not be immediately downstream of a channel constriction and should not contain anomalous deep areas (Dalrymple and Benson 1967).

Characteristics of a slope-area reach should be (1) length equal to or greater than 75 times mean depth, (2) the fall equal to or greater than the velocity head, and (3) the fall (Δ h) should be greater than or equal to 15.2 cm (Dalrymple and Benson 1967).

The Froude number will be computed for each cross section. Froude number (F) = $V/\sqrt{(g\, d_m)}$

Where V = mean velocity and d_m = average depth.

Streamflow measurements at ungauged sites.

Streamflow will be measured at locations distributed throughout the Upper Grande Ronde and Catherine Creek. The purpose of this is so that on the day that the FLIR flight is conducted it will be possible to know the streamflow at strategic locations throughout the study basins so that the water temperature model can be accurately developed and calibrated. Water temperature patterns caused by the accumulation of thermal loading are highly dependent upon streamflows. Preliminary streamflow measurements on the mainstem Grande Ronde indicated that the downstream pattern of streamflow was not uniform. That is, streamflow sometimes decreased from one cross section to another downstream from it, followed by an increase at the next cross section. These irregular patterns will require measurements at numerous cross sections along the mainstem. Selected sites are not subject to emergent vegetation growth that would alter flow relationships. At each location we will install benchmarks for measuring relative changes in flow height. See Cartier and Davidian (1968) for additional site location issues.

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Note: [The FlowPro macro is in our shared files on L drive: L:\Depts\SCI-FI\McCullough\MOA-data-documents\flowpro.xls]

Low Flows

The Oregon Department of Water Resources (Cooper 2002) has data on the 50th and 80th percentile natural streamflows for the Upper Grande Ronde and Catherine Creek. These flow indices represent the natural long-term performance of the hydrological systems for the two study streams. The current streamflows of some representative streams of the Grande Ronde basin (e.g., Lookingglass Creek, Wenaha River) will be measured and compared with their ODWR rating curves to assess current streamflow against the long-term rating curve. The disparity between the UGR and Catherine Creek current flows and estimated natural flows will then be made. The percentage improvement in summer flows will be evaluated in order to examine the potential improvement in stream temperatures.

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Channel Morphology

Identification of bankfull stage

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Table 15: Field quality control measurements: Water quality indicator. (Modified from Paulsen 1997).

Measurement	QC Sample Type	Description	Frequency	Acceptance Criteria	Corrective Action
Dissolved oxygen	PE Sample	Concurrent determination of sample by Winkler titration	Once per meter	Measured oxygen within ± 1 mg/L of oxygen estimated by Winkler titration	Replace meter and/or probe
	QC Check Sample	Water-saturated air	Daily	Instrument can be calibrated to theoretical value	Replace meter and/or probe
Temperature	PE Sample	Concurrent measurement of 0 °C and 25 °C solutions with NIST-traceable thermometer	Once per meter	Within ± 1 °C of thermometer reading	Replace meter and/or probe
	QC Check Sample	Concurrent measurement of sample with field thermometer	Weekly	Within ± 1 °C of thermometer reading	Replace meter and/or probe
Conductivity	QC Check Sample	Solution of known conductivity	Weekly	Within 10 µS/cm of theoretical value	Re-calibrate meter using NIST-traceable standards; replace probe and/or meter

QC - quality control
PE - performance evaluation
NIST - National Institute of Standards and Technology

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Table CQA-1: Data Qualit

Data Quality Level	Quality Assurance Plan	Water Temperature Methods	pH Methods	Dissolved Oxygen Methods
A+	DEQ QAPP approved by DEQ QA Officer	Thermometer Accuracy checked with NIST standards A ≤ ± 0.5°C P ≤ ± 1.5°C	Calibrated pH electrode A ≤ ± 0.2 S.U. P ≤ ± 0.3 S.U.	Winkler titration or calibrated Oxygen meter A ≤ ± 0.2 mgL^{-1} P ≤ ± 0.3 mgL^{-1}
A	External QAPP	External Data Thermometer Accuracy checked with NIST standards A ≤ ± 0.5°C P ≤ ± 1.5°C	External Data Calibrated pH electrode A ≤ ± 0.2 S.U. P ≤ ± 0.3 S.U.	External Data Winkler titration or calibrated Oxygen meter A ≤ ± 0.2 mgL^{-1} P ≤ ± 0.3 mgL^{-1}
B	Minimum Data Acceptance Criteria Met	Thermometer Accuracy checked with NIST standards A ≤ ± 1.0°C P ≤ ± 2.0°C	Any Method A ≤ ± 0.5 S.U. P ≤ ± 0.5 S.U.	Winkler titration or calibrated Oxygen meter A ≤ ± 1 mgL^{-1} P ≤ ± 1 mgL^{-1}

Table CQA-1: Data Quality Matrix, continued (OR DEQ, 2004)

Notes:

QA definitions of Data Quality Levels

A+ – Data of known Quality; collected by DEQ; meets QC limits established in the QAPP.

A – Data of known Quality; submitted by entities outside of DEQ; meets QC limits established in a *DEQ-approved* QAPP.

B – Data of known *but lesser* Quality; data may not meet established QC but is within marginal acceptance criteria; or data value may be accurate, however controls used to measure Data Quality Objective elements failed (e.g., batch failed to meet blank QC limit); the data may be useful in limited situations or in supporting other, higher quality data.

C – Data of unacceptable Quality; data are discarded (Void) typically in response to analytical failure.

D – Incomplete data; no sample collected or no reportable results, typically due to sampling failure.

E – Data of unknown quality or known to be of poor quality; no QA information is available, data could be valid, however, no evidence is available to prove either way. Data is provided for Educational Use Only.

F – Exceptional Event; "A" quality data (data is of known quality), but not representative of sampling conditions as required by the project plan.(e.g., a continuous water quality monitor intended to collect background environmental conditions collects a sample impacted by a fire that created anomalous conditions to the environment).

Data Quality Level Grading Criteria:

A = Accuracy as determined by comparison with standards, e.g., during equipment calibration or pre- and post-deployment checks

P = Precision as determined by replicate measurements, e.g., during field duplicates, field audits, or split samples

Table CQA-2: QA/QC Criteria for Auditing Instrumentation or Reagents

(To be performed in laboratory to insure accurate, reliable equipment)

Water Temperature (°C)	± 1.5 °C in field, comparable to a NIST-traceable thermometer; or ± 0.5 °C in lab (controlled warm and cold water baths)
Dissolved Oxygen (mg/L)	Sodium Thiosulfate reagent should be ± 0.1 mg/L on standard solution, Winkler titration (see Dissolved Oxygen section of MOM's for methodology)
pH (SU)	± 0.05 SU, standardized to ambient air temperature; minimum 2-point calibration check with pH buffer solutions and/or LIS (low ionic strength) solution in range of values expected.
Conductivity (μmhos/cm)	± 7% difference of Actual reading vs. Standard solution value • Use NIST Traceable/Lab certifiable standard solution • Check values between 5%-7% Actual reading vs. Standard solution reading

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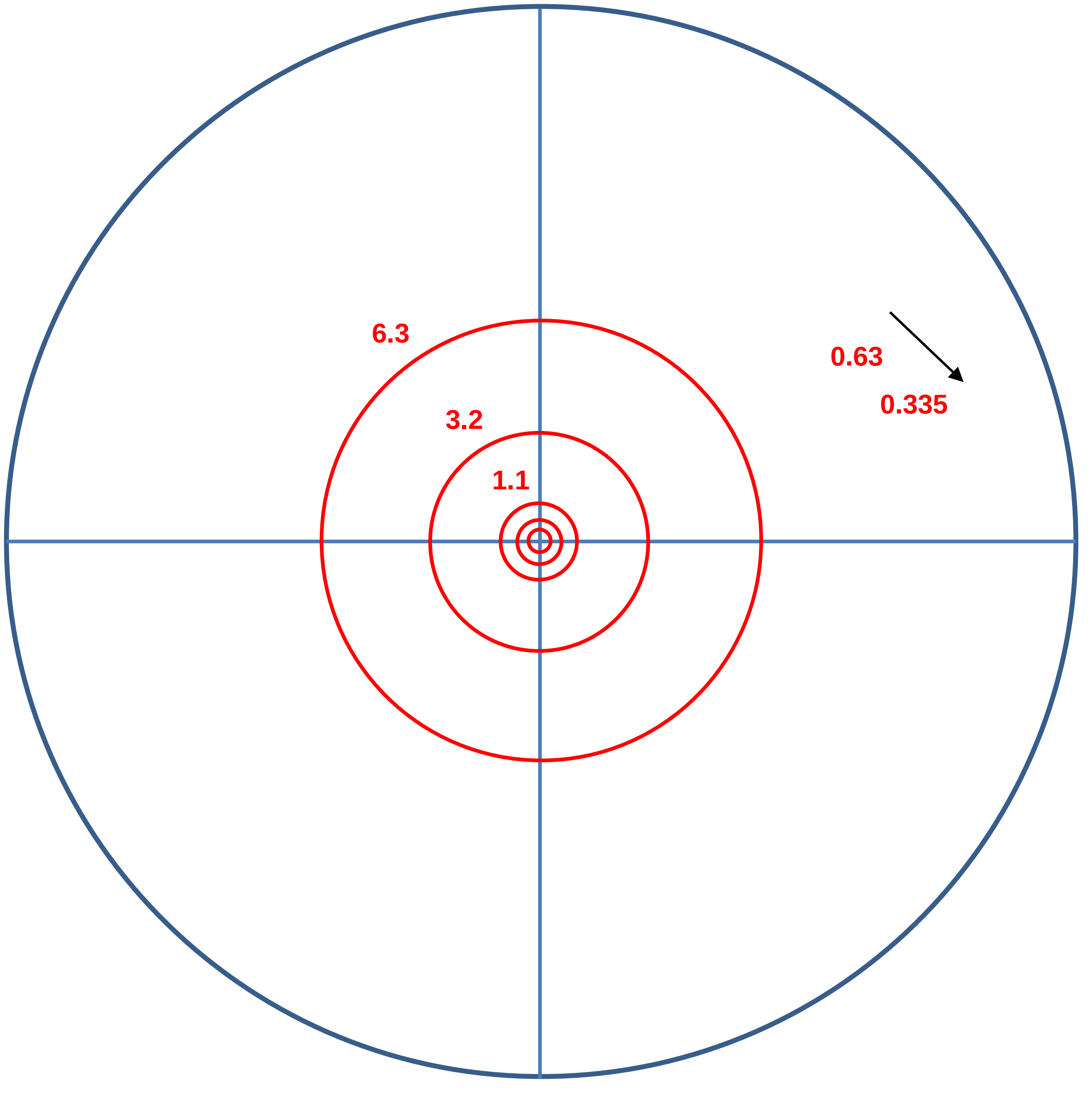
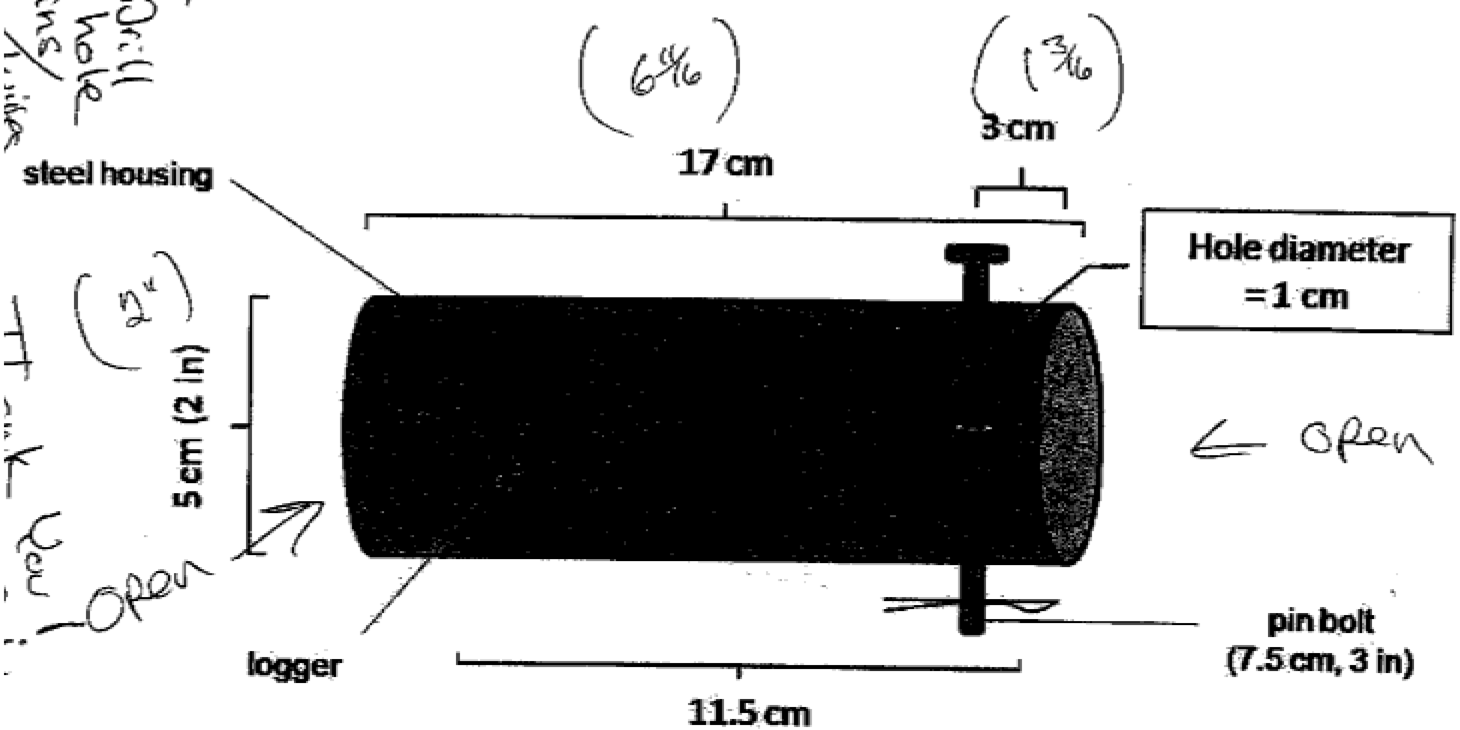
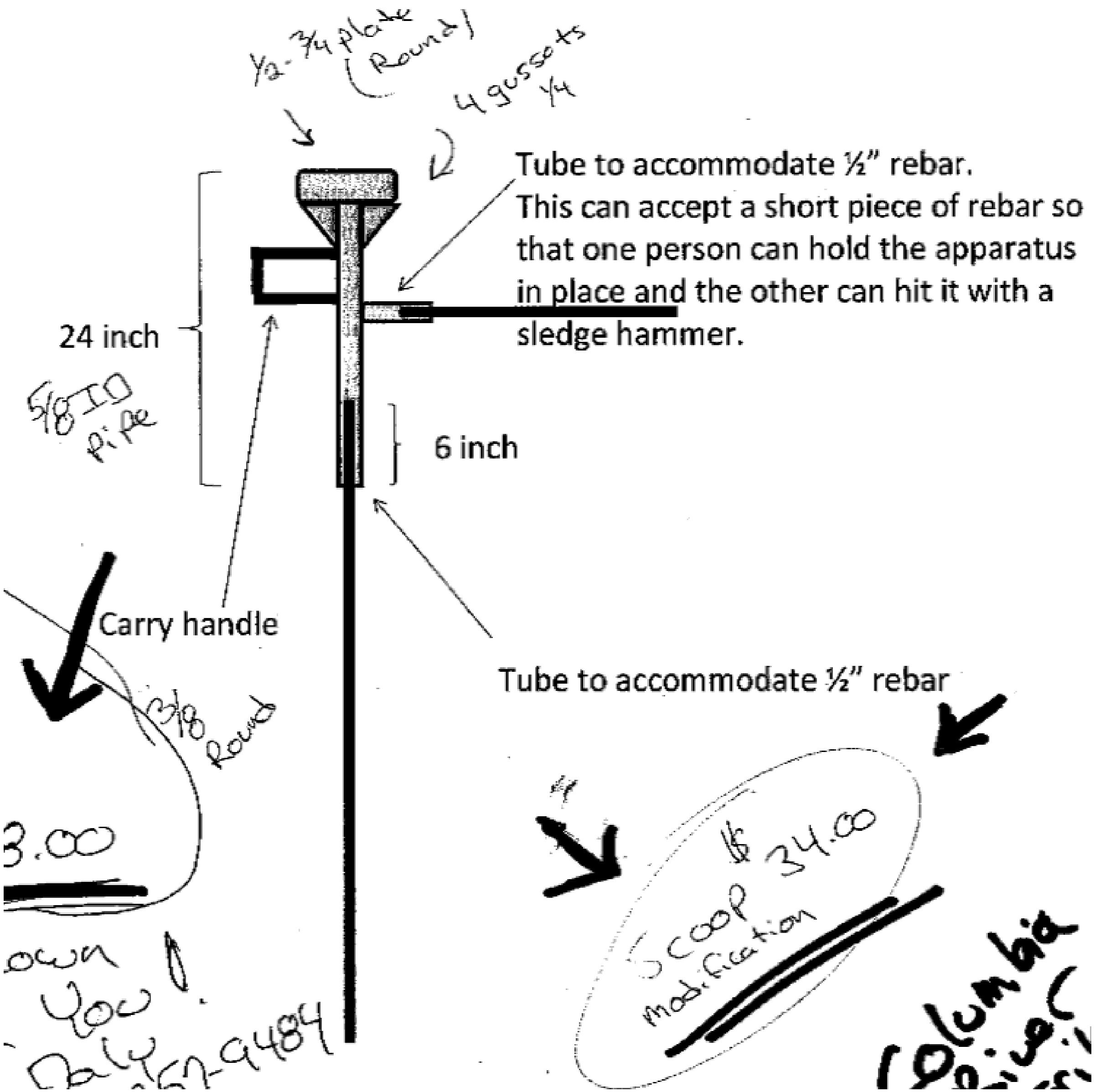
Appendix M

Design of the Polycarbonate View Scope for Measurement of Surface Particle Size Distribution


6.3
3.2
1.1
0.63
0.335

Temperature Logger Housing



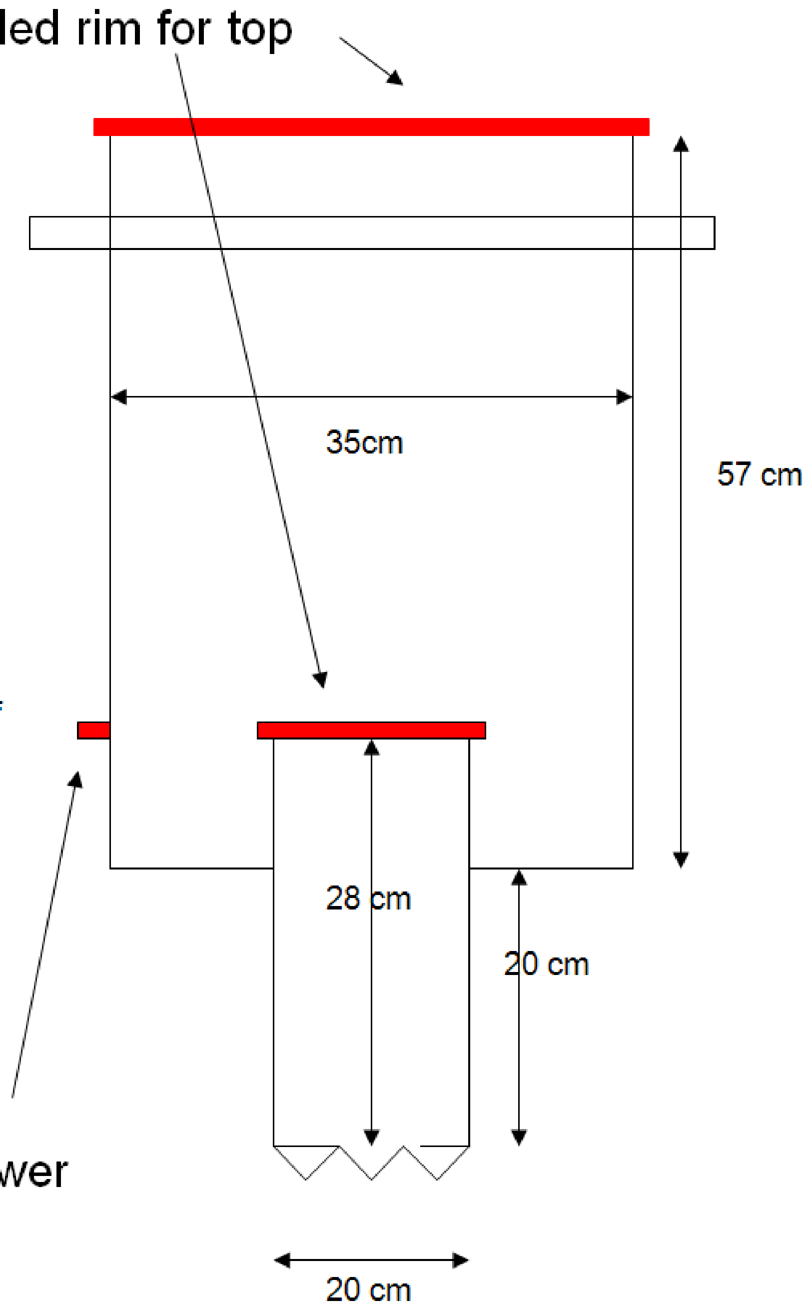

1/2-3/4 plate (Round)
4 gussets 1/4
Tube to accommodate ½" rebar.
This can accept a short piece of rebar so that one person can hold the apparatus in place and the other can hit it with a sledge hammer.
24 inch
5/8 ID pipe
6 inch
Carry handle
3/8 Round
Tube to accommodate ½" rebar
3.00
Scoop modification $34.00

Appendix N

Design of the Modified McNeil Sampler

Dale's design

CRITFC
503-731-1306



Modifications to device needed:

Need a circular piece of rod attached to the top sharp edge of the main bucket and also to the top edge of the inner cylinder to prevent getting cut.

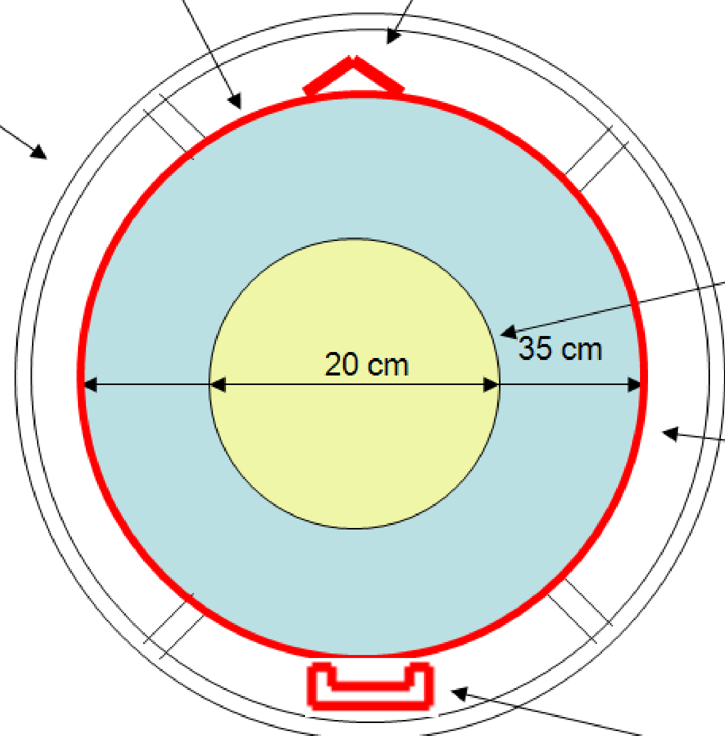
Add a handle to the lower portion of the main cylinder so that a person can hold the device with one hand on the main circular handle and the other hand on the new smaller handle. The new small handle can be a simple rectangular shape or a more circular shape and wide enough for a large hand.

Dale's design

Modifications:

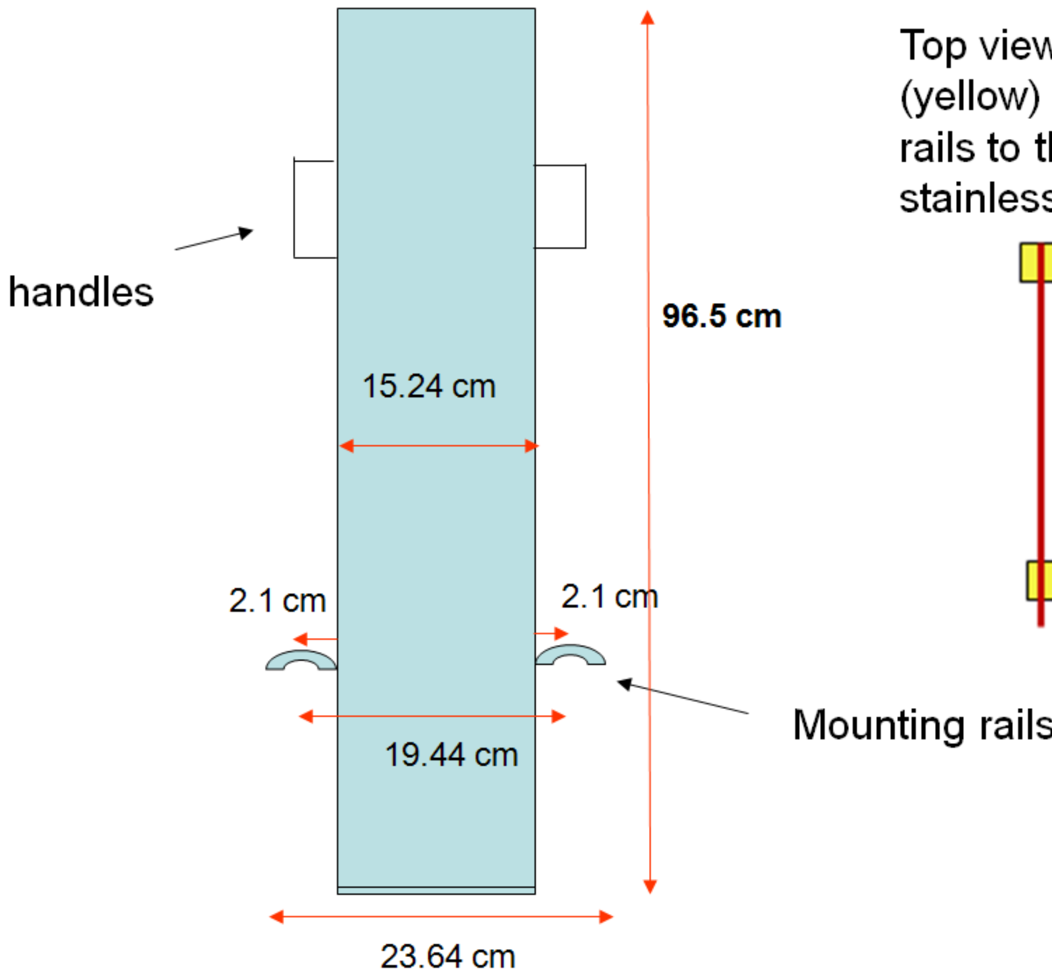
Add a pour spout and a handle opposite the pour spout.

Also shown is the circular rod added to the top of the main cylinder to prevent cuts on the sharp edge.

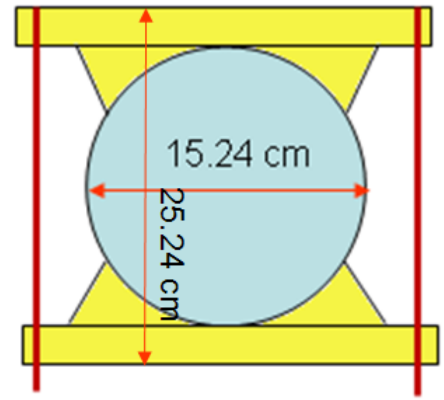


Place handle down from the top of the basin so that you can pour the contents of sediments held inside into a bucket and wash it out to a sieve. Handle should be sturdy enough so that it can be used possibly by 2 people to force it down 20 cm into the stream bed. Handle should be rounded and large enough in cross-section so that it doesn't hurt your hands to push down hard.

Side view of plexiglas tube, with handles, mounting rails



Top view of clamping mechanism (yellow) to clamp the mounting rails to the plexiglas tube, with stainless threaded rods (red)



Appendix O

Preliminary Results from Particle Size Analysis of a Simulated Streambed Using GIS

Preliminary Results from Particle Size Analysis of a Simulated Streambed Using GIS

Dale A. McCullough, David Graves, Saang-Yoon Hyun, and Rishi Sharma
Columbia River Inter-Tribal Fish Commission

Introduction. A simulated sampling of a streambed was conducted using a GIS (ArcGIS, ESRI) to determine what grid spacing would be optimum for measuring the particle size distribution of streambed substrate. Bunte and Abt (200x) recommended using a minimum grid spacing greater than or equal to the largest particle size encountered on the streambed in order to reduce spatial autocorrelation. That is, if the particle sizes include diameters of 25 cm, but the grid spacing between sample points is 2 cm, a grid placed over the large particle will have potentially many points falling on the same 25-cm diameter particle, creating a high level of redundancy.

Objective. Our GIS-based simulation had the following objectives: (1) To explore the relationship between particle size and the ability to accurately define the particle size distribution for a streambed of known percentage distribution of particle sizes, (2) to determine how many sample points are needed to define the particle size distribution with accuracy and precision needed to detect a change.

Methods. Using ArcGIS software three different particle distributions were created with which to draw samples from using computer simulation of sampling.

The three simulated streambeds were as follows:

(1) "Random reach" had a size of 5 m x 10 m. Largest size particles (class 6) were placed randomly first, followed by placement of the next largest particle (class 5), and so on, until class 1 particles were randomly placed. After all class 1 particles were placed, the remaining spaces were assumed to all be the smallest size class. X-Y coordinates were randomly selected for the centroid of each particle class. This point was then buffered to the diameter of the particle that was being located on the simulated streambed. It was then determined whether the particle being placed overlapped any other particle that had been previously placed. If not, the particle's position was fixed and subsequent particles were placed using the same procedure until the desired number of particles were placed to comprise the desired percentage surface coverage by that size class. Particles placed near the boundary of the wetted 5 x 10 m simulated stream reach could overlap the wetted border if the particle radius was greater than the distance from the particle centroid to the wetted edge.

(2) The "Zoned reach" was a 5 m x 20 m simulated reach that had the same overall particle size distribution as the "Random reach" but which had a longitudinal trend of particle sizes from one end to the other. This was intended to represent spatial variation inherent in a natural channel that might be so slight as to not be visually recognized but which could create sampling difficulties in determining the mean of particle size coverage. The effect of this level of spatial variation was examined. The largest particle size classes trended from higher than average from one end to the other while the smallest particle sizes had the reverse trend. The longitudinal particle size trends varied by steps. There

were 10 steps of 2 m length. The simulated streambed was constructed in 2-m increments by placing particles in each segment to represent the longitudinal trend.

(3) The "Sim3 reach" had a very different particle size distribution, with much lower levels of coarse particles and higher levels of fines. This simulated reach was 5 m x 10 m.

The particle size classes were:

class 6: 37.5 cm
class 5: 19.25 cm
class 4: 9.625 cm
class 3: 4.875 cm
class 2: 2 cm
class 1: . 815 cm
class <: < .815 cm (white space = fine grained particles)

The particle sizes selected were chosen to represent the mean of a series of particle size bins.

The percentages of surface coverage in the simulated reaches of each particle size were:

True percentage	50.58	2.00	6.00	11.85	8.82	14.82	5.93	**Random Reach**
True percentage	50.43	1.98	5.93	8.76	11.94	14.91	6.06	**Zoned Reach**
True percentage	18.40	1.94	9.95	18.22	19.68	19.24	12.57	**Sim3**
Size Class	0	1	2	3	4	5	6	
Mean size (cm)	<0.625	0.815	2	4.875	9.625	19.25	37.5	
Size Range (cm)	<0.625	0.625-1	1-3	3-6	6-13	13-25	25-50	

Sampling procedure. The three different simulated streambeds were sampled by a variety of techniques.

(1) Uniform transect. The first 1-m length of the 10-m long simulated reach was identified. A random start transect was selected within the first 1-m length. After this selection, all 10 sample transects were spaced at 1-m intervals and 20 transects were spaced at 0.5-m intervals in the longitudinal direction. Sample points were uniformly spaced across each transect in the center of each 0.5-m interval, producing 10 sample points on each transect. Sample points are at a distance from the wetted margin equal to the distance between points. This makes the distance between points laterally equal to 5/11 = 0.46 m.

(2) Grid toss. A grid frame that was 5 x 5 cells, with each cell having a grid spacing of 2, 5, 10, 20, or 40 cm. When grid spacing was 40 cm, the grid frame measured 2 m x 2 m. The grid frame was placed perpendicular to the longitudinal centerline of the channel at randomly selected points. A random selection of 10 points was made. Each grid frame provided 25 sample points.

(3) Transect/Grid frame. This method selected a random start location for the first transect. After this transect line was selected all other transect lines (10 or 20 for the 10-m long reach, and 20 for the 20-m long reach) were uniformly spaced. Grids selected for this analysis had 9 grid cells that varied from 2, 5, 10, 20, or 40 cm. The grid frames were placed in a uniformly spaced pattern across each transect. With 10 transects and 4 grid

frame placements per transect, there were 4 x 9 or 36 sample points per transect and 360 points total.

Sampling schemes used either the Transect method, Grid toss, or Transect/Grid placement method to select sample points.

Statistical analysis. Using the GIS procedure with the three sampling schemes summarized above, 100 different sets of data were collected from each sampling method. For example, using the Grid toss method, 100 grid frames were tossed at random on the simulated streambed. From this set of 100 tosses, each grid produced 25 sample points each for the 5 x 5 grid. Using this set of 100 grid frame tosses, we randomly selected 10, 16, or 20 of these tosses 1000 times to represent the simulated reach mean and variance by a Monte Carlo technique programmed in Visual Basic with Excel. Ten tosses produced a total of 250 sample points; 16 tosses—400 sample points; 20 tosses—500 sample points. A selection of 10 random tosses was replicated 1000 times to generate a mean and variance.

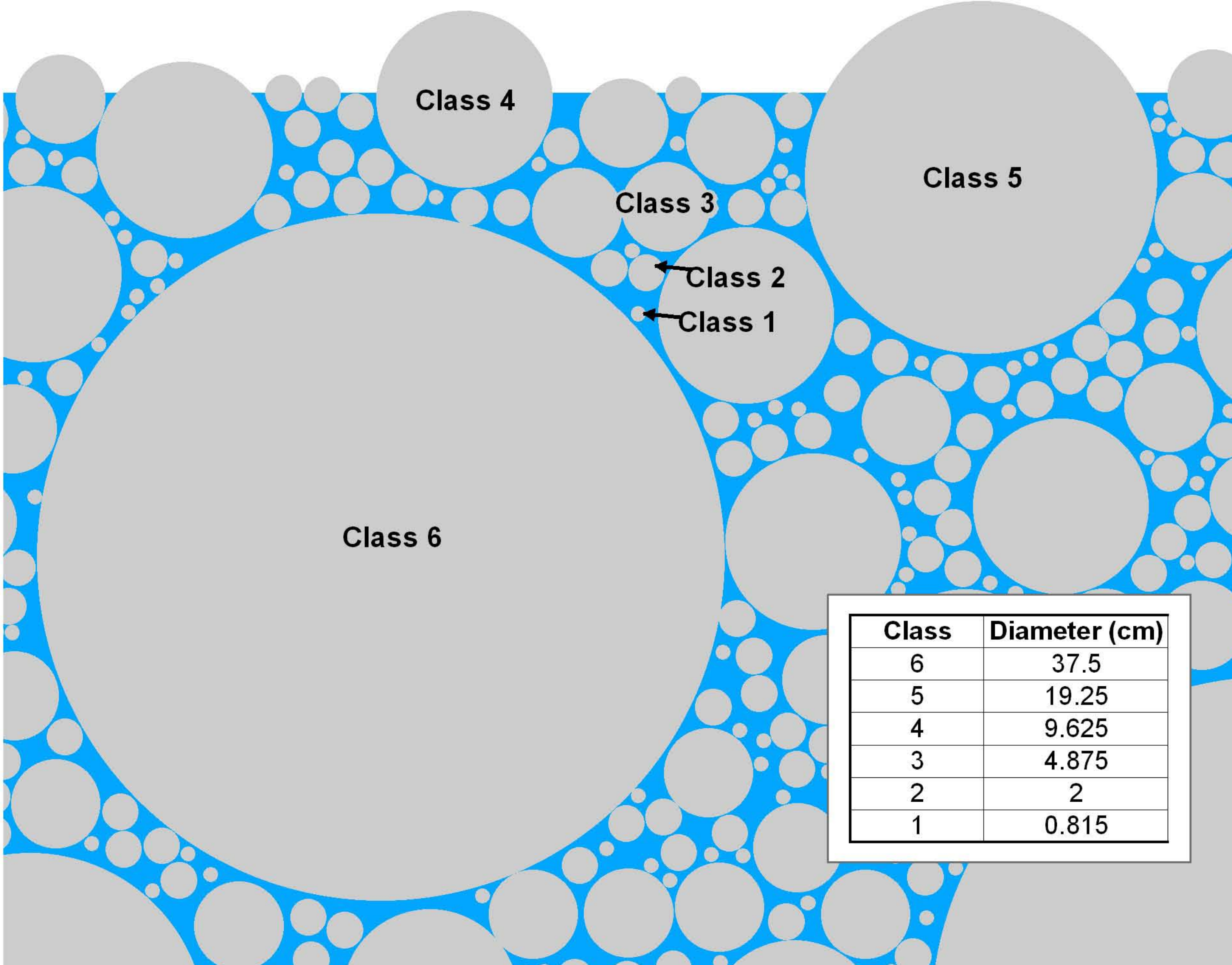
Using the Transect method with 10 transects and 10 or 20 points per transect, 100 samples were created by randomly selecting starting transect locations 100 times. For each initiating transect location, all 10 transects were uniformly distributed to sample the simulated reach. Reaches were sampled with either 100 or 200 total points. The simulated reach was sampled in this fashion 100 times with the transect method. The set of 100 samples of 10 transects each created the master sample. From this, the Monte Carlo process randomly selected 10 or 20 transects 1000 times to generate individual means from each set of 10 or 20 transects. The variance in mean values produced in this random process represents the variation in sampling that can be expected under various conditions in the field. The conditions represented by the simulated reaches include (1) variation in percentage composition by the various size fractions of particles, (2) uniform or longitudinal zonation of particle sizes within a stream reach.

In addition to calculation of coefficient of variation from the Monte Carlo simulations, we employed a maximum likelihood estimator to data on frequency of particle size occurrence to calculated mean, SE, and CV for each particle size class. These mean values were then compared to the true sample means.

Conclusions. The Monte Carlo method and the MLE methods were compared. We sought unbiased estimators of the mean. We determined that the MLE method was the preferable method of calculation. We intend to refine this method of calculation and use this GIS-based simulation as further support for appropriate sample sizes and grid spacing to accurately represent both percentage fine sediment and the full range of particle sizes. Our preliminary analysis indicates that a grid spacing of at least 20 cm is adequate to represent all size classes simulated in this GIS experiment. The larger size fractions, however, had a distribution that made it more difficult to represent the mean with a small sample size.

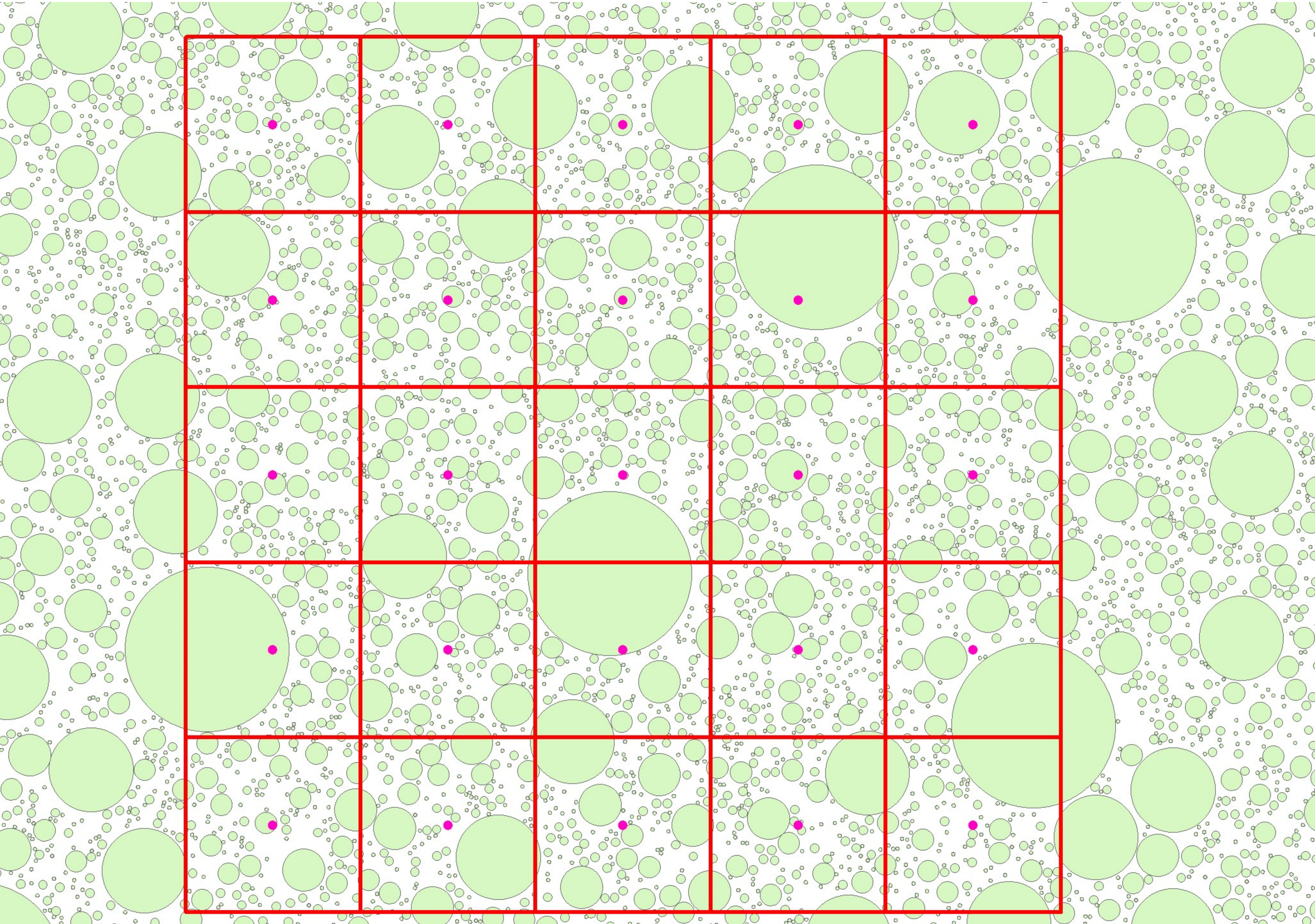
Preliminary Results from Particle Size Analysis of a Simulated Streambed Using GIS

Particle Size Classes

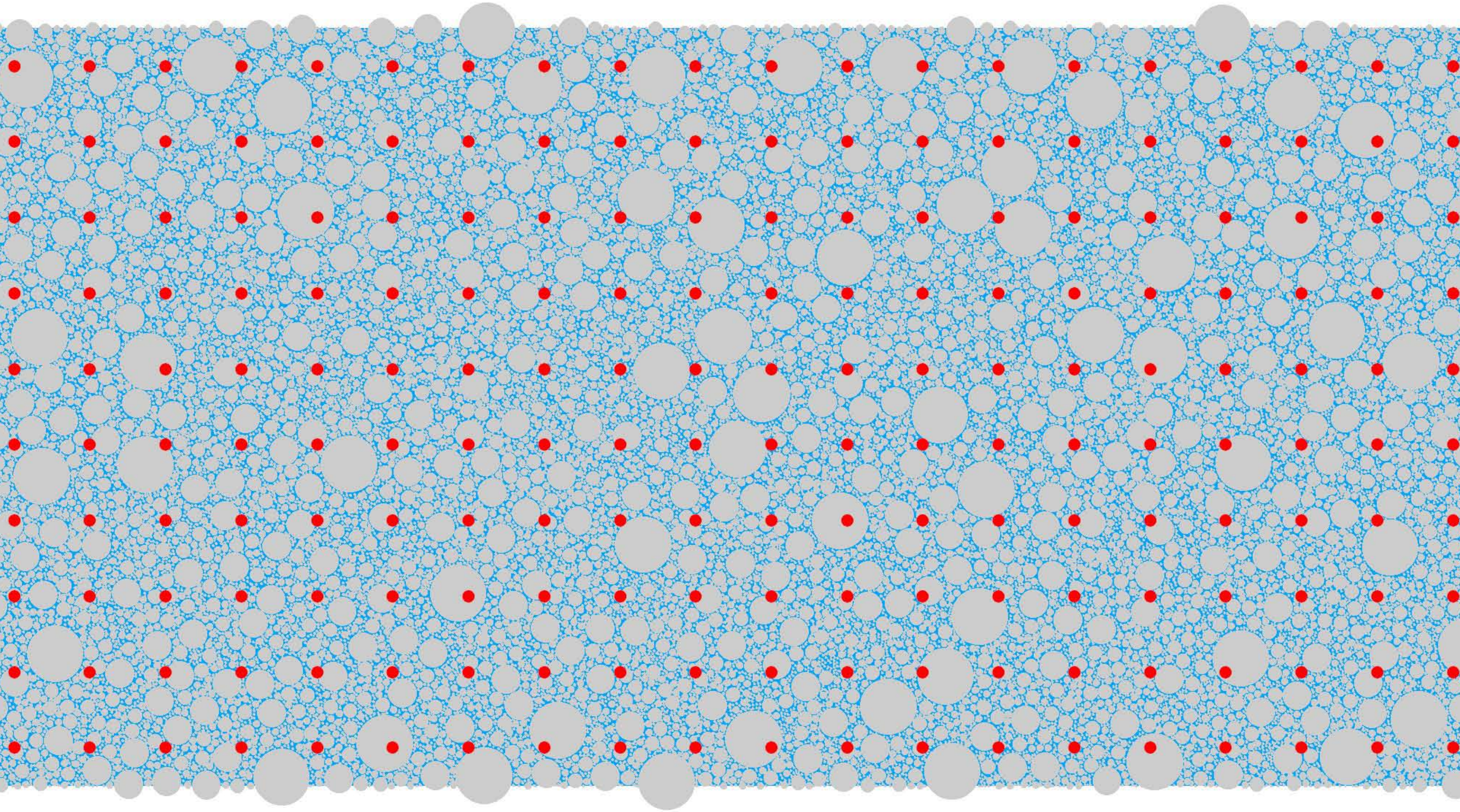


Class	Diameter (cm)
6	37.5
5	19.25
4	9.625
3	4.875
2	2
1	0.815

Grid (Random Throw) Sampling Approach

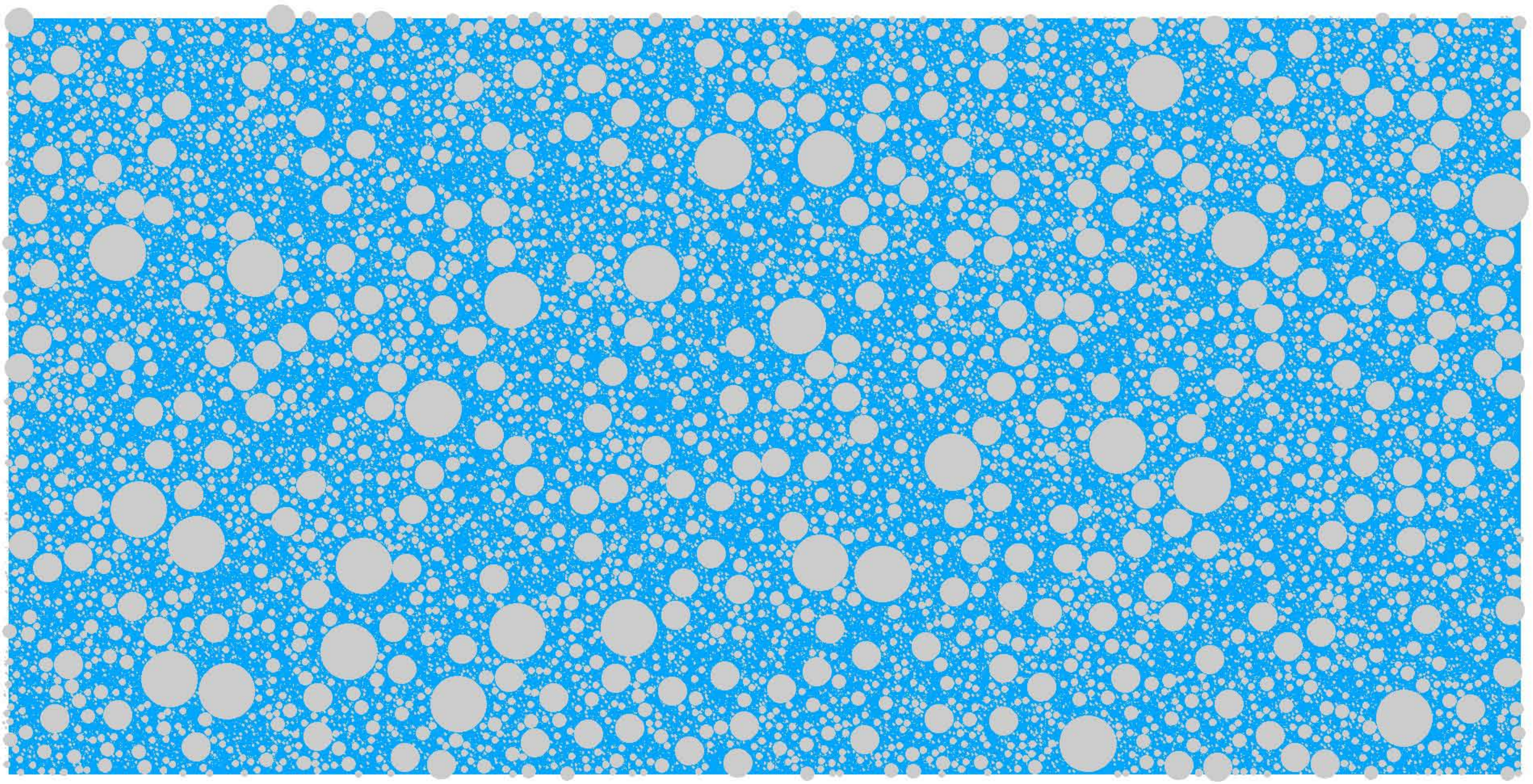


Uniform (Transect) Sampling Approach



Random Reach

Distribution 1 - Random



Size Classes and Areal Coverage

6	5	4	3	2	1	Fines
5.9%	14.8%	8.8%	11.9%	6.0%	2.0%	50.6%

Random Reach

Reach is 5 m x 10 m

Particle size distribution was:

True percentage	50.58	2.00	6.00	11.85	8.82	14.82	5.93	**Random Reach**
True percentage	50.43	1.98	5.93	8.76	11.94	14.91	6.06	**Zoned Reach**
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Size Range (cm)	<0.625	0.625-1	1-3	3-6	6-13	13-25	25-50	

Random Grid Sampling Method: Simulate randomly tossing gridded frames onto the substrate.

Raw data was 100 randomly selected tosses of the frame.
Each frame has 25 grid intersections. Spacing between grid points was:
2 cm, 5 cm, 10 cm, 20 cm, and 40 cm.

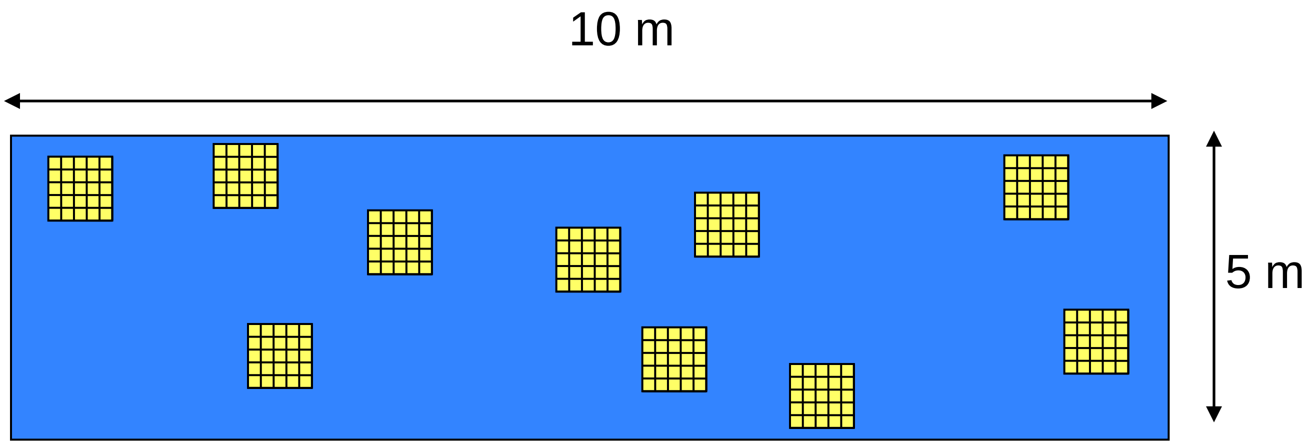
The set of 100 tosses provided 100 separate estimates of substrate composition, each based on 25 points. The diameter of the particle under each point was determined and percentage composition was calculated as percent of the points in each size class.

From the set of 100 random tosses that were analyzed using the GIS, samples of 10, 16, or 20 of these tosses were randomly selected to get an average percentage composition value for each of the 7 particle size classes.

10 tosses of the various sampling frames provided estimates based on 250 points (grid intersections).

16 tosses provide estimates based on 400 points.

20 tosses provide estimates based on 500 points.



Grid sampling of the Random Reach.

This example represents a random selection of 10 tosses from the master population of 100 random tosses. If we replicate this selection process 1000 times, we generate the CVs for particle size analysis. Each grid frame has 25 points for which the particle size is determined.

This analysis was designated SimRand_100x100x20. This means that the grid frames are 100 cm x 100 cm and the spacing between points is 20 cm. In the selection of 10 tosses, there are 250 sample points.

We can compare the CVs for 10 tosses with grid spacing of 2, 5, 10, 20, and 40 cm. We can also compare the CVs for 10, 16, and 20 tosses with any size grid frame. Or, we can compare on the basis of total number of points.

We used Excel to randomly select 1000 sets of 10, 16, or 20 tosses of the grid. These represent various combinations of the original 100 tosses on the simulated streambed.

For example, 1 random selection out of the 1000 could produce a set of mean particle sizes for the 7 classes based on toss i1, i6, i18, i23, i65, i78, i82, i85, i93, and i95 for a 10-toss sample. With a set of 1000 samples, we calculated the mean, standard deviation, and CV of the percentage of each particle size.

Grid frame 10 x 10 x 2 (i.e., 10 cm on a side and with grid spacing of 2 cm)

Data below shows part of the 100 rows of the total raw data. Each row is from one toss of a grid frame with 25 points each.

Run	Count	Class0_Pct	Class1_Pct	Class2_Pct	Class3_Pct	Class4_Pct	Class5_Pct	Class6_Pct
1	25	60	4	8	0	0	28	0
2	25	36	4	4	8	48	0	0
3	25	80	8	4	8	0	0	0
4	25	24	0	0	8	68	0	0
5	25	64	4	4	16	12	0	0
6	25	36	0	4	4	0	56	0
7	25	64	4	8	16	0	8	0
8	25	60	0	4	0	0	36	0
9	25	36	0	4	16	28	16	0
10	25	32	0	4	8	56	0	0
11	25	60	12	16	0	12	0	0
12	25	48	0	4	40	8	0	0
13	25	80	4	16	0	0	0	0
14	25	56	0	0	16	0	28	0
15	25	60	4	12	24	0	0	0
…	…	…	…	…	…	…	…	…
95	25	16	4	0	0	0	80	0
96	25	88	4	8	0	0	0	0
97	25	60	4	12	12	12	0	0
98	25	48	0	12	4	0	36	0
99	25	40	0	0	0	52	0	8
100	25	16	4	0	8	0	72	0
	mean	51.36	2.44	5.64	11.44	10.12	16.44	2.56

The macro that facilitated the selection of 1000 draws of 10, 16, or 20 grid toss data sets

```
Sub Rand20draw()
'
' Rand20draw Macro
' Macro recorded 3/11/2009 by  Dale A. McCullough
'
   For n = 1 To Worksheets("Random").[nosims].Value
' Application.Calculation = xlCalculationAutomatic    'turn on automatic calculation
   Worksheets("Random").Activate
        'Print samples
       Sheets("Results").Range("res").Columns(1).Rows(n + 1) = n
       Sheets("Results").Range("res").Columns(2).Rows(n + 1) = Worksheets("Random").[$m$32].Value
       Sheets("Results").Range("res").Columns(3).Rows(n + 1) = Worksheets("Random").[$n$32].Value
       Sheets("Results").Range("res").Columns(4).Rows(n + 1) = Worksheets("Random").[$o$32].Value
       Sheets("Results").Range("res").Columns(5).Rows(n + 1) = Worksheets("Random").[$p$32].Value
       Sheets("Results").Range("res").Columns(6).Rows(n + 1) = Worksheets("Random").[$q$32].Value
       Sheets("Results").Range("res").Columns(7).Rows(n + 1) = Worksheets("Random").[$r$32].Value
       Sheets("Results").Range("res").Columns(8).Rows(n + 1) = Worksheets("Random").[$s$32].Value
   Next n
End Sub
'
```

Random Number Generation for Selecting Rows from the Master Data Set of 100 Grid Frame Samples of the Simulated Streambed

nosims 1000

index to select a number from column 1 and row d1

20 random int	random selection							
	Class0_Pc	Class1_Pc	Class2_Pc	Class3_Pc	Class4_Pc	Class5_Pc	Class6_Pct	
16	80	0	4	16	0	0	0	**1**
98	48	0	12	4	0	36	0	**2**
43	52	0	4	20	0	20	4	**3**
11	60	12	16	0	12	0	0	**4**
34	40	0	8	0	12	40	0	**5**
59	48	0	20	4	28	0	0	**6**
37	56	0	8	20	0	16	0	**7**
39	68	12	4	0	0	16	0	**8**
3	80	8	4	8	0	0	0	**9**
12	48	0	4	40	8	0	0	**10**
38	52	0	12	8	0	28	0	**11**
37	56	0	8	20	0	16	0	**12**
98	48	0	12	4	0	36	0	**13**
19	52	0	12	0	36	0	0	**14**
28	72	4	4	20	0	0	0	**15**
70	68	0	16	4	0	12	0	**16**
74	68	0	16	16	0	0	0	**17**
43	52	0	4	20	0	20	4	**18**
75	64	4	4	0	28	0	0	**19**
71	48	4	4	8	36	0	0	**20**
	58	2.2	8.8	10.6	8	12	0.4	

Mean particle size percentages based on 20 random grid tosses

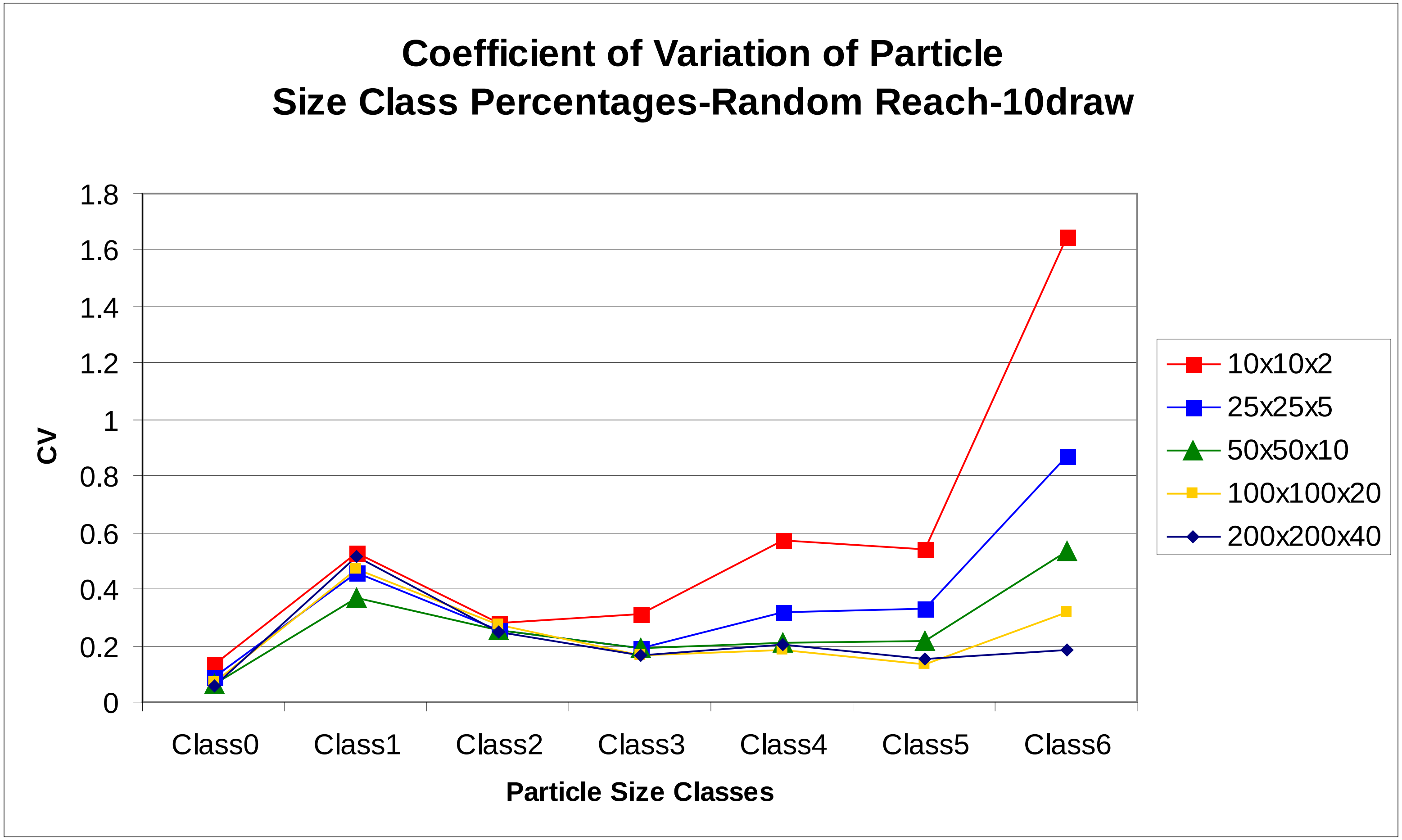
Grid frame 10 x 10 x 2 (i.e., 10 cm on a side and with grid spacing of 2 cm)
Example of the 1000 rows of means for sets of 10 randomly selected grid frame data from the master set of 100 frame tosses.

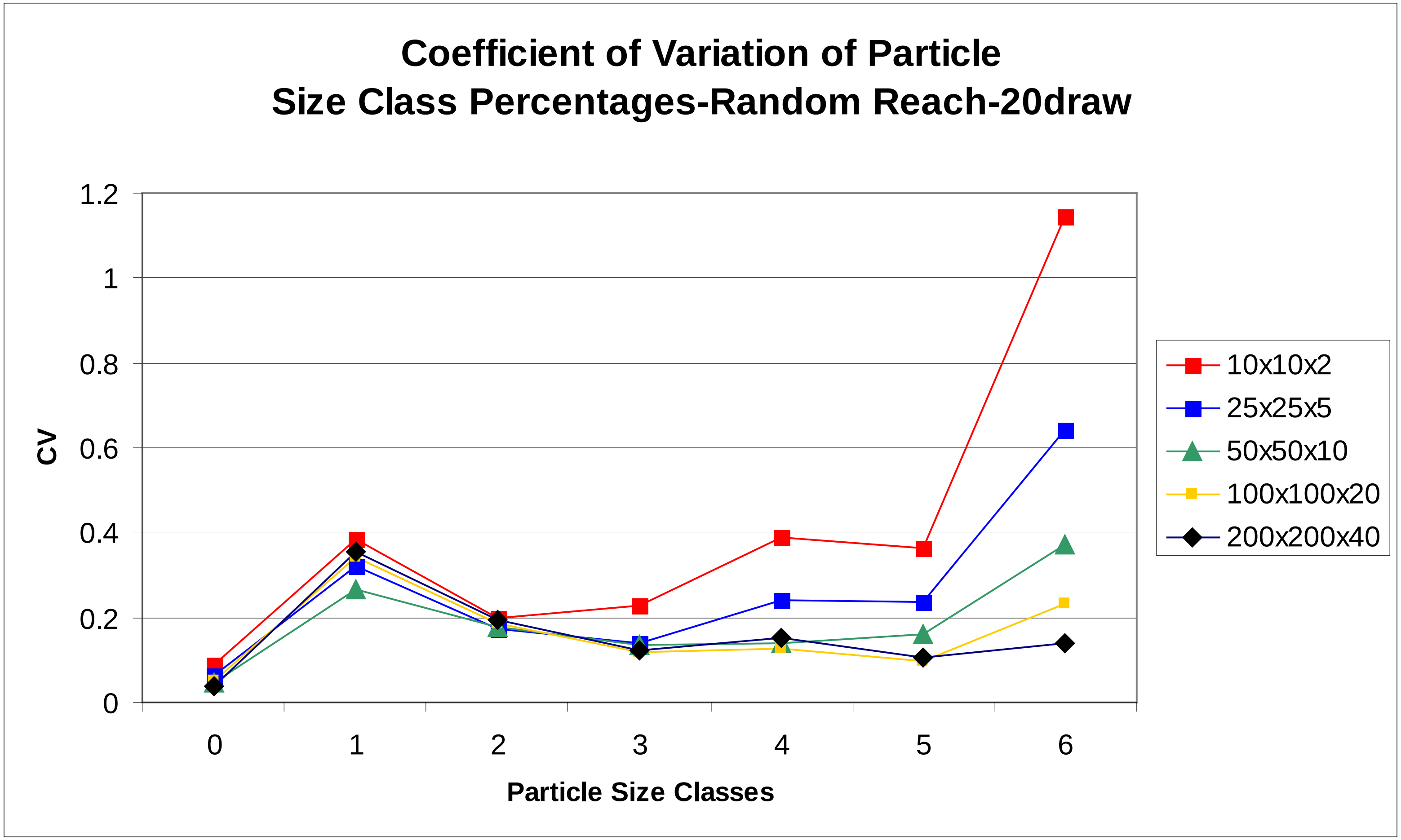
	Class0_Pc	Class1_Pc	Class2_Pc	Class3_Pc	Class4_Pc	Class5_Pc	Class6_Pct
1	48.8	1.6	5.6	7.6	17.2	17.2	4.4
2	67.6	1.6	5.2	10.8	10.4	15.2	2.0
3	53.6	2.8	4.4	8.8	9.6	22.0	0.0
4	45.6	1.6	5.2	22.8	4.0	16.4	0.0
5	52.8	2.4	8.0	13.6	6.8	9.2	0.0
6	51.2	1.2	4.8	13.2	10.8	14.0	15.6
7	44.4	2.4	4.8	18.4	19.6	31.2	0.0
8	37.2	2.4	6.4	8.8	8.8	5.2	0.0
9	45.2	2.8	7.6	15.6	10.4	5.6	0.0
10	49.6	2.4	6.0	18.0	2.8	6.0	0.0
11	58.0	4.0	2.8	13.2	9.6	16.0	0.0
12	50.0	1.2	5.6	6.0	9.2	22.4	10.0
13	49.6	3.6	4.0	10.0	8.8	25.2	7.6
14	39.6	5.2	4.4	11.6	5.2	26.0	0.0
15	58.4	4.4	4.4	15.2	8.4	7.2	0.4
990	53.6	3.2	6.4	10.8	10.0	18.4	14.0
991	55.2	2.4	3.6	13.6	10.0	7.2	0.0
992	44.8	2.4	5.6	8.0	4.4	35.2	0.0
993	54.8	0.8	5.2	7.6	2.4	18.4	0.0
994	61.2	4.0	4.8	4.4	5.6	17.2	0.4
995	50.8	1.2	4.8	11.6	15.6	20.0	0.0
996	48.0	2.4	4.0	13.2	12.4	6.4	2.0
997	50.0	4.0	3.6	11.2	9.6	2.8	0.0
998	46.0	2.0	8.0	5.2	3.6	8.0	7.6
999	54.0	3.6	6.4	4.4	21.6	8.8	4.4
1000	42.4	2.0	4.8	13.2	17.2	9.6	0.0

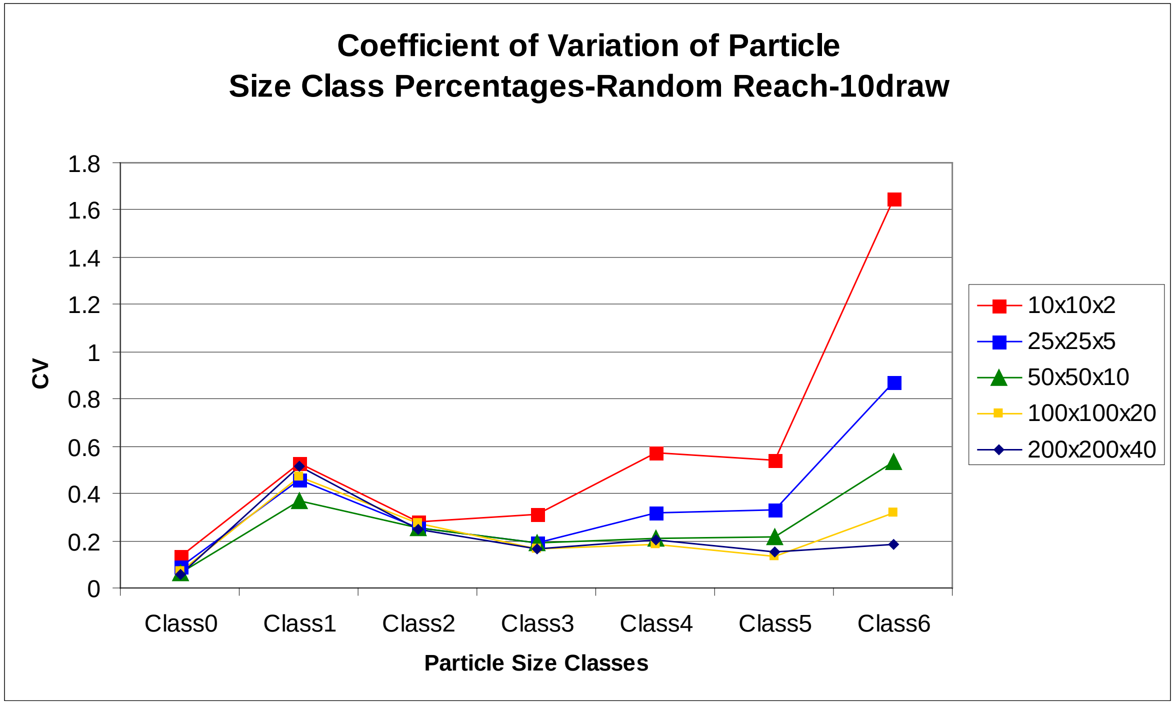
Statistics for 1000 random selections of data for % composition by size class where each selection was based on 10 tosses of the grid frame selected from a total population of 100 grid frame tosses.

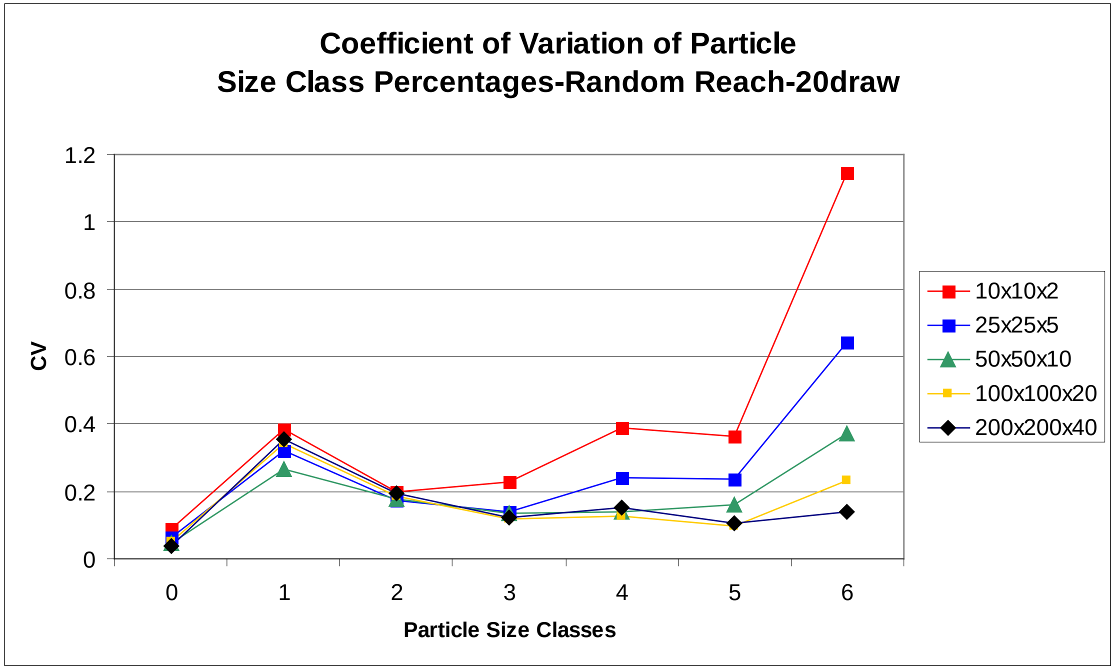
200x200x40

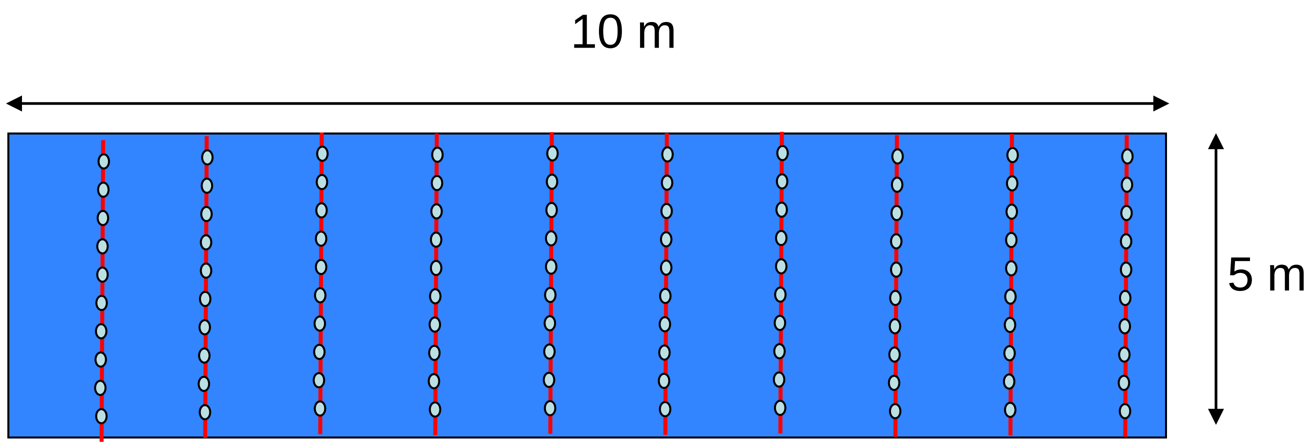
True mean	50.58	2.00	6.00	11.85	8.82	14.82	5.93
Size Class	*0*	*1*	*2*	*3*	*4*	*5*	*6*
Mean	50.5976	1.5124	6.3724	10.9544	8.582	15.3392	6.6028
Standard Error	0.0943	0.0247	0.0503	0.0579	0.0547	0.0741	0.0389
Median	50.4	1.6	6.4	10.8	8.4	15.2	6.4
Mode	49.6	1.6	6	10.4	8.4	14.4	6.4
Standard Deviation	2.9814	0.7807	1.5906	1.8311	1.7291	2.3426	1.2296
Sample Variance	8.8889	0.6094	2.5299	3.3530	2.9899	5.4876	1.5119
Kurtosis	0.0420	-0.0413	0.3265	-0.0511	-0.1665	-0.1613	0.2230
Skewness	0.0231	0.3958	0.2856	0.0806	0.0132	0.0251	0.2732
Range	20.8	4.4	12.8	12	10.8	13.2	8.4
Minimum	39.2	0	1.2	5.2	3.6	9.2	3.2
Maximum	60	4.4	14	17.2	14.4	22.4	11.6
Sum	50597.6	1512.4	6372.4	10954.4	8582	15339.2	6602.8
Count	1000	1000	1000	1000	1000	1000	1000
CV	0.058924	0.516167	0.249604	0.167157	0.201483	0.152717	0.186223


Coefficient of Variation of Particle
Size Class Percentages-Random Reach-10draw
CV
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Class0
Class1
Class2
Class3
Class4
Class5
Class6
Particle Size Classes
10x10x2
25x25x5
50x50x10
100x100x20
200x200x40


Coefficient of Variation of Particle
Size Class Percentages-Random Reach-20draw
1.2
1
0.8
0.6
0.4
0.2
0
CV
0
1
2
3
4
5
6
Particle Size Classes
10x10x2
25x25x5
50x50x10
100x100x20
200x200x40


Coefficient of Variation of Particle
Size Class Percentages-Random Reach-10draw
CV
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Class0
Class1
Class2
Class3
Class4
Class5
Class6
Particle Size Classes
10x10x2
25x25x5
50x50x10
100x100x20
200x200x40

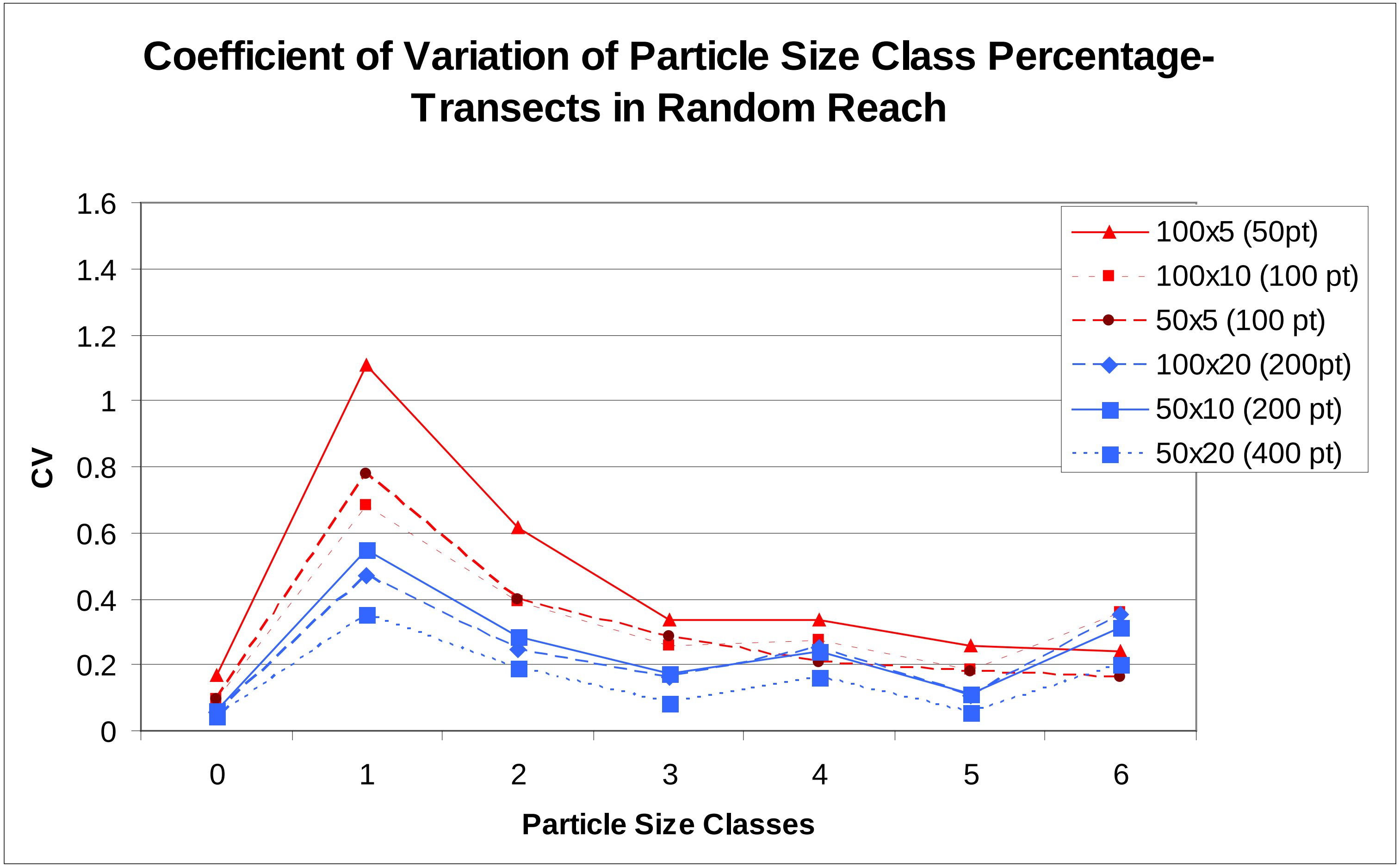

Coefficient of Variation of Particle
Size Class Percentages-Random Reach-20draw
CV
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Particle Size Classes
10x10x2
25x25x5
50x50x10
100x100x20
200x200x40



Transect sampling of the Random Reach.

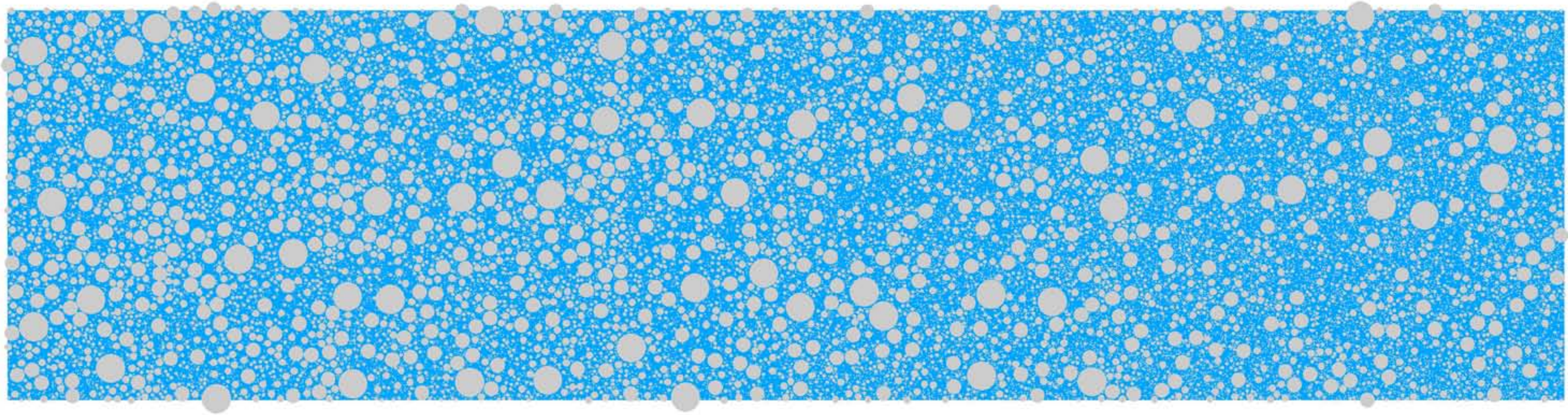
This example has a transect placed every 100 cm and 10 equally-spaced sample points across the 5-m stream width. Sample points are at a distance from the wetted margin equal to the distance between points. This makes the distance between points laterally equal to 5/11 = 0.46 m.

This analysis was designated SimRand_Tran100x10. There are 100 sample points in this analysis.


Coefficient of Variation of Particle Size Class Percentage-Transects in Random Reach
CV
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Particle Size Classes
100x5 (50pt)
100x10 (100 pt)
50x5 (100 pt)
100x20 (200pt)
50x10 (200 pt)
50x20 (400 pt)

Zoned Reach

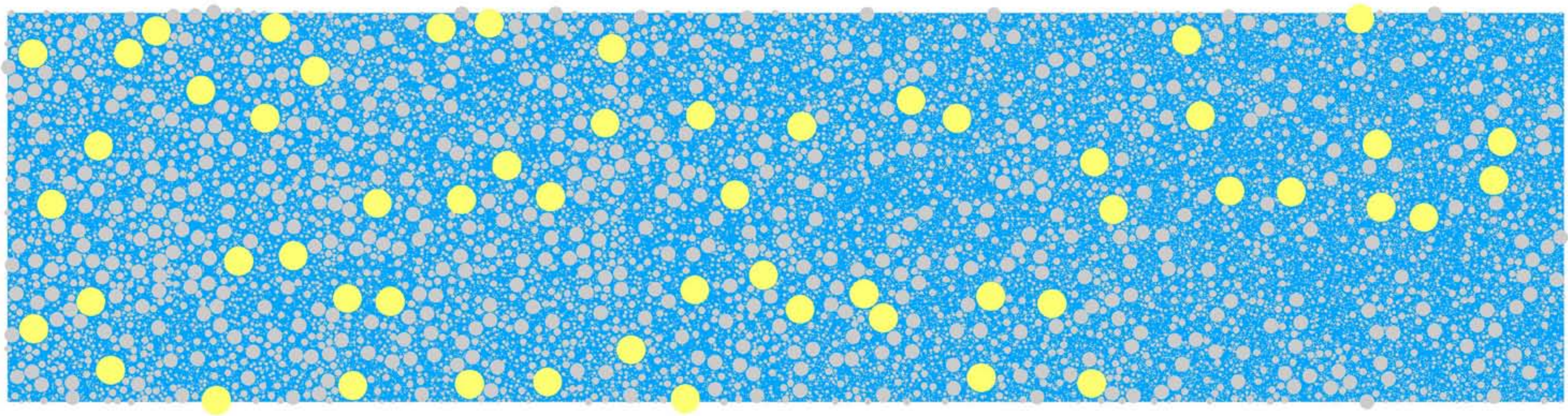
Distribution 2 - Longitudinal Zones



Size Classes and Areal Coverage

6	5	4	3	2	1	Fines
6.1%	14.9%	11.9%	8.8%	5.9%	2.0%	50.4%

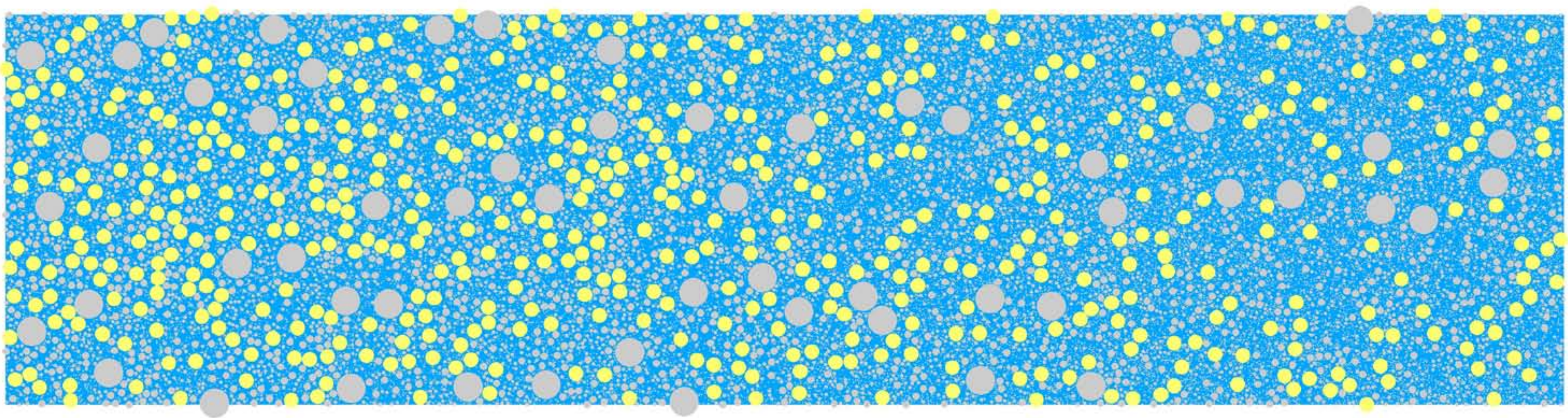
Distribution 2 - Longitudinal Zones



				Size Class 6					
Zone1	Zone2	Zone3	Zone4	Zone5	Zone6	Zone7	Zone8	Zone9	Zone10
15%	13%	12%	11%	10%	10%	8%	8%	7%	6%

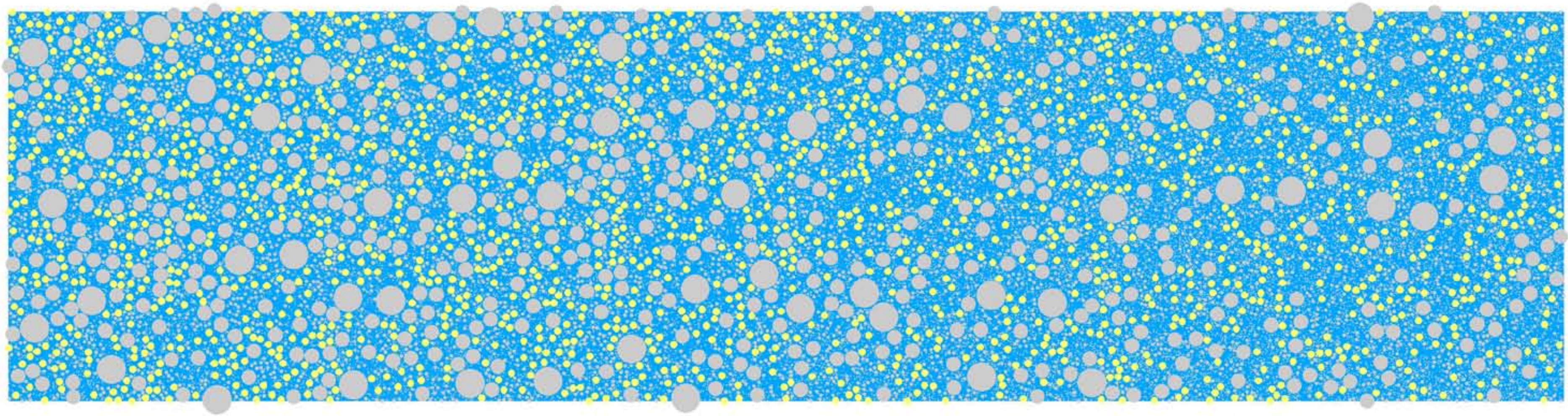
Note: The percentages by zone identify the % of the overall coverage by the particle size that should be distributed into each of the zones. The % in each zone totals 100%. In this case, there is 15% of all coverage by size class 6 found in Zone 1.

Distribution 2 - Longitudinal Zones



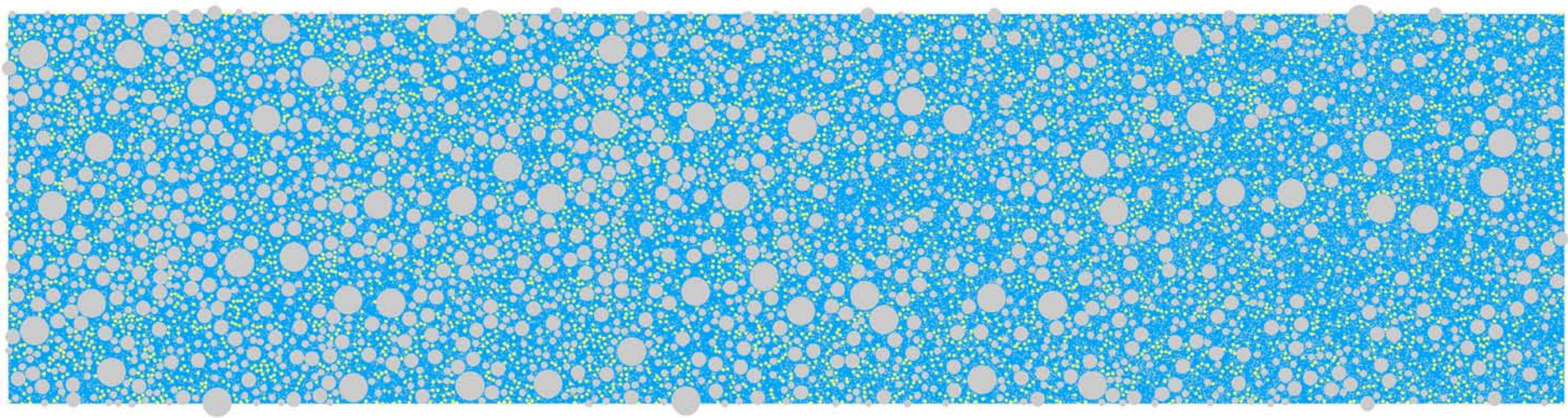
				Size Class 5					
Zone1	**Zone2**	**Zone3**	**Zone4**	**Zone5**	**Zone6**	**Zone7**	**Zone8**	**Zone9**	**Zone10**
14%	12%	11%	11%	10%	10%	8%	9%	8%	7%

Distribution 2 - Longitudinal Zones



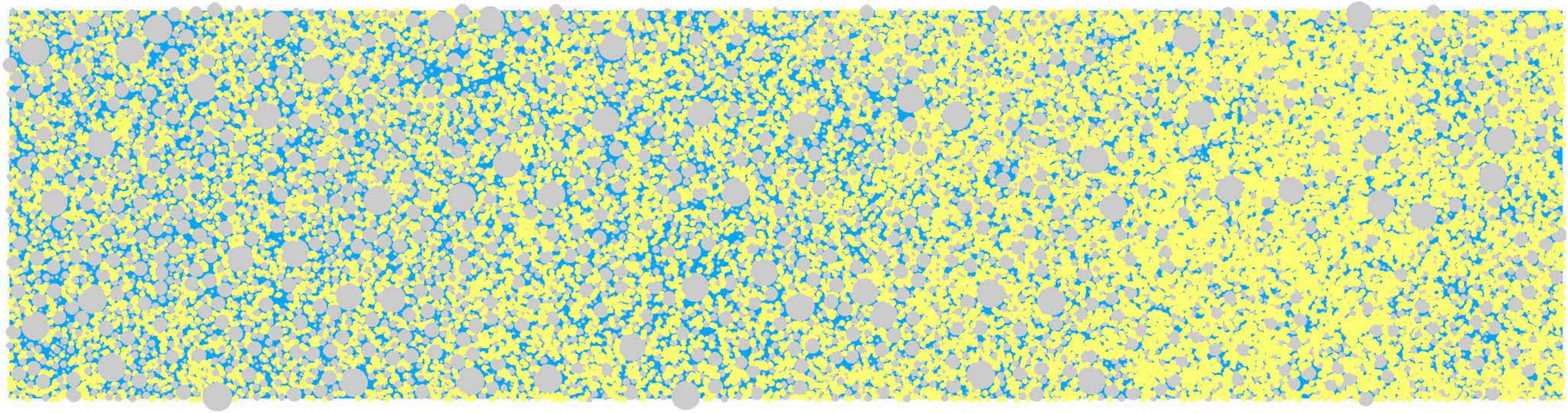
				Size Class 4					
Zone1	**Zone2**	**Zone3**	**Zone4**	**Zone5**	**Zone6**	**Zone7**	**Zone8**	**Zone9**	**Zone10**
12%	12%	11%	11%	11%	10%	9%	9%	8%	7%

Distribution 2 - Longitudinal Zones



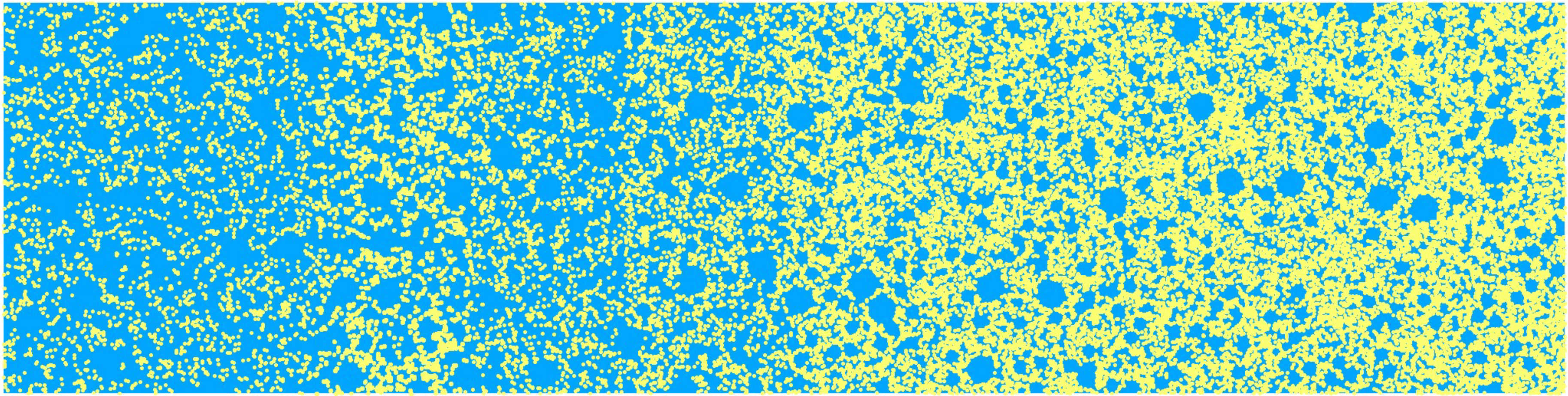
				Size Class 3					
Zone1	Zone2	Zone3	Zone4	Zone5	Zone6	Zone7	Zone8	Zone9	Zone10
10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

Distribution 2 - Longitudinal Zones

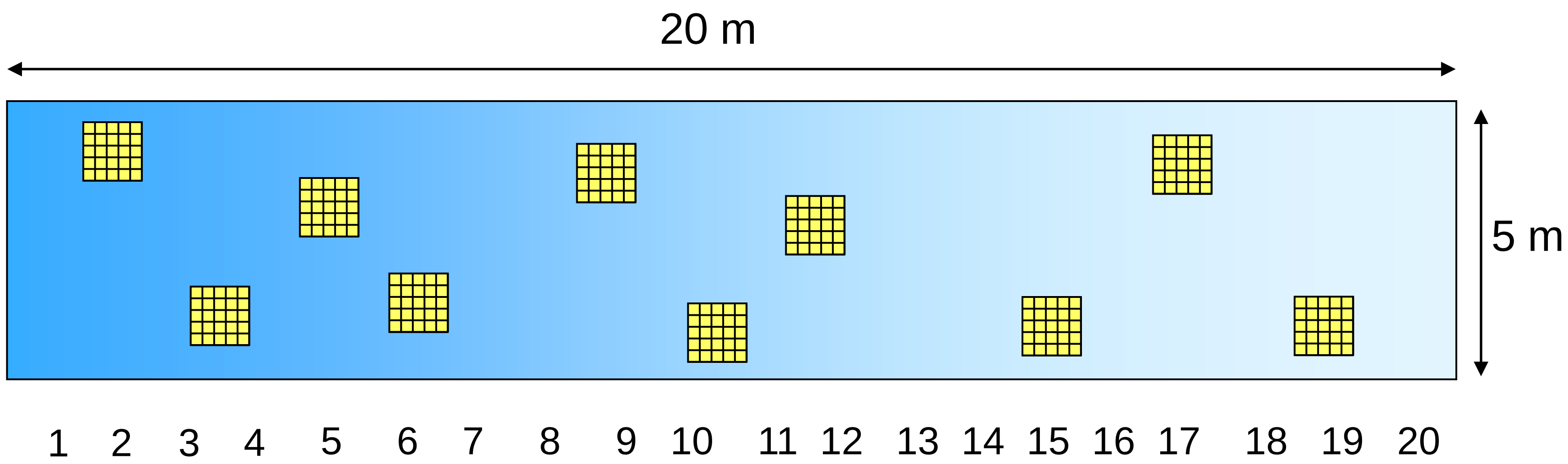


				Size Class 2					
Zone1	**Zone2**	**Zone3**	**Zone4**	**Zone5**	**Zone6**	**Zone7**	**Zone8**	**Zone9**	**Zone10**
8%	8%	9%	9%	10%	10%	12%	11%	11%	12%

Distribution 2 - Longitudinal Zones



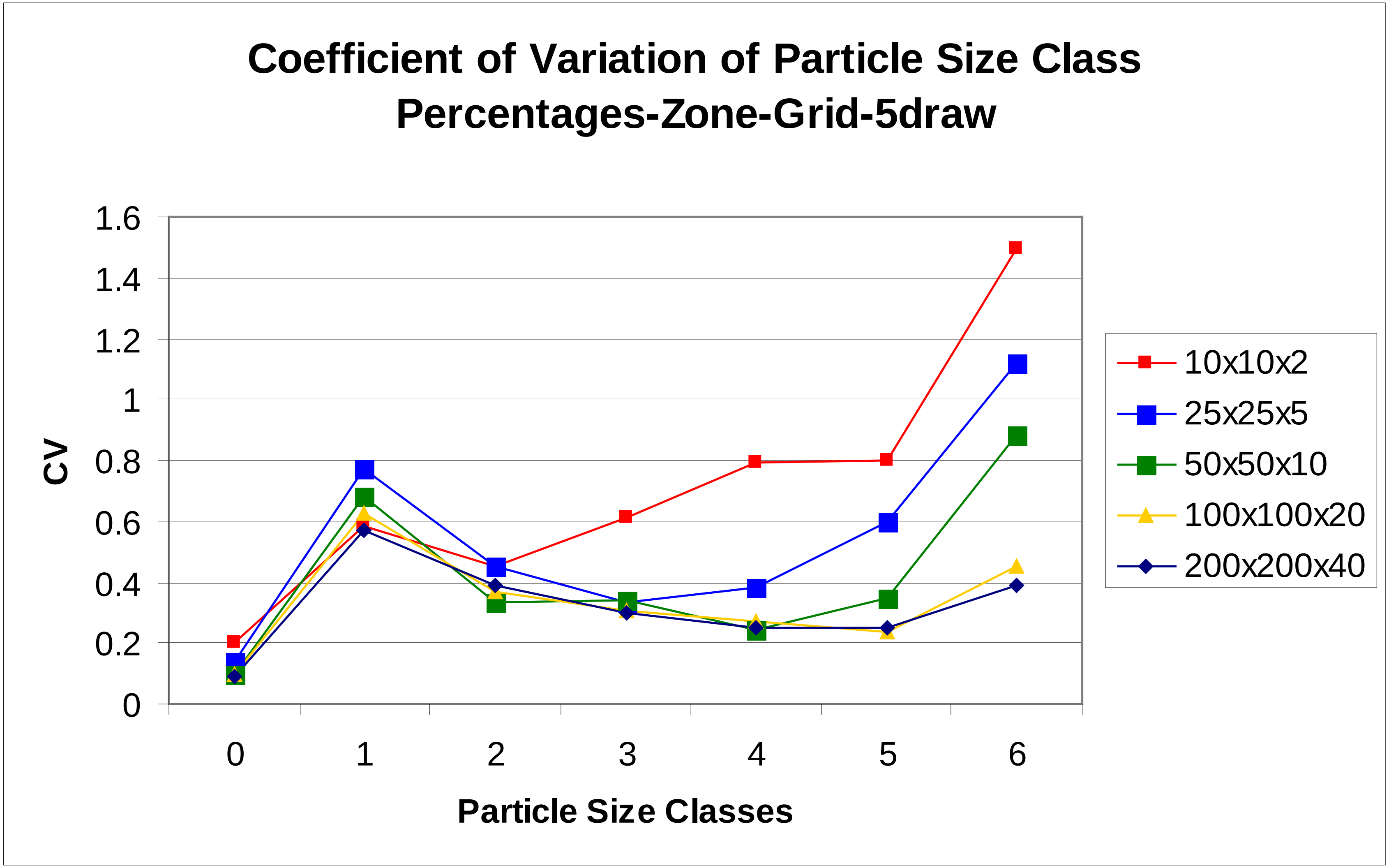
				Size Class 1					
Zone1	Zone2	Zone3	Zone4	Zone5	Zone6	Zone7	Zone8	Zone9	Zone10
7%	7%	8%	8%	9%	10%	12%	12%	13%	14%



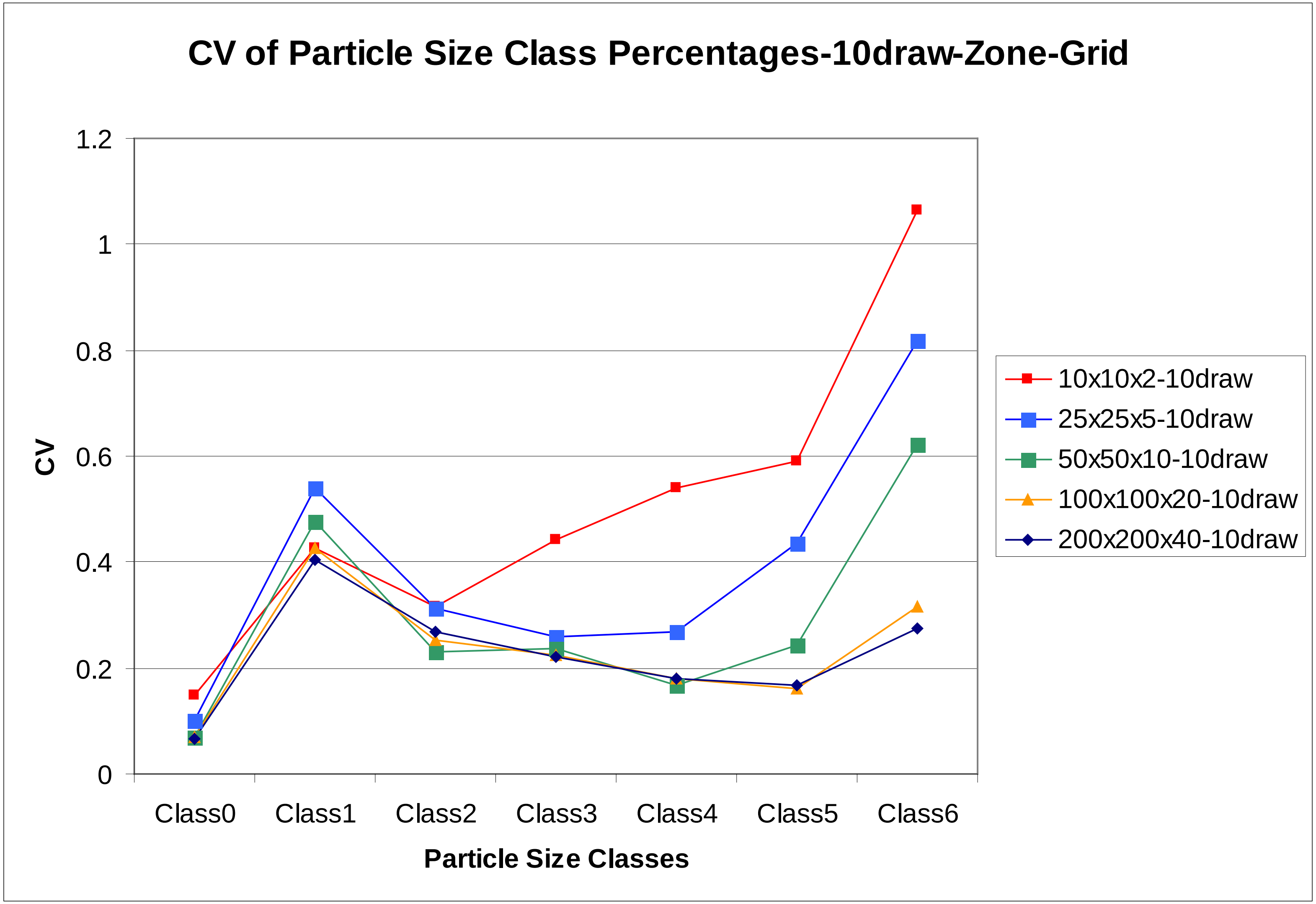
Grid sampling of the Zoned Reach.
This example represents a random selection of 10 tosses from the master population of 100 random tosses. If we replicate this selection process 1000 times, we generate the CVs for particle size analysis. Each grid frame has 25 points for which the particle size is determined.

This analysis was designated SimZone_100x100x20. This means that the grid frames are 100 cm x 100 cm and the spacing between points is 20 cm. In the selection of 10 tosses, there are 250 sample points.

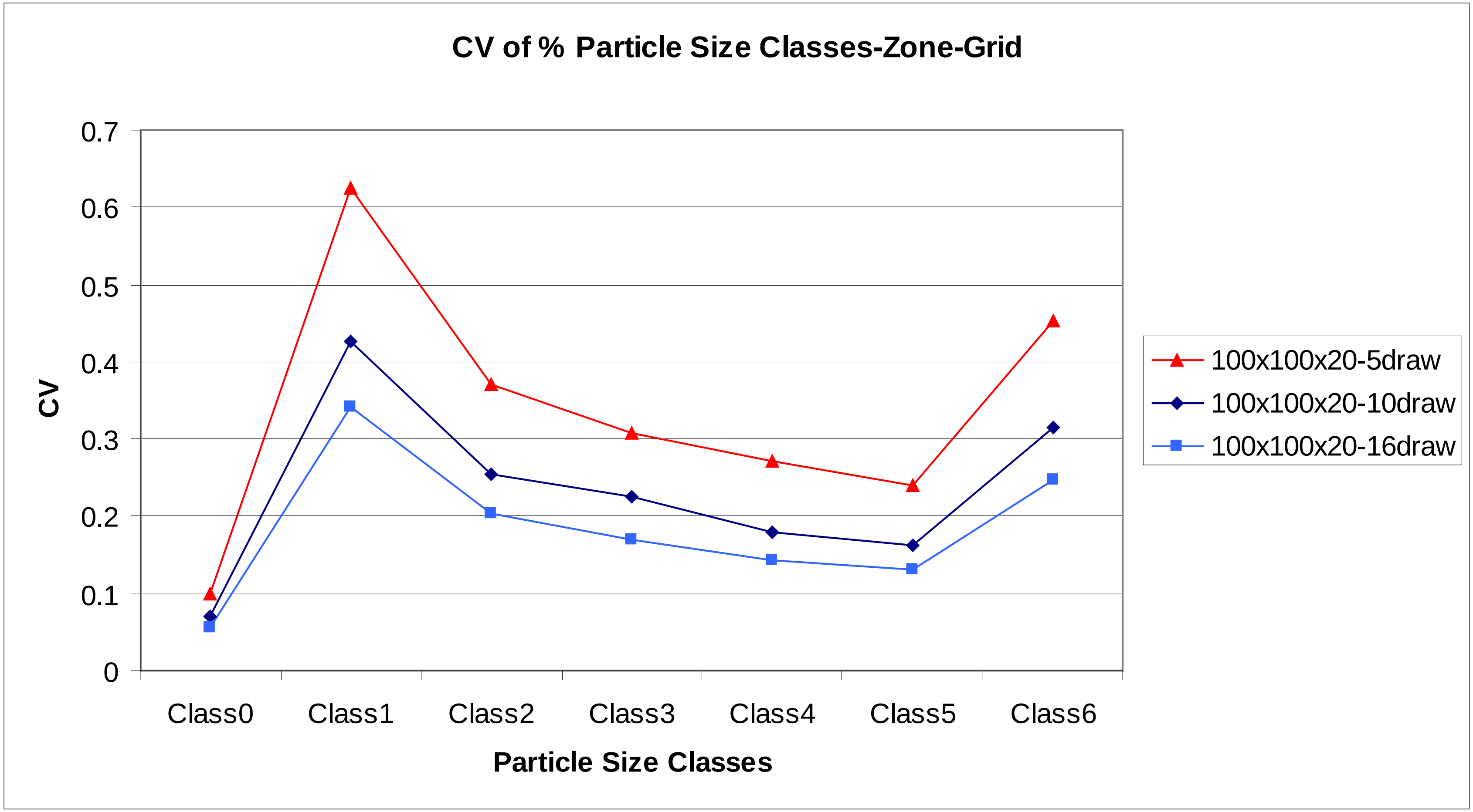
We can compare the CV for 10 tosses with grid spacing of 2, 5, 10, 20, and 40 cm.



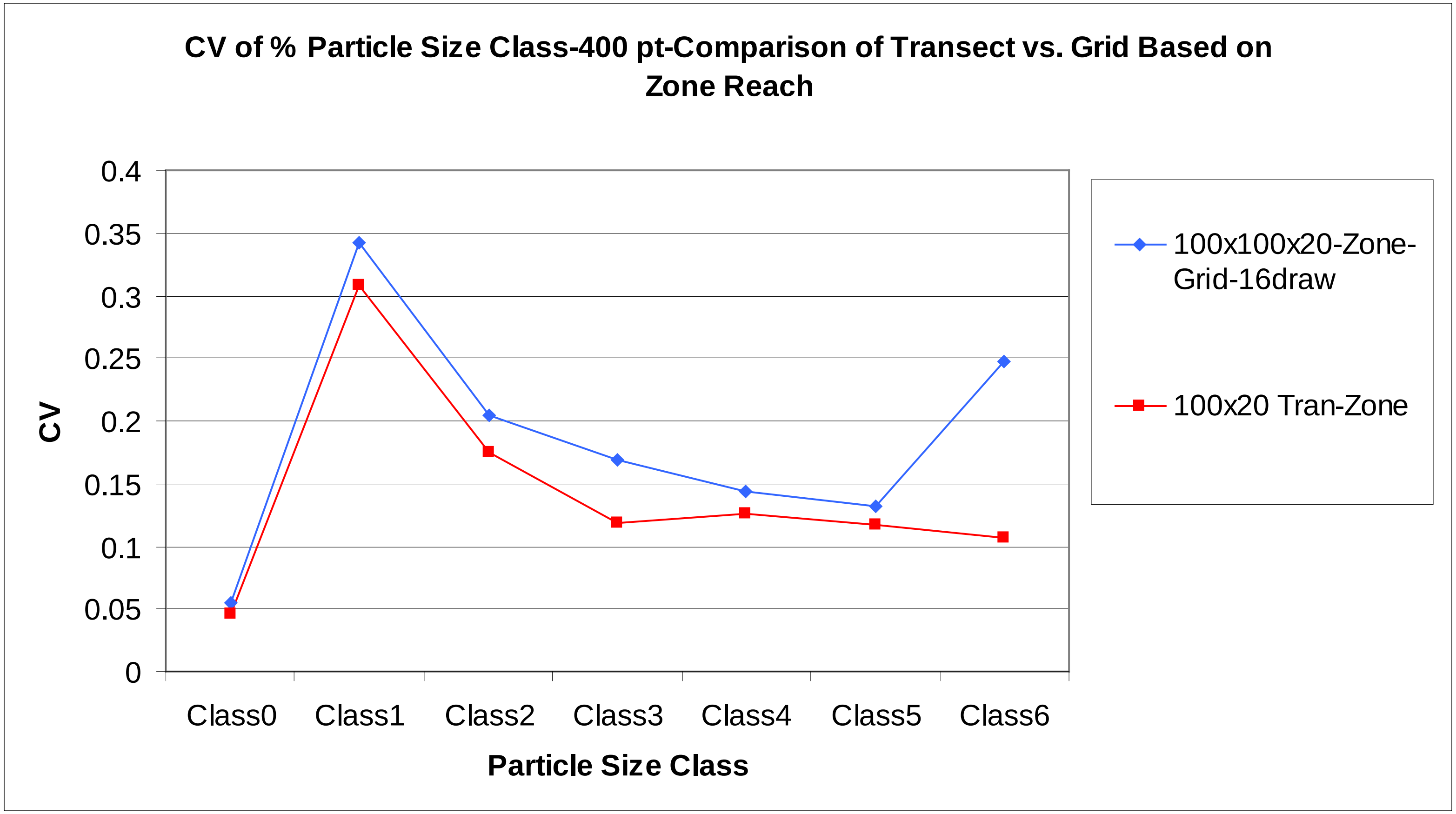
Coefficient of Variation of Particle Size Class Percentages-Zone-Grid-5draw
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
CV
0
1
2
3
4
5
6
Particle Size Classes
10x10x2
25x25x5
50x50x10
100x100x20
200x200x40



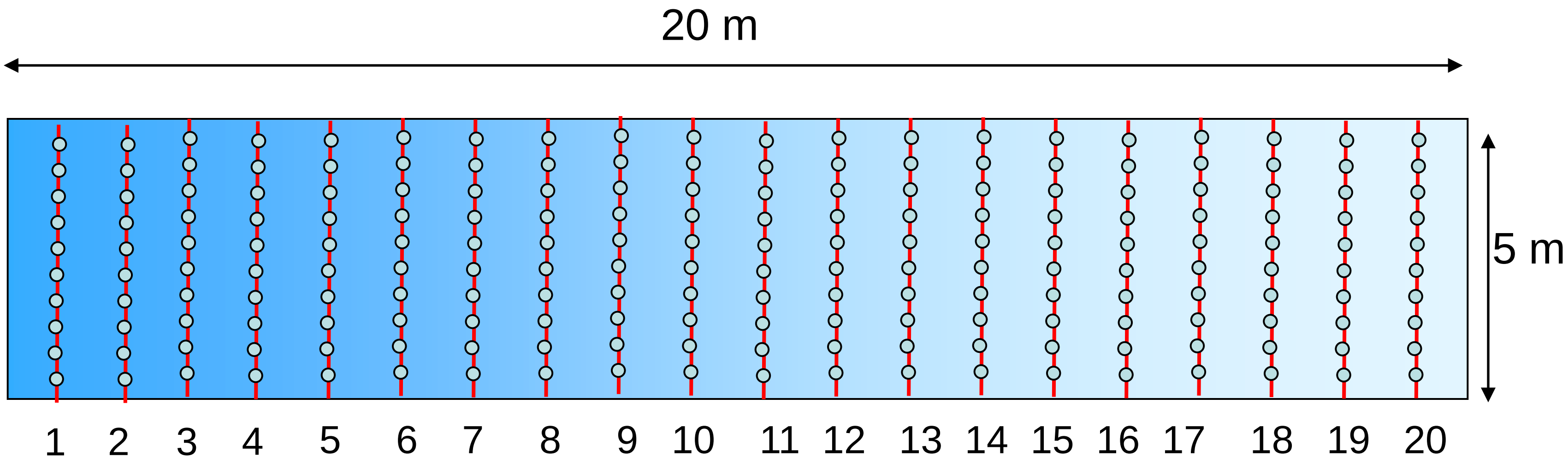
CV of Particle Size Class Percentages-10draw-Zone-Grid
1.2
1
0.8
0.6
0.4
0.2
0
CV
Class0
Class1
Class2
Class3
Class4
Class5
Class6
Particle Size Classes
10x10x2-10draw
25x25x5-10draw
50x50x10-10draw
100x100x20-10draw
200x200x40-10draw



CV of % Particle Size Classes-Zone-Grid
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CV
Class0
Class1
Class2
Class3
Class4
Class5
Class6
Particle Size Classes
100x100x20-5draw
100x100x20-10draw
100x100x20-16draw



CV of % Particle Size Class-400 pt-Comparison of Transect vs. Grid Based on Zone Reach
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
CV
Class0
Class1
Class2
Class3
Class4
Class5
Class6
Particle Size Class
100x100x20-Zone-Grid-16draw
100x20 Tran-Zone



Transect sampling of the Zoned Reach.

This example has a transect placed every 100 cm and 10 equally-spaced sample points across the 5-m stream width. Sample points are at a distance from the wetted margin equal to the distance between points. This makes the distance between points laterally equal to 5/11 = 0.46 m.

This analysis was designated SimZone_Tran100x10. There are 200 sample points in this analysis.

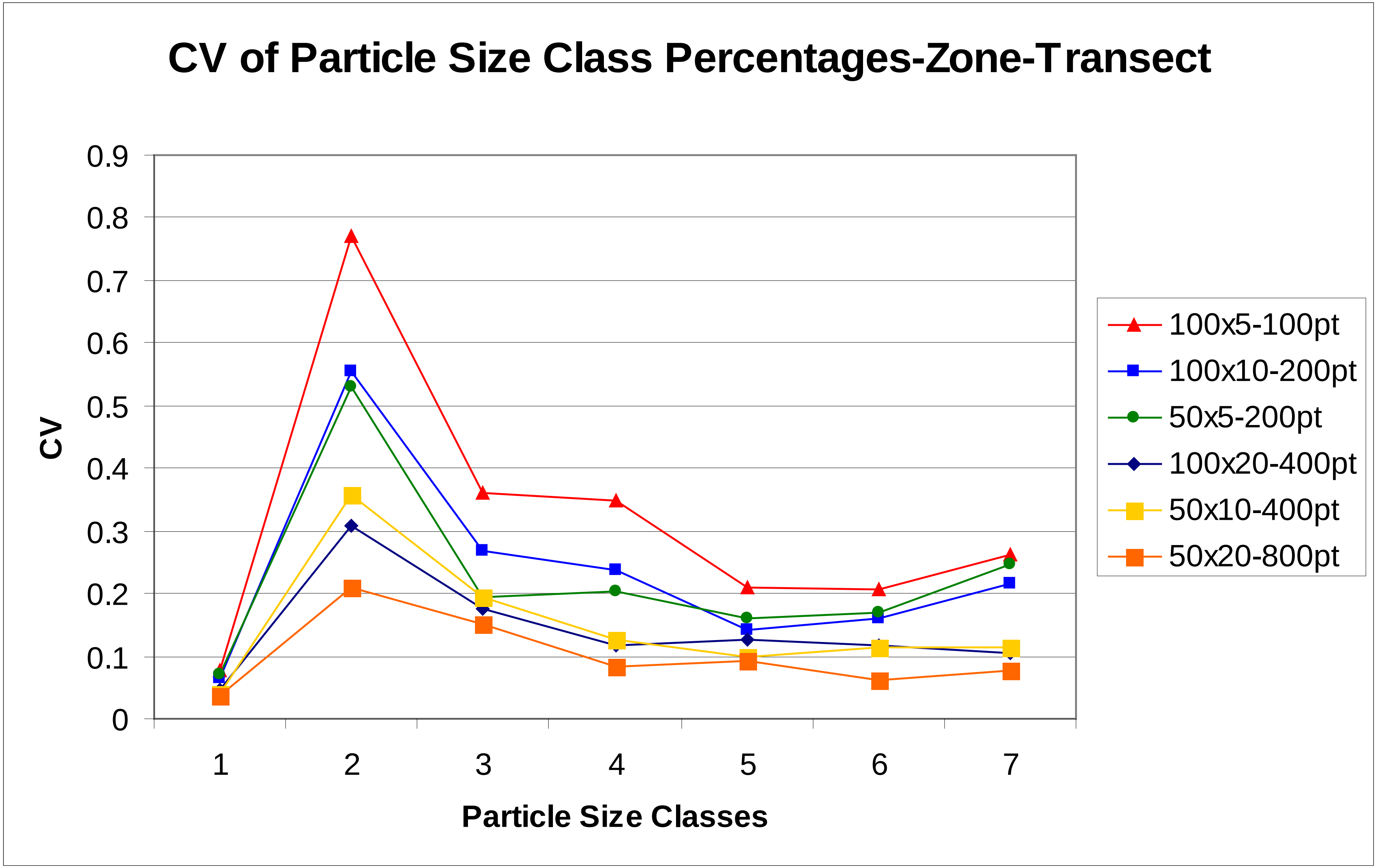
SimZone_Tran

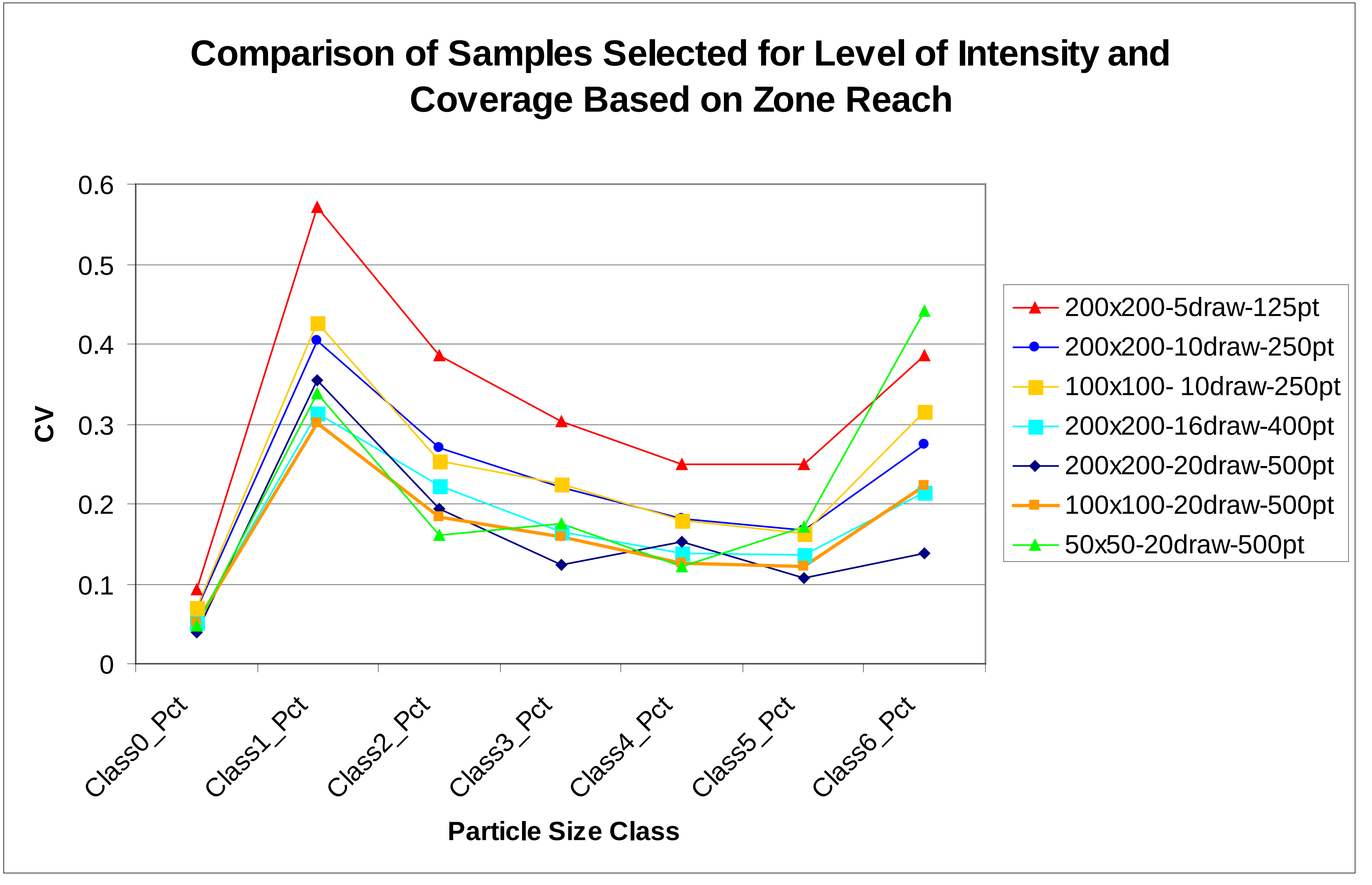
100x20

Class0_Pct		Class1_Pct		Class2_Pct		Class3_Pct		Class4_Pct		Class5_Pct		Class6_Pct	
Mean	50.3425	Mean	1.845	Mean	6.27	Mean	9.0025	Mean	11.265	Mean	15.3125	Mean	5.9625
Standard E	0.228678	Standard E	0.056829	Standard E	0.109791	Standard E	0.106036	Standard E	0.142348	Standard E	0.17899	Standard E	0.063203
Median	50.375	Median	1.75	Median	6.25	Median	9	Median	11	Median	15.25	Median	6
Mode	49.25	Mode	2	Mode	6.25	Mode	9	Mode	11.25	Mode	15.5	Mode	5.75
Standard D	2.28678	Standard D	0.568291	Standard D	1.097909	Standard D	1.06036	Standard D	1.423477	Standard D	1.789904	Standard D	0.632031
Sample Va	5.229362	Sample Va	0.322955	Sample Va	1.205404	Sample Va	1.124362	Sample Va	2.026288	Sample Va	3.203756	Sample Va	0.399463
Kurtosis	-0.032099	Kurtosis	0.312537	Kurtosis	0.274478	Kurtosis	-0.235725	Kurtosis	2.313467	Kurtosis	-0.434612	Kurtosis	-0.829504
Skewness	0.01373	Skewness	0.385516	Skewness	-0.307429	Skewness	0.158259	Skewness	1.437097	Skewness	-0.046076	Skewness	-0.137736
Range	11.5	Range	3	Range	6	Range	5.25	Range	6.5	Range	7.75	Range	2.5
Minimum	44.25	Minimum	0.5	Minimum	3	Minimum	6.75	Minimum	9	Minimum	11	Minimum	4.75
Maximum	55.75	Maximum	3.5	Maximum	9	Maximum	12	Maximum	15.5	Maximum	18.75	Maximum	7.25
Sum	5034.25	Sum	184.5	Sum	627	Sum	900.25	Sum	1126.5	Sum	1531.25	Sum	596.25
Count	100	Count	100	Count	100	Count	100	Count	100	Count	100	Count	100
CV	0.045424	CV	0.308017	CV	0.175105	CV	0.117785	CV	0.126363	CV	0.116892	CV	0.106001

100x10

Class0_Pct		Class1_Pct		Class2_Pct		Class3_Pct		Class4_Pct		Class5_Pct		Class6_Pct	
Mean	51.085	Mean	1.97	Mean	5.425	Mean	8.635	Mean	11.51	Mean	14.705	Mean	6.67
Standard E	0.324431	Standard E	0.109365	Standard E	0.145882	Standard E	0.205831	Standard E	0.163296	Standard E	0.236247	Standard E	0.143763
Median	51	Median	1.75	Median	5	Median	8.5	Median	11.5	Median	15	Median	6.5
Mode	52.5	Mode	1	Mode	5	Mode	7	Mode	11	Mode	16.5	Mode	6
Standard D	3.244307	Standard D	1.093646	Standard D	1.45882	Standard D	2.05831	Standard D	1.632962	Standard D	2.362475	Standard D	1.437626
Sample Va	10.52553	Sample Va	1.196061	Sample Va	2.128157	Sample Va	4.236641	Sample Va	2.666566	Sample Va	5.581288	Sample Va	2.066768
Kurtosis	-0.043994	Kurtosis	-0.118262	Kurtosis	-0.477983	Kurtosis	-0.471287	Kurtosis	-0.323831	Kurtosis	-0.53687	Kurtosis	-0.109475
Skewness	0.087939	Skewness	0.544956	Skewness	0.328085	Skewness	0.429659	Skewness	-0.202786	Skewness	-0.547814	Skewness	0.743775
Range	16	Range	5	Range	6.5	Range	9.5	Range	7.5	Range	9.5	Range	6
Minimum	43.5	Minimum	0	Minimum	2.5	Minimum	4.5	Minimum	8	Minimum	9.5	Minimum	4
Maximum	59.5	Maximum	5	Maximum	9	Maximum	14	Maximum	15.5	Maximum	19	Maximum	10
Sum	5108.5	Sum	197	Sum	542.5	Sum	863.5	Sum	1151	Sum	1470.5	Sum	667
Count	100	Count	100	Count	100	Count	100	Count	100	Count	100	Count	100
CV	0.063508	CV	0.55515	CV	0.268907	CV	0.238368	CV	0.141873	CV	0.160658	CV	0.215536

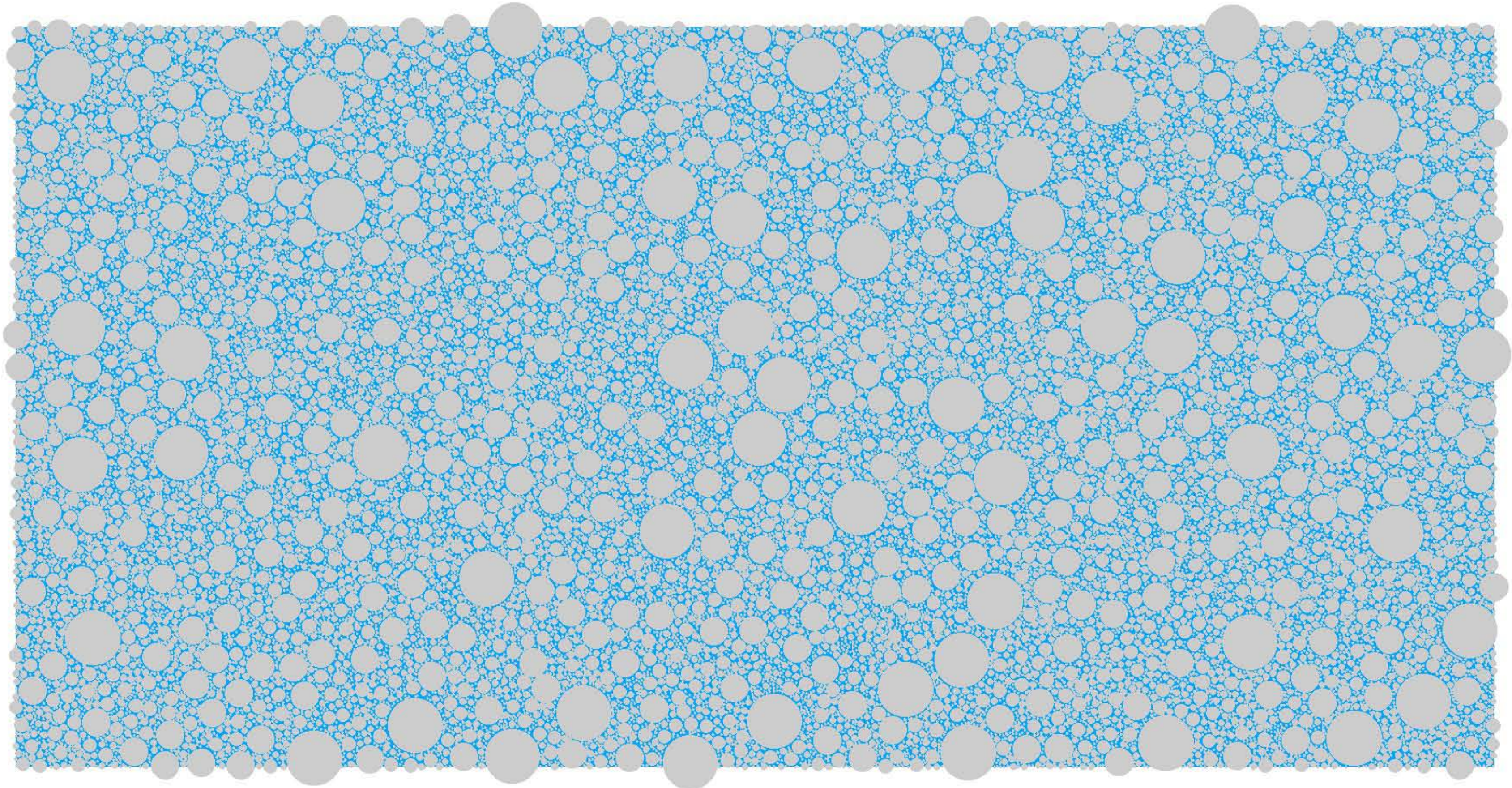

CV of Particle Size Class Percentages-Zone-Transect
CV
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
Particle Size Classes
100x5-100pt
100x10-200pt
50x5-200pt
100x20-400pt
50x10-400pt
50x20-800pt



Comparison of Samples Selected for Level of Intensity and Coverage Based on Zone Reach
CV
0.6
0.5
0.4
0.3
0.2
0.1
0
Class0_Pct
Class1_Pct
Class2_Pct
Class3_Pct
Class4_Pct
Class5_Pct
Class6_Pct
Particle Size Class
200x200-5draw-125pt
200x200-10draw-250pt
100x100- 10draw-250pt
200x200-16draw-400pt
200x200-20draw-500pt
100x100-20draw-500pt
50x50-20draw-500pt

Third Reach Simulation

Distribution 3 - Random, Dense Distribution

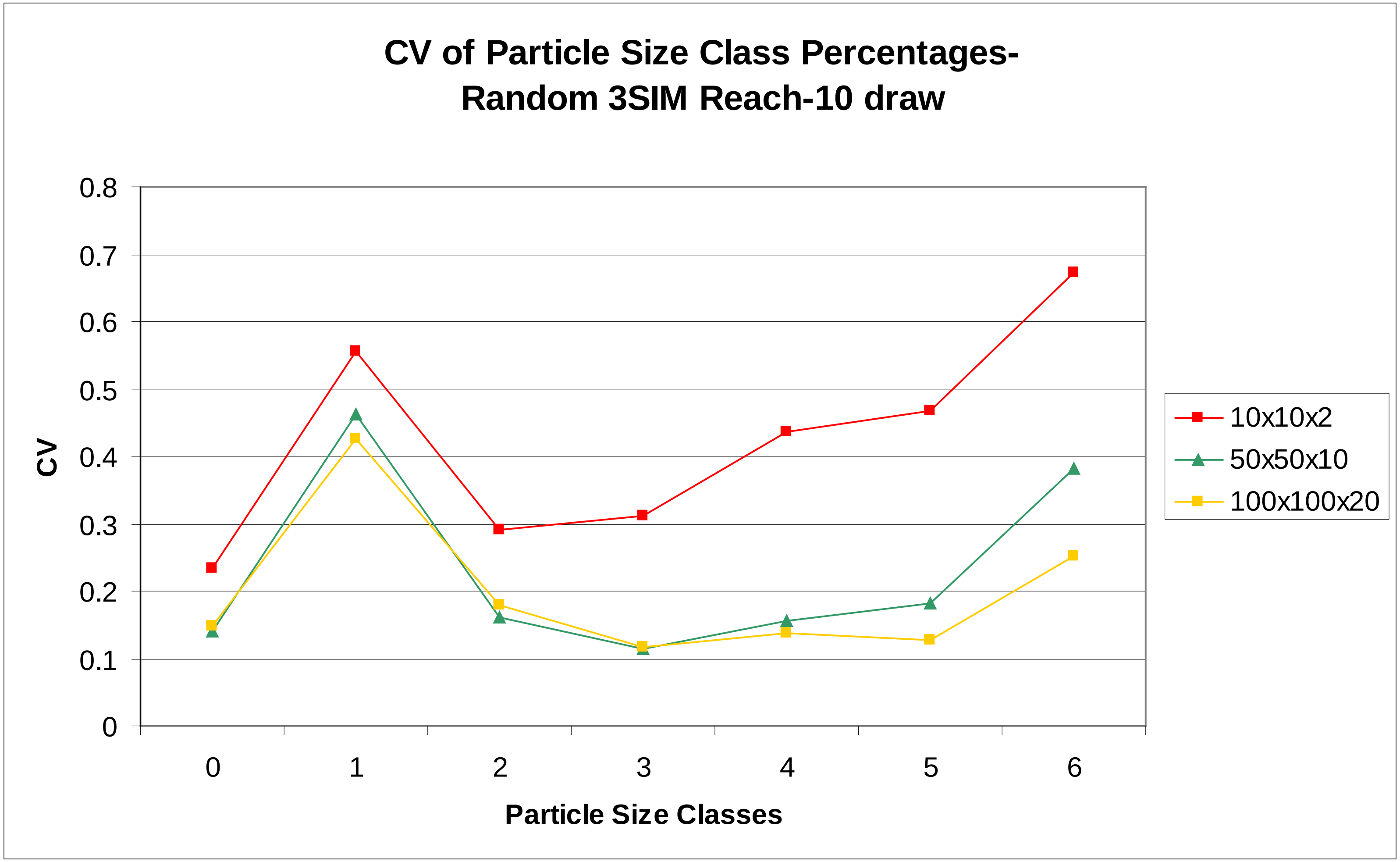


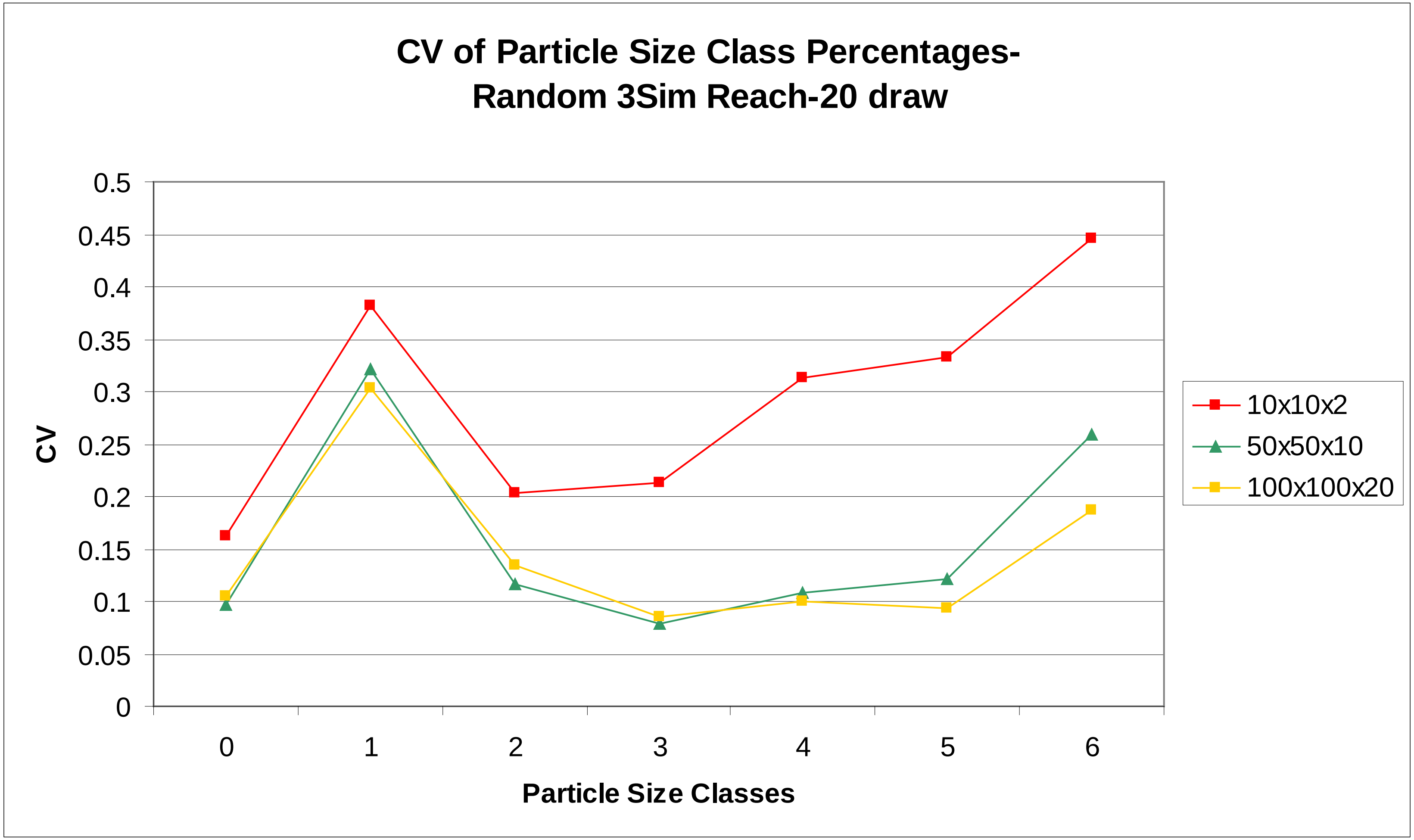
Size Classes and Areal Coverage

6	5	4	3	2	1	Fines
12.6%	19.2%	19.7%	18.2%	10.0%	1.9%	18.4%

Use of the Sim3 Reach to make estimates of substrate composition using the Grid and Transect methods

True percentage	50.58	2.00	6.00	11.85	8.82	14.82	5.93	**Random Reach**
True percentage	50.43	1.98	5.93	8.76	11.94	14.91	6.06	**Zoned Reach**
True percentage	18.40	1.94	9.95	18.22	19.68	19.24	12.57	**Sim3**
Size Class	0	1	2	3	4	5	6	
Mean size (cm)	<0.625	0.815	2	4.875	9.625	19.25	37.5	
Size Range (cm)	<0.625	0.625-1	1-3	3-6	6-13	13-25	25-50	


CV of Particle Size Class Percentages-
Random 3SIM Reach-10 draw
CV
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
Particle Size Classes
10x10x2
50x50x10
100x100x20


CV of Particle Size Class Percentages-
Random 3Sim Reach-20 draw
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
CV
0
1
2
3
4
5
6
Particle Size Classes
10x10x2
50x50x10
100x100x20

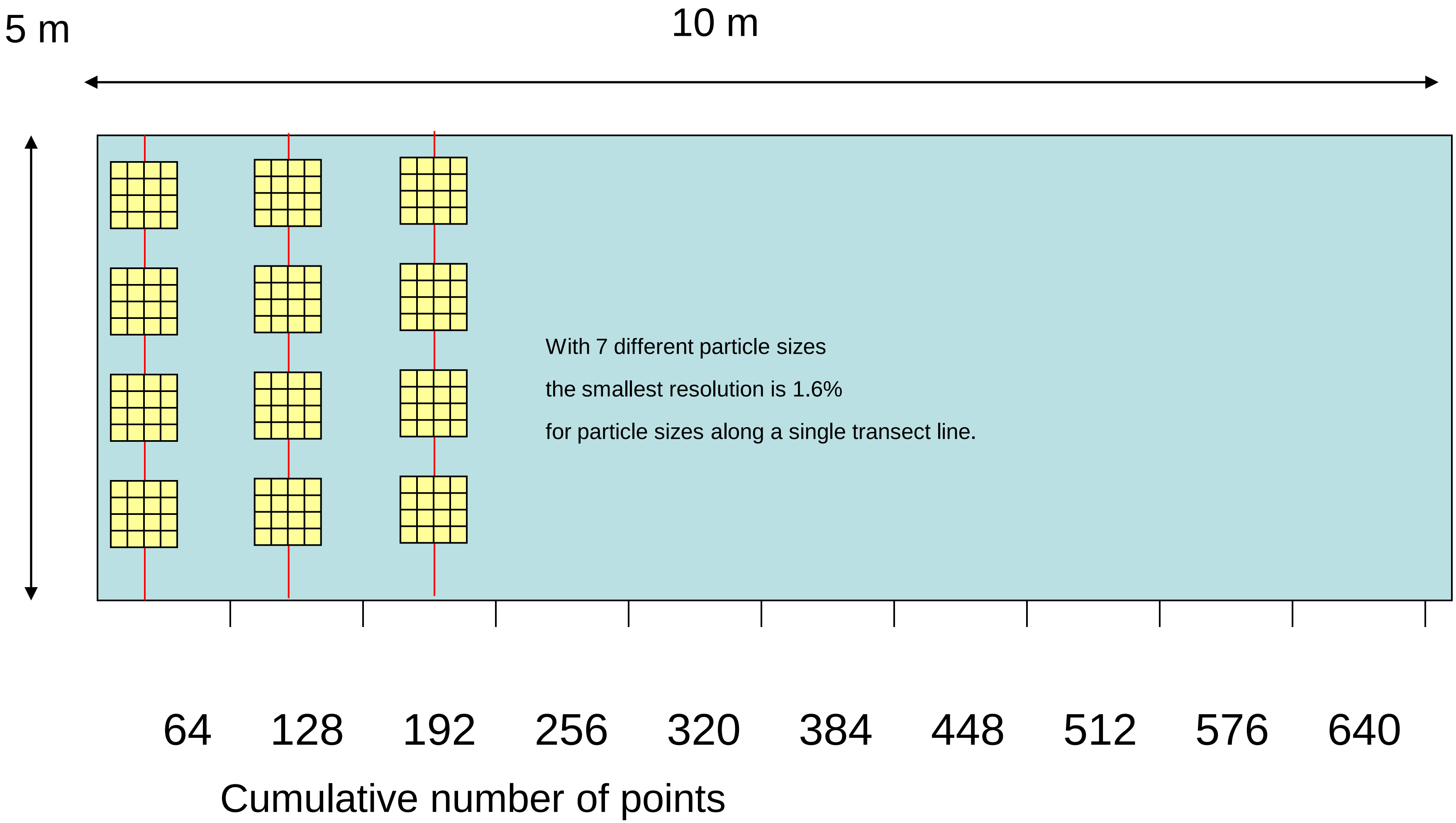
10x10x2	10 draw	True mean	18.4	1.94	9.95	18.22	19.68	19.24	12.57
		Class0_Pct	*0*	*1*	*2*	*3*	*4*	*5*	*6*
		Mean	15.9736	1.9232	9.268	17.6872	16.3272	21.2752	16.7568
		Standard E	0.118341	0.033847	0.085023	0.174456	0.22496	0.31486	0.356127
		Median	16	2	9.2	17.2	15.6	20.4	15.2
		Mode	16.8	1.6	7.6	16.4	13.6	15.6	10
		Standard D	3.742281	1.070349	2.688651	5.516792	7.113853	9.956757	11.26174
		Sample Va	14.00467	1.145647	7.228845	30.43499	50.60691	99.137	126.8267
		Kurtosis	-0.180516	-0.008657	0.004456	-0.162251	-0.147816	-0.081029	-0.038174
		Skewness	0.081255	0.506595	0.266357	0.17028	0.468115	0.439315	0.54169
		Range	22.4	5.2	16.4	32	38	56.4	57.2
		Minimum	6	0	2.4	2.4	0.8	0	0
		Maximum	28.4	5.2	18.8	34.4	38.8	56.4	57.2
		Sum	15973.6	1923.2	9268	17687.2	16327.2	21275.2	16756.8
		Count	1000	1000	1000	1000	1000	1000	1000
		CV	0.234279	0.556546	0.2901	0.311909	0.435706	0.467998	0.67207

10x10x2	16 draw	True mean	18.4	1.94	9.95	18.22	19.68	19.24	12.57
		Class0_Pct							
		Mean	16.29025	1.907	9.39375	17.36375	16.5145	21.6685	16.646
		Standard E	0.089703	0.026402	0.065133	0.133706	0.177758	0.250332	0.278388
		Median	16.25	1.75	9.5	17.5	16.25	20.75	16.125
		Mode	18.25	1.75	8.75	19	15	20.5	12.5
		Standard D	2.836655	0.834894	2.059676	4.228165	5.621211	7.91618	8.803405
		Sample Va	8.046614	0.697048	4.242266	17.87738	31.59801	62.6659	77.49993
		Kurtosis	-0.02188	0.532493	-0.112795	-0.066337	-0.152856	0.020233	-0.034319
		Skewness	-0.013931	0.561469	0.105068	0.032442	0.268595	0.314369	0.374563
		Range	17.25	5.25	13.75	24.75	34.25	54.25	46.5
		Minimum	6.75	0	3.25	6	2	0.75	0
		Maximum	24	5.25	17	30.75	36.25	55	46.5
		Sum	16290.25	1907	9393.75	17363.75	16514.5	21668.5	16646
		Count	1000	1000	1000	1000	1000	1000	1000
		CV	0.174132	0.437805	0.21926	0.243505	0.34038	0.365331	0.52886

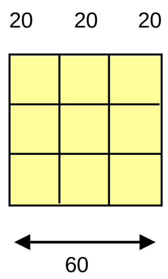
Questions:

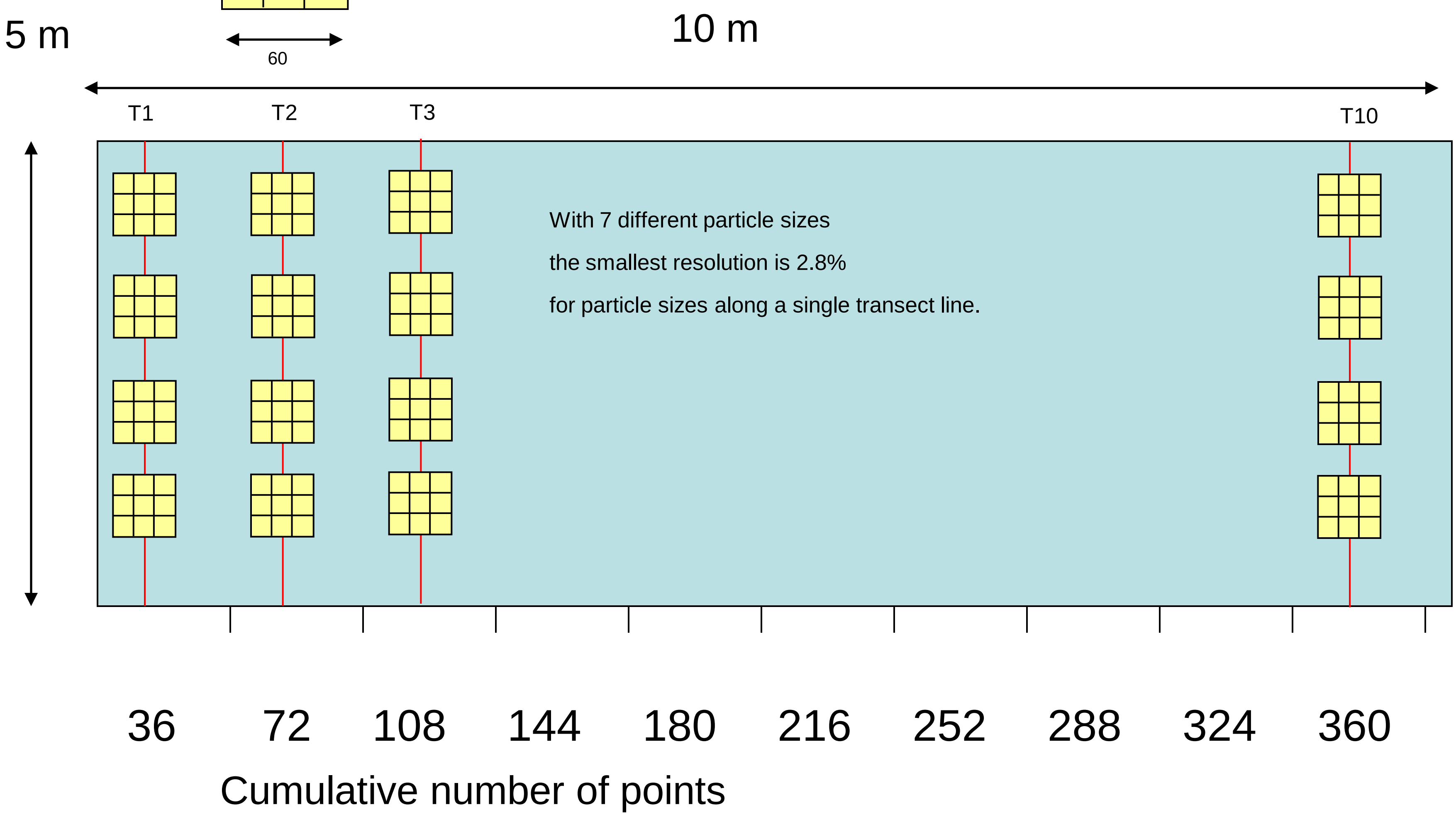
1. Are there other statistics than CV that are useful?
2. Which method is best: the grid frame or the transect?
3. How many samples are needed? How many grid tosses; which size frame; what transect spacing; how many points across the channel; how many total points?
4. What do you do when there is obvious zonation of particle size in a reach? Is the reach one where you will sample again year after year to determine changes? Or do you just need to determine a meaningful average condition by reach and tributary?
5. What number of samples are needed in order to detect a change with a certain level of precision?
6. Problems with overlapping of particles in a real streambed.
7. Problems with particles being embedded so that the intermediate diameter is not visible.

Transect-GridFrame design



Note: points are in center of the grid squares. The center points should all be located within the boundary of the designated 5x10m reach. The location of the T1 line is randomly located within first 1-m zone but the center line of the entire grid frame is restricted to 0.3 m to 0.7 m so that the grid points all fall within the 0 to 1.0 m zone.





TranFrameMethod_RandomDist1-results.xls

MLE method

360 points		Run 1			
mean	**SE**	**CV**	**True value**	**Abs error**	**Rel. error**
0.492	0.026	0.054	0.506	0.0141	-2.8
0.014	0.006	0.444	0.020	0.0061	-30.6
0.053	0.012	0.223	0.060	0.0071	-11.9
0.131	0.018	0.136	0.119	0.0121	10.2
0.086	0.015	0.172	0.088	0.0021	-2.4
0.153	0.019	0.124	0.148	0.0046	3.1
0.072	0.014	0.189	0.059	0.0129	21.8

1440 points	Runs 1-4		True value	Abs error	Rel. error
0.492	0.013	0.027	0.506	0.0134	-2.7
0.023	0.004	0.172	0.020	0.0029	14.6
0.058	0.006	0.107	0.060	0.0023	-3.8
0.128	0.009	0.069	0.119	0.0093	7.8
0.091	0.008	0.083	0.088	0.0028	3.1
0.143	0.009	0.064	0.148	0.0051	-3.5
0.065	0.007	0.100	0.059	0.0060	10.1

points	Runs 1-2		True value	Abs error	Rel. error
0.506	0.019	0.037	0.506	0.0002	0.0
0.022	0.005	0.247	0.020	0.0022	11.1
0.051	0.008	0.160	0.060	0.0085	-14.2
0.118	0.012	0.102	0.119	0.0004	-0.4
0.088	0.011	0.120	0.088	0.0007	-0.8
0.144	0.013	0.091	0.148	0.0038	-2.5
0.071	0.010	0.135	0.059	0.0115	19.4

1800 points	Runs 1-5		True value	Abs error	Rel. error
0.491	0.012	0.024	0.506	0.0147	-2.9
0.025	0.004	0.147	0.020	0.0050	25.0
0.059	0.006	0.094	0.060	0.0005	-0.8
0.124	0.008	0.063	0.119	0.0059	5.0
0.091	0.007	0.074	0.088	0.0029	3.3
0.143	0.008	0.058	0.148	0.0049	-3.3
0.066	0.006	0.089	0.059	0.0063	10.5

points	Runs 1-3		True value	Abs error	Rel. error
0.491	0.015	0.031	0.506	0.0151	-3.0
0.021	0.004	0.206	0.020	0.0013	6.5
0.056	0.007	0.124	0.060	0.0034	-5.7
0.124	0.010	0.081	0.119	0.0056	4.7
0.089	0.009	0.097	0.088	0.0007	0.8
0.148	0.011	0.073	0.148	0.0000	0.0
0.070	0.008	0.111	0.059	0.0111	18.7

TranFrameMethod_RandomDist1-results.xls

MLE method

360 points Run 1

mean	SE	CV	True value	Abs error	Rel. error
0.492	0.026	0.054	0.506	0.0141	-2.8
0.014	0.006	0.444	0.020	0.0061	-30.6
0.053	0.012	0.223	0.060	0.0071	-11.9
0.131	0.018	0.136	0.119	0.0121	10.2
0.086	0.015	0.172	0.088	0.0021	-2.4
0.153	0.019	0.124	0.148	0.0046	3.1
0.072	0.014	0.189	0.059	0.0129	21.8

360 points Run 2

			True value	Abs error	Rel. error
0.519	0.026	0.051	0.506	0.0136	2.7
0.031	0.009	0.297	0.020	0.0106	52.8
0.050	0.011	0.230	0.060	0.0099	-16.5
0.106	0.016	0.153	0.119	0.0129	-10.9
0.089	0.015	0.169	0.088	0.0007	0.8
0.136	0.018	0.133	0.148	0.0121	-8.2
0.069	0.013	0.193	0.059	0.0101	17.1

360 points Run 3

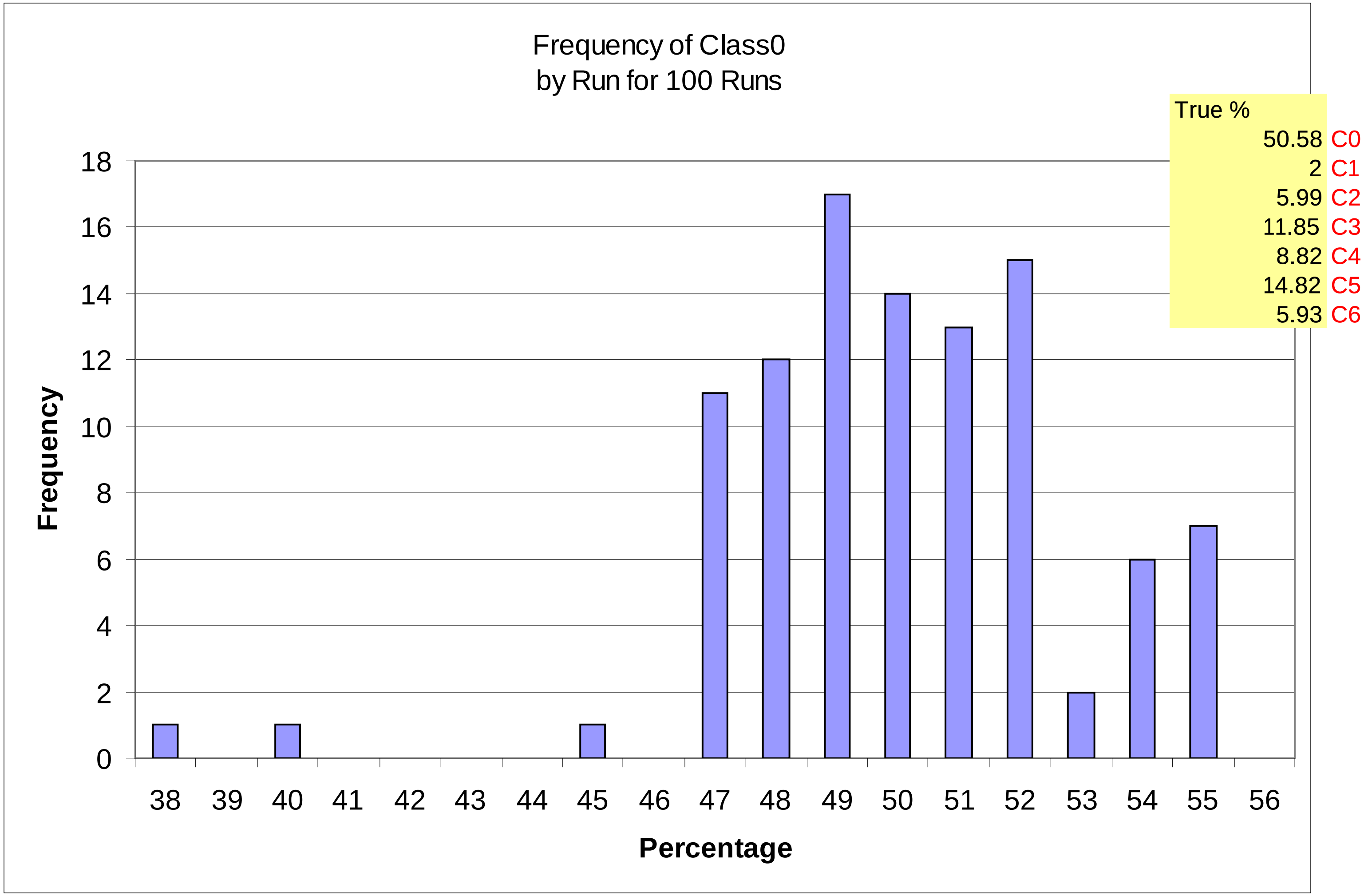
			True value	Abs error	Rel. error
0.461	0.026	0.057	0.506	0.0447	-8.8
0.019	0.007	0.374	0.020	0.0006	-2.8
0.067	0.013	0.197	0.060	0.0068	11.3
0.136	0.018	0.133	0.119	0.0176	14.9
0.092	0.015	0.166	0.088	0.0035	3.9
0.156	0.019	0.123	0.148	0.0074	5.0
0.069	0.013	0.193	0.059	0.0101	17.1

360 points Run 4

			True value	Abs error	Rel. error
0.497	0.026	0.053	0.506	0.0086	-1.7
0.028	0.009	0.312	0.020	0.0078	38.9
0.061	0.013	0.207	0.060	0.0012	2.0
0.139	0.018	0.131	0.119	0.0204	17.2
0.097	0.016	0.161	0.088	0.0090	10.2
0.128	0.018	0.138	0.148	0.0204	-13.8
0.050	0.011	0.230	0.059	0.0093	-15.7

TranFrameMethod_RandomDist1-results.xls

MLE method



TranFrameMethod_RandomDist2-results.xls MLE method

Run 1-odd transects

180 points

			True value	Abs error	Rel. error
0.172	0.028	0.163	0.184	0.0118	-6.4
0.039	0.014	0.371	0.019	0.0195	100.5
0.106	0.023	0.217	0.100	0.0061	6.1
0.178	0.028	0.160	0.182	0.0044	-2.4
0.200	0.030	0.149	0.197	0.0032	1.6
0.144	0.026	0.181	0.192	0.0480	-24.9
0.161	0.027	0.170	0.126	0.0354	28.2

Run 1-even transects

180 points

			True value	Abs error	Rel. error
0.222	0.031	0.139	0.184	0.0382	20.8
0.006	0.006	0.997	0.019	0.0138	-71.4
0.089	0.021	0.239	0.100	0.0106	-10.7
0.144	0.026	0.181	0.182	0.0378	-20.7
0.233	0.032	0.135	0.197	0.0365	18.6
0.178	0.028	0.160	0.192	0.0146	-7.6
0.128	0.025	0.195	0.126	0.0021	1.7

360 points Run 1

mean	SE	CV	True value	Abs error	Rel. error
0.197	0.021	0.106	0.184	0.0132	7.2
0.022	0.008	0.350	0.019	0.0028	14.5
0.097	0.016	0.161	0.100	0.0023	-2.3
0.161	0.019	0.120	0.182	0.0211	-11.6
0.217	0.022	0.100	0.197	0.0199	10.1
0.161	0.019	0.120	0.192	0.0313	-16.3
0.144	0.019	0.128	0.126	0.0187	14.9

720 points Runs 1-2

mean	SE	CV	True value	Abs error	Rel. error
0.199	0.015	0.075	0.184	0.0146	7.9
0.021	0.005	0.255	0.019	0.0014	7.4
0.094	0.011	0.115	0.100	0.0051	-5.1
0.174	0.014	0.081	0.182	0.0086	-4.7
0.204	0.015	0.074	0.197	0.0074	3.7
0.167	0.014	0.083	0.192	0.0257	-13.4
0.142	0.013	0.092	0.126	0.0160	12.7

TranFrameMethod_RandomDist2-results.xls MLE method

1080 points Runs 1-3

mean	SE	CV	True value	Abs error	Rel. error
0.193	0.012	0.062	0.184	0.0086	4.7
0.018	0.004	0.227	0.019	0.0018	-9.3
0.093	0.009	0.095	0.100	0.0069	-6.9
0.180	0.012	0.065	0.182	0.0026	-1.4
0.201	0.012	0.061	0.197	0.0041	2.1
0.174	0.012	0.066	0.192	0.0183	-9.5
0.143	0.011	0.075	0.126	0.0169	13.4

1800 points Runs 1-5

mean	SE	CV	True value	Abs error	Rel. error
0.183	0.009	0.050	0.184	0.0012	-0.7
0.019	0.003	0.170	0.019	0.0005	-2.6
0.104	0.007	0.069	0.100	0.0044	4.4
0.186	0.009	0.049	0.182	0.0039	2.1
0.198	0.009	0.047	0.197	0.0015	0.8
0.173	0.009	0.052	0.192	0.0196	-10.2
0.137	0.008	0.059	0.126	0.0115	9.2

36000 points		Runs 1-100	True value	Abs error	Rel. error
0.179	0.002	0.011	0.184	0.0054	-2.9
0.021	0.001	0.036	0.019	0.0017	8.7
0.102	0.002	0.016	0.100	0.0021	2.2
0.182	0.002	0.011	0.182	0.0002	0.1
0.201	0.002	0.011	0.197	0.0041	2.1
0.177	0.002	0.011	0.192	0.0152	-7.9
0.138	0.002	0.013	0.126	0.0124	9.9

TranFrameMethod_RandomDist2-results.xls MLE method

360 points Run 1

mean	SE	CV	True value	Abs error	Rel. error
0.197	0.021	0.106	0.184	0.0132	7.2
0.022	0.008	0.350	0.019	0.0028	14.5
0.097	0.016	0.161	0.100	0.0023	-2.3
0.161	0.019	0.120	0.182	0.0211	-11.6
0.217	0.022	0.100	0.197	0.0199	10.1
0.161	0.019	0.120	0.192	0.0313	-16.3
0.144	0.019	0.128	0.126	0.0187	14.9

360 points Run 2

			True value	Abs error	Rel. error
0.200	0.021	0.105	0.184	0.0160	8.7
0.019	0.007	0.374	0.019	0.0000	0.2
0.092	0.015	0.166	0.100	0.0078	-7.9
0.186	0.021	0.110	0.182	0.0039	2.1
0.192	0.021	0.108	0.197	0.0051	-2.6
0.172	0.020	0.116	0.192	0.0202	-10.5
0.139	0.018	0.131	0.126	0.0132	10.5

360 points Run 3

			True value	Abs error	Rel. error
0.181	0.020	0.112	0.184	0.0034	-1.9
0.011	0.006	0.497	0.019	0.0083	-42.7
0.089	0.015	0.169	0.100	0.0106	-10.7
0.192	0.021	0.108	0.182	0.0095	5.2
0.194	0.021	0.107	0.197	0.0024	-1.2
0.189	0.021	0.109	0.192	0.0035	-1.8
0.144	0.019	0.128	0.126	0.0187	14.9

360 points Run 4

			True value	Abs error	Rel. error
0.178	0.020	0.113	0.184	0.0062	-3.4
0.017	0.007	0.405	0.019	0.0027	-14.1
0.119	0.017	0.143	0.100	0.0199	20.0
0.183	0.020	0.111	0.182	0.0011	0.6
0.189	0.021	0.109	0.197	0.0079	-4.0
0.178	0.020	0.113	0.192	0.0146	-7.6
0.136	0.018	0.133	0.126	0.0104	8.3

Run	Transect	Count	Class0	Class1	Class2	Class3	Class4	Class5	Class6	
Run 1			41.9	13.4	12.4	39.1	97.4	15.1	56.2	VAR
	360	points	6.5	3.7	3.5	6.3	9.9	3.9	7.5	SD
			18.4	1.9	10.0	18.2	19.7	19.2	12.6	true mean
			19.7	2.2	9.7	16.1	21.7	16.1	14.4	sample mean
			0.33	1.65	0.36	0.39	0.46	0.24	0.52	CV
			1.3	0.3	0.2	2.1	2.0	3.1	1.9	absolute error (%)
			7.2	14.5	-2.3	-11.6	10.1	-16.3	14.9	relative error (%)
Runs 1 and 2			37.6	8.0	13.3	37.3	57.9	15.4	50.3	VAR
	720	points	6.1	2.8	3.6	6.1	7.6	3.9	7.1	SD
			18.4	1.9	10.0	18.2	19.7	19.2	12.6	true mean
			19.9	2.1	9.4	17.4	20.4	16.7	14.2	sample mean
			0.31	1.36	0.39	0.35	0.37	0.24	0.50	CV
			1.5	0.1	0.5	0.9	0.7	2.6	1.6	absolute error (%)
			7.9	7.4	-5.1	-4.7	3.7	-13.4	12.7	relative error (%)
Runs 1, 2, and 3			48.4	7.2	22.0	33.4	50.4	22.3	45.1	VAR
	1080	points	7.0	2.7	4.7	5.8	7.1	4.7	6.7	SD
			18.4	1.9	10.0	18.2	19.7	19.2	12.6	true mean
			19.3	1.8	9.3	18.0	20.1	17.4	14.3	sample mean
			0.36	1.52	0.51	0.32	0.35	0.27	0.47	CV
			0.9	0.2	0.7	0.3	0.4	1.8	1.7	absolute error (%)
			4.7	-9.3	-6.9	-1.4	2.1	-9.5	13.4	relative error (%)
Runs 1, 2, 3, 4, 5			47.9	7.4	24.5	35.7	46.3	32.5	42.0	VAR
	1800	points	6.9	2.7	5.0	6.0	6.8	5.7	6.5	SD
			18.4	1.9	10.0	18.2	19.7	19.2	12.6	true mean
			18.3	1.9	10.4	18.6	19.8	17.3	13.7	sample mean
			0.38	1.44	0.48	0.32	0.34	0.33	0.47	CV
			0.1	0.1	0.4	0.4	0.2	2.0	1.2	absolute error (%)
			-0.7	-2.6	4.4	2.1	0.8	-10.2	9.2	relative error (%)
Runs 1-100			43.60038	5.877166	25.60214	43.11135	38.36587	26.72117	43.68775	VAR
	36000	points	6.9	2.7	5.0	6.0	6.8	5.7	6.5	SD
			18.4	1.9	10.0	18.2	19.7	19.2	12.6	true mean
			17.9	2.1	10.2	18.2	20.1	17.7	13.8	sample mean
			0.39	1.29	0.49	0.33	0.34	0.32	0.47	CV
			0.5	0.2	0.2	0.0	0.4	1.5	1.2	absolute error (%)
			-2.9	8.7	2.1	0.1	2.1	-7.9	9.9	relative error (%)

For the preceding table:

Note:

The statistics above are calculated by simple averages and variances of the percentages of each particle size

from each of the transects for each run. Each run has 10 transects.

TranFrameMethod_RandomDist2-results.xls

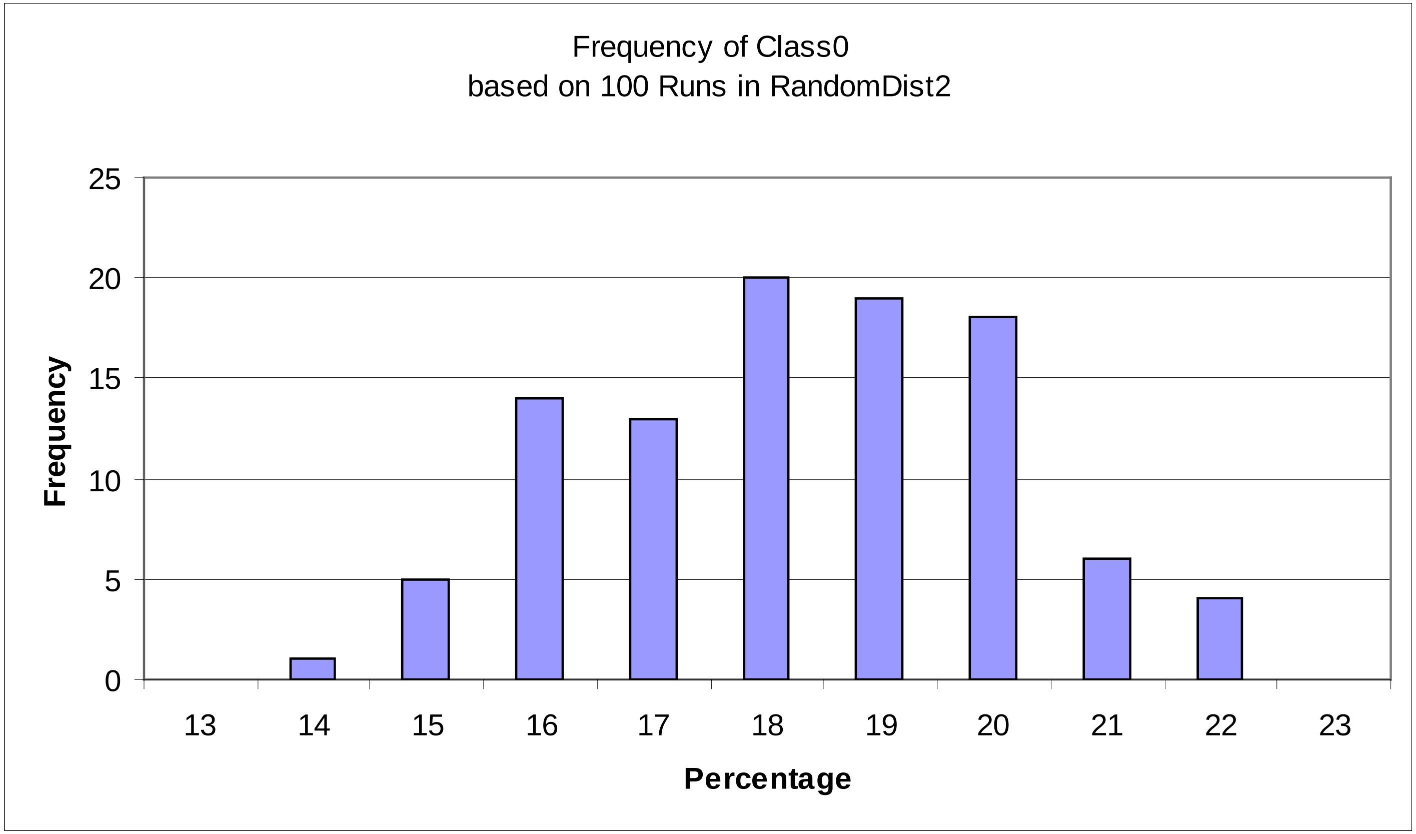
Mean by Transect for 7 Particle Size Classes

	Data						
Transect	Average of Class0	Average of Class1	Average of Class2	Average of Class3	Average of Class4	Average of Class5	Average of Class6
1	15.56	1.75	7.72	17.44	20.89	13.92	22.72
2	18.72	2.83	11.75	25.06	16.36	20.89	4.39
3	23.33	3.94	12.81	19.14	21.44	10.61	8.72
4	16.50	1.50	9.81	17.58	27.64	20.89	6.08
5	20.03	1.58	12.89	16.67	19.28	18.08	11.47
6	15.72	1.56	8.81	19.53	17.08	25.19	12.11
7	17.83	2.42	8.14	17.64	16.92	18.44	18.61
8	16.47	1.47	9.28	17.06	22.47	15.03	18.22
9	16.97	1.69	9.78	19.50	17.86	18.81	15.39
10	17.44	2.33	10.67	12.78	21.00	15.36	20.42
Grand Total	17.86	2.11	10.16	18.24	20.09	17.72	13.81

SD by Transect for 7 Particle Size Classes

	Data						
Transect	StdDev of Class0	StdDev of Class1	StdDev of Class2	StdDev of Class3	StdDev of Class4	StdDev of Class5	StdDev of Class6
1	5.56	2.08	4.94	5.13	4.84	2.57	2.88
2	7.20	3.01	4.55	6.22	3.48	4.07	2.93
3	7.07	3.33	4.64	5.04	3.95	3.71	2.05
4	5.58	1.87	4.54	7.45	7.21	4.35	2.67
5	6.54	1.69	5.32	6.59	5.34	2.60	2.32
6	6.38	2.17	5.75	7.78	4.94	3.01	3.27
7	5.95	2.42	4.63	4.11	7.49	2.94	4.04
8	6.02	1.65	4.44	4.38	5.54	3.04	2.94
9	6.06	1.97	4.94	7.15	4.07	4.25	2.91
10	5.80	2.36	3.72	3.37	4.69	2.18	2.96
Grand Total	6.60	2.42	5.06	6.57	6.19	5.17	6.61

TranFrameMethod_RandomDist2-results.xls



18.4	C0
1.94	C1
9.95	C2
18.22	C3
19.68	C4
19.24	C5
12.57	C6

TranFrameMethod_ZonalDist-results.xls

TranFrameMethod_ZonalDist-results.xls

360 points Run 1

Mean	SE	CV	True value	Abs error	Rel. error
0.519	0.026	0.051	0.5043	0.0151	3.0
0.000	0.000	997.568	0.0198	0.0198	-100.0
0.022	0.008	0.350	0.0593	0.0371	-62.5
0.086	0.015	0.172	0.0876	0.0015	-1.7
0.139	0.018	0.131	0.1194	0.0195	16.3
0.178	0.020	0.113	0.1491	0.0287	19.2
0.056	0.012	0.217	0.0606	0.0050	-8.3

780 points Runs 1-2

			True value	Abs error	Rel. error
0.517	0.019	0.036	0.5043	0.0124	2.5
0.001	0.001	0.999	0.0198	0.0184	-93.0
0.035	0.007	0.196	0.0593	0.0246	-41.4
0.079	0.010	0.127	0.0876	0.0084	-9.6
0.126	0.012	0.098	0.1194	0.0070	5.9
0.186	0.015	0.078	0.1491	0.0370	24.8
0.056	0.009	0.154	0.0606	0.0050	-8.3

1080 points Runs 1-3

			True value	Abs error	Rel. error
0.496	0.015	0.031	0.5043	0.0080	-1.6
0.003	0.002	0.577	0.0198	0.0170	-86.0
0.042	0.006	0.146	0.0593	0.0176	-29.7
0.084	0.008	0.100	0.0876	0.0033	-3.8
0.132	0.010	0.078	0.1194	0.0130	10.9
0.189	0.012	0.063	0.1491	0.0398	26.7
0.054	0.007	0.128	0.0606	0.0069	-11.4

1800 points Runs 1-5

			True value	Abs error	Rel. error
0.476	0.012	0.025	0.5043	0.0282	-5.6
0.006	0.002	0.315	0.0198	0.0142	-71.9
0.041	0.005	0.114	0.0593	0.0182	-30.7
0.091	0.007	0.075	0.0876	0.0030	3.4
0.139	0.008	0.059	0.1194	0.0195	16.3
0.194	0.009	0.048	0.1491	0.0448	30.0
0.054	0.005	0.099	0.0606	0.0067	-11.1

36000 points Runs 1-100

			True value	Abs error	Rel. error
0.479	0.003	0.005	0.5043	0.0249	-4.9
0.009	0.000	0.056	0.0198	0.0111	-56.2
0.043	0.001	0.025	0.0593	0.0161	-27.2
0.089	0.001	0.017	0.0876	0.0010	1.2
0.135	0.002	0.013	0.1194	0.0156	13.1
0.192	0.002	0.011	0.1491	0.0430	28.8
0.053	0.001	0.022	0.0606	0.0075	-12.4

TranFrameMethod_ZonalDist-results.xls

Mean for particle sizes by transect line for 100 runs

	Transect										
Data	1	2	3	4	5	6	7	8	9	10	Grand Total
Average of Class0	42.6	45.9	47.3	48.7	45.6	51.0	50.2	40.3	57.4	50.4	47.9
Average of Class1	0.4	0.8	0.6	0.4	0.1	1.5	1.1	0.6	1.7	1.6	0.9
Average of Class2	4.0	3.4	3.1	3.3	4.6	4.9	5.4	4.0	6.1	4.4	4.3
Average of Class3	8.5	7.7	10.1	11.7	9.6	5.7	8.4	11.7	5.6	9.7	8.9
Average of Class4	17.7	14.4	14.3	12.8	16.1	12.8	13.3	13.2	10.9	9.7	13.5
Average of Class5	17.1	12.8	20.9	16.8	23.9	24.0	13.8	25.2	17.7	20.0	19.2
Average of Class6	9.8	15.0	3.8	6.5	0.1	0.0	8.0	5.0	0.7	4.2	5.3

SD for particle sizes by transect line for 100 runs

	Transect										
Data	1	2	3	4	5	6	7	8	9	10	Grand Total
StdDev of Class0	7.52	6.10	4.76	9.79	9.74	6.55	5.95	6.66	8.28	6.48	8.62
StdDev of Class1	1.02	1.24	1.12	1.12	0.48	2.10	1.62	1.14	2.56	2.21	1.66
StdDev of Class2	2.31	2.68	2.88	3.09	3.33	2.55	3.21	3.17	3.84	3.04	3.16
StdDev of Class3	6.80	4.61	3.80	4.01	4.17	2.85	4.48	4.36	4.43	2.91	4.80
StdDev of Class4	3.63	7.03	3.88	3.97	6.44	2.46	4.38	5.42	3.38	3.82	5.11
StdDev of Class5	2.51	3.44	4.09	3.04	3.05	3.88	2.72	2.93	3.25	3.46	5.24
StdDev of Class6	4.24	3.89	2.55	3.35	0.48	0.00	2.26	3.14	1.37	1.60	5.23

Class	Var of means	SD	CV
0	20.72	4.55	0.107
1	0.29	0.54	1.208
2	0.82	0.90	0.227
3	4.10	2.02	0.239
4	4.76	2.18	0.124
5	16.86	4.11	0.240
6	20.38	4.51	0.462

Overall means for the Zonal Dist

Scenario	Longitudinal Zones
Class0_Pct	50.43
Class1_Pct	1.98
Class2_Pct	5.93
Class3_Pct	8.76
Class4_Pct	11.94
Class5_Pct	14.91
Class6_Pct	6.06

Comparison of the actual vs. measured percentages of particle sizes by zone (transect) based on 36 points/transect and 100 runs

Actual percentages of each particle size by zone (transect)

Transect	C0	C1	C2	C3	C4	C5	C6
1	45.4	0.7	4.0	8.4	13.5	19.2	8.8
2	49.1	0.7	4.0	7.8	13.2	18.0	7.3
3	47.1	1.0	4.5	8.5	12.3	18.8	7.7
4	48.2	1.0	4.5	9.1	13.1	17.6	6.5
5	50.0	1.5	4.5	9.0	12.9	15.9	6.2
6	51.3	2.5	6.0	9.0	11.9	13.8	5.5
7	50.6	2.8	7.0	9.0	11.0	13.0	6.6
8	52.7	3.0	8.0	9.0	11.3	11.6	4.4
9	54.2	3.0	9.0	8.9	10.4	10.3	4.1
10	55.5	3.5	8.0	8.9	9.9	10.8	3.3
Mean	50.4	2.0	6.0	8.8	12.0	14.9	6.0

Measured percentages of each particle size by zone (transect) based on 36 pts/transect

Transect	C0	C1	C2	C3	C4	C5	C6
1	42.6	0.4	4.0	8.5	17.7	17.1	9.8
2	45.9	0.8	3.4	7.7	14.4	12.8	15.0
3	47.3	0.6	3.1	10.1	14.3	20.9	3.8
4	48.7	0.4	3.3	11.7	12.8	16.8	6.5
5	45.6	0.1	4.6	9.6	16.1	23.9	0.1
6	51.0	1.5	4.9	5.7	12.8	24.0	0.0
7	50.2	1.1	5.4	8.4	13.3	13.8	8.0
8	40.3	0.6	4.0	11.7	13.2	25.2	5.0
9	57.4	1.7	6.1	5.6	10.9	17.7	0.7
10	50.4	1.6	4.4	9.7	9.7	20.0	4.2
Mean	47.9	0.9	4.3	8.9	13.5	19.2	5.3

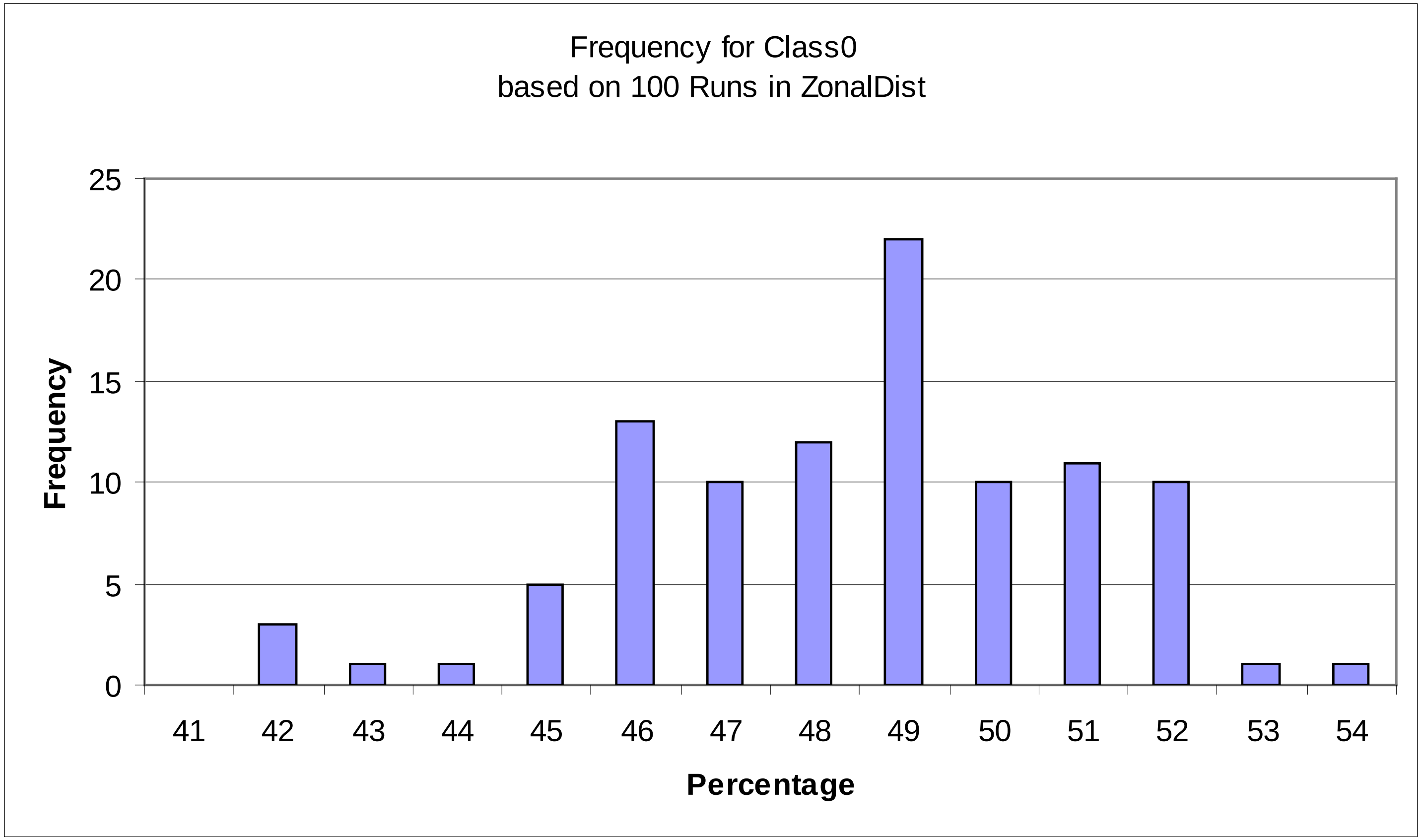
Comparison of the actual vs. measured percentages of particle sizes by zone (transect) based on 36 points/transect and 2 individual runs of 100

Actual percentages of each particle size by zone (transect)

Transect	C0	C1	C2	C3	C4	C5	C6
1	45.4	0.7	4.0	8.4	13.5	19.2	8.8
2	49.1	0.7	4.0	7.8	13.2	18.0	7.3
3	47.1	1.0	4.5	8.5	12.3	18.8	7.7
4	48.2	1.0	4.5	9.1	13.1	17.6	6.5
5	50.0	1.5	4.5	9.0	12.9	15.9	6.2
6	51.3	2.5	6.0	9.0	11.9	13.8	5.5
7	50.6	2.8	7.0	9.0	11.0	13.0	6.6
8	52.7	3.0	8.0	9.0	11.3	11.6	4.4
9	54.2	3.0	9.0	8.9	10.4	10.3	4.1
10	55.5	3.5	8.0	8.9	9.9	10.8	3.3
Mean	50.4	2.0	6.0	8.8	12.0	14.9	6.0

Run	Transect	Class0	Class1	Class2	Class3	Class4	Class5	Class6	Count
1	1	50.0	0.0	0.0	5.6	16.7	11.1	16.7	36
1	2	44.4	0.0	5.6	2.8	13.9	11.1	22.2	36
1	3	47.2	0.0	0.0	11.1	19.4	19.4	2.8	36
1	4	41.7	0.0	0.0	19.4	16.7	19.4	2.8	36
1	5	47.2	0.0	2.8	11.1	13.9	25.0	0.0	36
1	6	58.3	0.0	2.8	5.6	13.9	19.4	0.0	36
1	7	50.0	0.0	2.8	16.7	8.3	16.7	5.6	36
1	8	47.2	0.0	0.0	8.3	19.4	22.2	2.8	36
1	9	75.0	0.0	2.8	0.0	8.3	13.9	0.0	36
1	10	58.3	0.0	5.6	5.6	8.3	19.4	2.8	36
mean		51.9	0.0	2.2	8.6	13.9	17.8	5.6	
2	1	50.0	0.0	5.6	5.6	22.2	16.7	0.0	36
2	2	50.0	0.0	8.3	2.8	8.3	16.7	13.9	36
2	3	41.7	0.0	5.6	5.6	19.4	19.4	8.3	36
2	4	36.1	0.0	2.8	11.1	16.7	22.2	11.1	36
2	5	63.9	0.0	0.0	5.6	8.3	22.2	0.0	36
2	6	52.8	0.0	2.8	8.3	11.1	25.0	0.0	36
2	7	50.0	0.0	13.9	5.6	11.1	11.1	8.3	36
2	8	47.2	0.0	2.8	13.9	2.8	25.0	8.3	36
2	9	66.7	0.0	2.8	0.0	11.1	19.4	0.0	36
2	10	55.6	2.8	2.8	13.9	2.8	16.7	5.6	36
mean		51.4	0.3	4.7	7.2	11.4	19.4	5.6	

TranFrameMethod_ZonalDist-results.xls



Next slides show calculation by the MLE method with the Random Distribution 1 Simulated Reach. This distribution has 50.6% fines.

Grid frames had 25 points each and were tossed randomly in the reach. A “Run” consists of 1 toss of a grid frame. There were 100 separate runs.

SimRand_10x10x2

Random toss in Simulated Reach 1

MLE calculation

350 points **SimRand_10x10x2** 2-cm grid point spacing
Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.526	0.027	0.051	0.506	0.0199	3.9
0.029	0.009	0.312	0.020	0.0086	42.8
0.057	0.012	0.217	0.060	0.0028	-4.7
0.100	0.016	0.160	0.119	0.0185	-15.6
0.166	0.020	0.120	0.088	0.0775	87.9
0.123	0.018	0.143	0.148	0.0253	-17.1
0.000	0.000	997.704	0.059	0.0593	-100.0

Run 1-29
725 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.549	0.018	0.034	0.506	0.0431	8.5
		0.026	0.006	0.226	0.020	0.0062	30.9
		0.057	0.009	0.152	0.060	0.0034	-5.7
		0.126	0.012	0.098	0.119	0.0070	5.9
		0.135	0.013	0.094	0.088	0.0470	53.3
		0.108	0.012	0.107	0.148	0.0406	-27.4
		0.000	0.000	995.771	0.059	0.0593	-100.0

SimRand_10x10x2

Random toss in Simulated Reach 1

MLE calculation

Runs 1-43
1075 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.558	0.015	0.027	0.506	0.0523	10.3
		0.022	0.005	0.202	0.020	0.0023	11.6
		0.063	0.007	0.117	0.060	0.0033	5.5
		0.112	0.010	0.086	0.119	0.0069	-5.8
		0.128	0.010	0.079	0.088	0.0402	45.6
		0.114	0.010	0.085	0.148	0.0338	-22.8
		0.002	0.001	0.706	0.059	0.0574	-96.9

Runs 1-72
1800 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.538	0.012	0.022	0.506	0.0319	6.3
		0.025	0.004	0.147	0.020	0.0050	24.9
		0.058	0.006	0.095	0.060	0.0016	-2.7
		0.115	0.008	0.065	0.119	0.0035	-3.0
		0.112	0.007	0.066	0.088	0.0235	26.6
		0.138	0.008	0.059	0.148	0.0104	-7.0
		0.014	0.003	0.195	0.059	0.0448	-75.6

350 points **SimRand_10x10x2** 2-cm grid point spacing

Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.526	0.027	0.051	0.506	0.0199	3.9
0.029	0.009	0.312	0.020	0.0086	42.8
0.057	0.012	0.217	0.060	0.0028	-4.7
0.100	0.016	0.160	0.119	0.0185	-15.6
0.166	0.020	0.120	0.088	0.0775	87.9
0.123	0.018	0.143	0.148	0.0253	-17.1
0.000	0.000	997.704	0.059	0.0593	-100.0

350 points

Run 15-28

mean	SE	CV	True value	Abs error	Rel. error
0.569	0.026	0.047	0.506	0.0627	12.4
0.011	0.006	0.497	0.020	0.0086	-42.9
0.057	0.012	0.217	0.060	0.0028	-4.7
0.149	0.019	0.128	0.119	0.0301	25.4
0.114	0.017	0.149	0.088	0.0261	29.6
0.100	0.016	0.160	0.148	0.0482	-32.5
0.000	0.000	997.635	0.059	0.0593	-100.0

350 points

Run 29-42

mean	SE	CV	True value	Abs error	Rel. error
0.583	0.026	0.045	0.506	0.0770	15.2
0.029	0.009	0.312	0.020	0.0086	42.8
0.077	0.014	0.185	0.060	0.0172	28.6
0.080	0.015	0.181	0.119	0.0385	-32.5
0.114	0.017	0.149	0.088	0.0261	29.6
0.114	0.017	0.149	0.148	0.0339	-22.9
0.003	0.003	0.999	0.059	0.0564	-95.2

350 points **SimRand_100x100x20** 20-cm grid point spacing

Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.431	0.026	0.061	0.506	0.0744	-14.7
0.043	0.011	0.253	0.020	0.0228	114.1
0.066	0.013	0.202	0.060	0.0057	9.6
0.120	0.017	0.145	0.119	0.0015	1.3
0.069	0.014	0.197	0.088	0.0196	-22.2
0.183	0.021	0.113	0.148	0.0347	23.4
0.089	0.015	0.171	0.059	0.0293	49.5

Run 1-29

725 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.437	0.018	0.042	0.506	0.0686	-13.6
		0.030	0.006	0.210	0.020	0.0103	51.6
		0.068	0.009	0.138	0.060	0.0076	12.7
		0.126	0.012	0.098	0.119	0.0070	5.9
		0.073	0.010	0.132	0.088	0.0151	-17.1
		0.171	0.014	0.082	0.148	0.0228	15.4
		0.095	0.011	0.115	0.059	0.0359	60.6

Runs 1-43
1075 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.458	0.015	0.033	0.506	0.0482	-9.5
		0.030	0.005	0.174	0.020	0.0098	48.7
		0.063	0.007	0.117	0.060	0.0033	5.5
		0.117	0.010	0.084	0.119	0.0013	-1.1
		0.082	0.008	0.102	0.088	0.0063	-7.2
		0.166	0.011	0.068	0.148	0.0174	11.7
		0.085	0.008	0.100	0.059	0.0254	42.8

Runs 1-72
1800 points

index	name	mean	SE	CV	True value	Abs error	Rel. error
		0.475	0.012	0.025	0.506	0.0308	-6.1
		0.022	0.003	0.156	0.020	0.0022	11.0
		0.066	0.006	0.089	0.060	0.0056	9.3
		0.118	0.008	0.065	0.119	0.0007	-0.6
		0.087	0.007	0.076	0.088	0.0010	-1.1
		0.156	0.009	0.055	0.148	0.0074	5.0
		0.077	0.006	0.082	0.059	0.0174	29.4

350 points **SimRand_100x100x20** 20-cm grid point spacing
Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.431	0.026	0.061	0.506	0.0744	-14.7
0.043	0.011	0.253	0.020	0.0228	114.1
0.066	0.013	0.202	0.060	0.0057	9.6
0.120	0.017	0.145	0.119	0.0015	1.3
0.069	0.014	0.197	0.088	0.0196	-22.2
0.183	0.021	0.113	0.148	0.0347	23.4
0.089	0.015	0.171	0.059	0.0293	49.5

350 points **SimRand_100x100x20** 20-cm grid point spacing
Run 15-28

mean	SE	CV	True value	Abs error	Rel. error
0.443	0.027	0.060	0.506	0.0630	-12.5
0.020	0.007	0.374	0.020	0.0000	-0.1
0.071	0.014	0.193	0.060	0.0114	19.1
0.134	0.018	0.136	0.119	0.0158	13.3
0.071	0.014	0.193	0.088	0.0168	-19.0
0.160	0.020	0.122	0.148	0.0118	8.0
0.100	0.016	0.160	0.059	0.0407	68.7

350 points **SimRand_100x100x2** 20-cm grid point spacing
Run 29-42

mean	SE	CV	True value	Abs error	Rel. error
0.497	0.027	0.054	0.506	0.0087	-1.7
0.029	0.009	0.312	0.020	0.0086	42.8
0.046	0.011	0.244	0.060	0.0143	-23.8
0.103	0.016	0.158	0.119	0.0157	-13.2
0.100	0.016	0.160	0.088	0.0118	13.4
0.154	0.019	0.125	0.148	0.0061	4.1
0.071	0.014	0.193	0.059	0.0122	20.5

Next slides show calculation by the MLE method with the Random Distribution 3 Simulated Reach. This distribution has 18.4% fines.

Grid frames had 25 points each and were tossed randomly in the reach. A “Run” consists of 1 toss of a grid frame. There were 100 separate runs. Percentages of the various particle sizes were computed from the 25 points.

350 points SimThird_10x10x2 2-cm grid point spacing

Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.214	0.022	0.102	0.184	0.0303	16.5
0.011	0.006	0.497	0.019	0.0080	-41.1
0.117	0.017	0.147	0.100	0.0176	17.7
0.246	0.023	0.094	0.182	0.0635	34.9
0.177	0.020	0.115	0.197	0.0197	-10.0
0.177	0.020	0.115	0.192	0.0153	-7.9
0.057	0.012	0.217	0.126	0.0686	-54.5

Runs 1-72

1800 points

mean	SE	CV	True value	Abs error	Rel. error
0.161	0.009	0.054	0.184	0.0234	-12.7
0.021	0.003	0.163	0.019	0.0012	6.0
0.093	0.007	0.074	0.100	0.0067	-6.8
0.177	0.009	0.051	0.182	0.0055	-3.0
0.148	0.008	0.057	0.197	0.0490	-24.9
0.226	0.010	0.044	0.192	0.0332	17.2
0.176	0.009	0.051	0.126	0.0504	40.1

Runs 1-100

2500 points

mean	SE	CV	True value	Abs error	Rel. error
0.162	0.007	0.046	0.184	0.0224	-12.2
0.019	0.003	0.143	0.019	0.0002	-1.0
0.093	0.006	0.063	0.100	0.0067	-6.7
0.174	0.008	0.044	0.182	0.0082	-4.5
0.165	0.007	0.045	0.197	0.0316	-16.1
0.216	0.008	0.038	0.192	0.0240	12.5
0.171	0.008	0.044	0.126	0.0451	35.9

350 points SimThird_10x10x2 2-cm grid point spacing

Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.214	0.022	0.102	0.184	0.0303	16.5
0.011	0.006	0.497	0.019	0.0080	-41.1
0.117	0.017	0.147	0.100	0.0176	17.7
0.246	0.023	0.094	0.182	0.0635	34.9
0.177	0.020	0.115	0.197	0.0197	-10.0
0.177	0.020	0.115	0.192	0.0153	-7.9
0.057	0.012	0.217	0.126	0.0686	-54.5

350 points

Run 15-28

mean	SE	CV	True value	Abs error	Rel. error
0.154	0.019	0.125	0.184	0.0297	-16.1
0.020	0.007	0.374	0.019	0.0006	3.1
0.100	0.016	0.160	0.100	0.0005	0.5
0.186	0.021	0.112	0.182	0.0035	1.9
0.089	0.015	0.171	0.197	0.1082	-55.0
0.320	0.025	0.078	0.192	0.1276	66.3
0.131	0.018	0.137	0.126	0.0057	4.6

350 points

Run 29-42

mean	SE	CV	True value	Abs error	Rel. error
0.137	0.018	0.134	0.184	0.0469	-25.5
0.026	0.008	0.329	0.019	0.0063	32.5
0.054	0.012	0.223	0.100	0.0452	-45.4
0.177	0.020	0.115	0.182	0.0051	-2.8
0.120	0.017	0.145	0.197	0.0768	-39.0
0.129	0.018	0.139	0.192	0.0638	-33.2
0.357	0.026	0.072	0.126	0.2314	184.1

350 points SimThird_100x100x20 20-cm grid point spacing
Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.162	0.007	0.046	0.184	0.0224	-12.2
0.019	0.003	0.143	0.019	0.0002	-1.0
0.093	0.006	0.063	0.100	0.0067	-6.7
0.174	0.008	0.044	0.182	0.0082	-4.5
0.165	0.007	0.045	0.197	0.0316	-16.1
0.216	0.008	0.038	0.192	0.0240	12.5
0.171	0.008	0.044	0.126	0.0451	35.9

SimThird_100x100x20 20-cm grid point spacing
Runs 1-72
1800 points

mean	SE	CV	True value	Abs error	Rel. error
0.160	0.020	0.122	0.184	0.0240	-13.0
0.026	0.008	0.329	0.019	0.0063	32.5
0.117	0.017	0.147	0.100	0.0176	17.7
0.183	0.021	0.113	0.182	0.0007	0.4
0.177	0.020	0.115	0.197	0.0197	-10.0
0.194	0.021	0.109	0.192	0.0019	1.0
0.143	0.019	0.131	0.126	0.0172	13.7

350 points **SimThird_100x100x20** 20-cm grid point spacing

Run 1-14

mean	SE	CV	True value	Abs error	Rel. error
0.162	0.007	0.046	0.184	0.0224	-12.2
0.019	0.003	0.143	0.019	0.0002	-1.0
0.093	0.006	0.063	0.100	0.0067	-6.7
0.174	0.008	0.044	0.182	0.0082	-4.5
0.165	0.007	0.045	0.197	0.0316	-16.1
0.216	0.008	0.038	0.192	0.0240	12.5
0.171	0.008	0.044	0.126	0.0451	35.9

350 points **SimThird_100x100x20** 20-cm grid point spacing

Run 15-28

mean	SE	CV	True value	Abs error	Rel. error
0.194	0.021	0.109	0.184	0.0103	5.6
0.011	0.006	0.497	0.019	0.0080	-41.1
0.091	0.015	0.169	0.100	0.0081	-8.1
0.191	0.021	0.110	0.182	0.0092	5.1
0.180	0.021	0.114	0.197	0.0168	-8.5
0.217	0.022	0.101	0.192	0.0247	12.9
0.114	0.017	0.149	0.126	0.0114	-9.1

350 points **SimThird_100x100x20** 20-cm grid point spacing

Run 29-42

mean	SE	CV	True value	Abs error	Rel. error
0.160	0.020	0.122	0.184	0.0240	-13.0
0.026	0.008	0.329	0.019	0.0063	32.5
0.117	0.017	0.147	0.100	0.0176	17.7
0.183	0.021	0.113	0.182	0.0007	0.4
0.177	0.020	0.115	0.197	0.0197	-10.0
0.194	0.021	0.109	0.192	0.0019	1.0
0.143	0.019	0.131	0.126	0.0172	13.7

Appendix P

Multinomial Likelihood

Multinomial likelihood

We classify sediment particles into k categories in order of particle size, and take frequencies of categories as multinomial random variables.

$$(X_1, X_2, \cdots, X_k) \sim Multinomial(S, \boldsymbol{\theta}) \quad (1.1)$$

where X_i = frequency of particles in category i; S = the sum of the frequencies; and $\boldsymbol{\theta}$ is the vector of probabilities that particles are assigned to the respective categories. Our goal is to estimate the parameter vector $\boldsymbol{\theta}$ given data. To do so, we take the multinomial likelihood function:

$$L(\boldsymbol{\theta} \mid \mathbf{X}) = \frac{S!}{\prod_{i=1}^{k} X_i !} \prod_{i=1}^{k} \theta_i^{X_i} \quad (1.2)$$

To estimate θ_i s and the variances of their estimates, we need to differentiate the likelihood function up to twice. For the differentiation purposes, we take the negative log-likelihood function:

$$-\ell(\boldsymbol{\theta} \mid \mathbf{X}) \propto -1 \cdot \left(\sum_{i=1}^{k} X_i \cdot \log(\theta_i) \right) \quad (1.3)$$

We use ADMB software (Fournier 2001) for numerical differentiations.

References

Fournier, D.A. 2001. An introduction to AD Model Builder Version 6.0.2 for use in nonlinear modeling and statistics. Otter Research Ltd., Sidney, B.C., Canada.

Appendix Q

List of Files in the Grande Ronde Geodatabase

List of files in the Grande Ronde Geodatabase

1. Bio_Fish
    a. Brkt_v09
        i. ODFW distribution layer for brook trout.
    b. Bull_v12
        i. ODFW distribution layer for bull trout.
    c. Coho_v12
        i. ODFW distribution layer for coho salmon.
    d. Dist_anadromous_GrandeR
        i. This dataset is a record of fish distribution and life history stage of anadromous fishes, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables. All data are referenced to the PNW 1:100,000 River Reach Hydrography (http://www.streamnet.org/pnwr/pnwrhome) on the LLID-based stream routing system.
    e. Dist_Fall_Chinook_GrandeR
        i. This dataset is a record of fish distribution and life history stage of chinook salmon, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.
    f. Dist_ Spring_Chinook_GrandeR

i. This dataset is a record of fish distribution and life history stage of spring chinook salmon, based upon the best professional judgment of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.

g. Dist_Summer_Steelhead_GrandeR

    i. This dataset is a record of fish distribution and life history stage of summer steelhead salmon, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.

h. Fish_barriers

    i. Regional data from ODFW representing known barriers to fish passage. Clipped to the Grande Ronde. For metadata see http://rainbow.dfw.state.or.us/nrimp/information/fishbarrierdata.htm

i. Juv_release

    i. This point shapefile depicts locations where juvenile spring chinook salmon and steelhead were released into the mainstem and tributaries of the Grande Ronde River. The points located at anadromous fish hatcheries are the exact latitude and longitude release points while the other points were placed according to the data available. If the location was near a bridge or a bend in the stream then the locations' latitude and longitude were recorded. The shapefile was created by adding xy data and then exporting that event into a shapefile. Fields in the attribute tables were added to describe and to quantify the the points. The attributes associated with these points include hatchery source of the fish released, what stock they originated from, age at release (in terms of life stage), total number

released, marked and no-marked fish numbers, purpose of releasing fish and funding source.

j. ODFW_spawnindex
    i. Basic data created from the Report "Grande_Ronde_ODFW_spawning_report2004.pdf" located at I:\Depts\gis\project\MOA_Habitat_Monitoring\Grande Ronde\GIS working files\Spawning. Denise turned it into a shapefile and created some attribute fields. After comparing the locations, it became obvious that the report had incorrect information. This version has not been changed to correct locations. Each reach has a begin and end point. The beginning point of one reach may be in the same location as the end point of another index reach.
k. Rain_v09
    i. ODFW distribution layer for rainbow trout. Metadata can be found at http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm
l. Redds_2009
    i. Contains the GPS points identified by Casey Justice, Dale McCullough, and the CTUIR staff in GPS surveys after the ODFW/CTUIR/CRITFC redd counting crews flagged redds for the 2009 spawning season.
m. Redds_odfw_2004_2008
    i.
n. TRT_grandronde200ms
    i. This metadata imported from David Grave's previous REMAND version: "This data set was obtained from Damon Holzer (NOAA Upper Columbia TRT) in June of 2006. It shows distribution and habitat characteristics of Spring Chinoook in the Upper Grande Ronde Basin. Attribute definitions are not available but Dale McCullough may be familiar with many of the attributes. The WC_Factor is a derived value from the habitat characteristics and known distribution of Spring Chinook, which defines the Spring Chinook spawning quality of each stream segment as High (1), Medium (0.5), or Poor (0)." Any applications where spring chinook spawning habitat are important. A clipped version of this data set with only the upper watershed was used to define the path of the Upper Grande Ronde FLIR flight (to be conducted in 2010).

2. Bio_Invert
3. Bio_Other
4. Climate
5. DEM
6. Habitat_Flow
    a. Flow_station

i. This DRAFT spatial dataset includes point flow stations and descriptions based primarily on data from the US Geological Survey (USGS) and US Forest Service (USFS) for Oregon daily flow. Each point represents a location where data for daily flow were gathered, analyzed, and associated with a stream reach for purposes of modeling fish habitat. The flow stations represented here are locations where flow data were gathered, analyzed and presented to each Oregon subbasin team for their work with Mobrand Biometric's Ecosystem Diagnostic and Treatment (EDT; http://www.mobrand.com/MBI/edt.html) model during the 2002-2004 Oregon Subbasin Planning effort.

b. Gauges_gr_v2a

i. USGS stream gauge locations--developed by the Grande Ronde subbasin planning team (Austin Streetman, Spatial Dynamics?). This folder contains another shapefile called flow_stations.shp that should be compared to gauges_gr_v2a.shp since it contains corrected gauge locations obtained by TOAST from USGS.

7. Habitat_Other

a. Str_303d02

i. 303d listed waterchourses of Oregon in 2002, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\or\303d. Metadate can be found at http://www.sscgis.state.or.us/data/metadata/k100/streams303d_02.html

b. Str_303d98

i. 303d listed waterchourses of Oregon in 1998, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\or\303d. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k100/98303.pdf

8. Habitat_Sed

9. Habitat_Temp

a. Wq_station

i. This DRAFT spatial dataset includes point (continuous temperature and water quality grab sample) stations and descriptions based on data from the Oregon Department of Enviromental Quality (ODEQ) laser database or sent directly to us by ODEQ staff. Each point represents a location where data were gathered, analyzed, and associated with a stream reach for purposes of modeling fish habitat.

10. HabitatProjects

a. Bpa_projects_GrandeR

i. BPA habitat projects completed or ongoing at the time of Subbasin Planning 2002-2004. Metadata can be found at I:\Depts\gis\project\subbasin_planning\new_work\Grande Ronde\gis_data\metadata and file is called meta_bpa_projects.doc.

b. GRMW_project_pts

i. Assuming that Casey received this data from Grande Ronde Model Watershed from their sponsored projects.

11. HLR

12. Hydro_paek

a. Beaver_natpaek_pts

i. The Arc Hydro model was used to build a stream network. Several cell thresholds values were used for Stream Definition in an attempt to build a network that resemble a 24k scale stream layer in number of streams. For the 10 m DEM used a default of 13,000 produced a large number of streams. The value of 7000 produced a 24k scale number of streams most of which matched the locations of known streams. Known streams reference is the StreamNet mixed hydro layer. However to get a realistic stream length the high resolution NHD layer was used. So from the NHD layer streams were selected that matched the StreamNet layer. This new layer of known streams was used to compare and selected the modeled streams from ArcHydro. Parts of the NHD layer were sometimes used to substitute parts of the modeled layer in valleys were streams are channelized or forced into canals. Once the streams were selected from the modeled layer the feature was smoothed using the PAEK algorithm with a 30 m smoothing tolerance. A 30 m smoothing tolerance produced a stream with a similar length to the NHD length for the same stream. Using this smoothed modeled stream this point layer was created starting at the mouth and placing a point every 10 m. Built to estimate slope along the stream. Starting at the mouth of the stream a point was place every 10 m and then the elevation value from a USGS 10m DEM was extracted from the DEM and associated with each pt. Result is that the elevation of the stream is known every 10 meters.

b. Catherineatpaek_pts

c. Clear_natpaek_pts

d. Flynatpaek_pts

e. Ladd_nhd_natpaek_pts

f. Littlecathnatpaek_pts

g. Littlenatpaek_pts

h. Mccoy_natpaek_pts

i. meadow_natpaek_pts

j. milknhd_spchonly_pts
k. mill_nhd_natpaek_pts
l. nfcathnatpaek_pts
m. oldgr_natpaek_pts
n. pelican_natpaek_pts
o. pyles_natpaek_pts
p. rock_natpaek_pts
q. sfcathnatpaek_pts
r. sheep_natpaek_pts
s. spring_natpaek_pts
t. ugr_natpaek_pts
u. whiskey_natpaek_pts

13. Hydrography
    a. Cath_boundary
        i. This is the Catherine Cr boundary as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The HUC 6 boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
    b. Cath_boundary_Buf
        i. This is the Catherine Cr boundary buffered out 300m to capture 10m DEM cells on the other side of ridges. This was done to work with watershed models (TauDEM and Arc Hydro). The boundary is as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The HUC 6 boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
    c. Cath_HUC6
        i. These are the HUC 6 boundaries for Catherine Cr as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
    d. GR_boundary

i. This is the Grande Ronde boundary created from HUC 6 boundaries that were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.

e. GR_HUC6

i. These are the HUC 6 boundaries for Grande Ronde. The boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.

f. GR_mixed_hydro

i. CLIPPED for the GRANDE RONDE BASIN. This whole-stream routed hydrography layer serves as the base hydrography for the StreamNet project's Linear Referencing System (LRS). To distinguish this hydrography layer from the previous system(s), StreamNet refers to it as "MSHv1" (Mixed-scale hydrography, version 1). At version1: this dataset includes all routed streams present in the PNW River Reach Files (PNWRF3), StreamNet's previous base hydrography. In addition, those features within the state of Washington are now depicted at a higher resolution (1:24k scale) and densified to include all named streams present in Washington Department of Fish and Wildlife's 1:24k hydrography layer, and additional unnamed streams from that source where fish data exists and is compiled across the region. Future versions of this dataset will include similar improvements for StreamNet's other partner states (Oregon, Idaho, and Montana). In addition, the extent of StreamNet's regional hydrography has expanded to include integration with the 1:100k scale routed hydrography for California (CalHydro). While the StreamNet project does not manage fish data for California, the integration of California hydrography facilitates collaboration with StreamNet's partner project, "CalFISH". For more information about the CalFISH project, visit http://www.CalFISH.org. For more information about the source data contributing to this dataset, see the lineage section of this metadata record. The primary purpose of this dataset is to provide a route system ideal for storing, organizing, and displaying stream related fisheries and habitat data across the Pacific Northwest and California at the best practically available source scale. An on-going effort involves improving the resolution of the source datasets that makeup this regional layer. In addition to providing a regionally standard LRS, the MSHv1 can support many different types of GIS analysis including: buffering around reaches, stream network routing, and basin characteristics analysis.

g. Hydro100K
    i. 100k resolution streams and rivers clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k100/rivers.pdf
h. NHD_named
    i. The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD data was originally developed at 1:100,000-scale and exists at that scale for the whole country. This high-resolution NHD, generally developed at 1:24,000/1:12,000 scale, adds detail to the original 1:100,000-scale NHD. (Data for Alaska, Puerto Rico and the Virgin Islands was developed at high-resolution, not 1:100,000 scale.) Local resolution NHD is being developed where partners and data exist. The NHD contains reach codes for networked features, flow direction, names, and centerline representations for areal water bodies. Reaches are also defined on waterbodies and the approximate shorelines of the Great Lakes, the Atlantic and Pacific Oceans and the Gulf of Mexico. The NHD also incorporates the National Spatial Data Infrastructure framework criteria established by the Federal Geographic Data Committee. The NHD is a national framework for assigning reach addresses to water-related entities, such as industrial discharges, drinking water supplies, fish habitat areas, wild and scenic rivers. Reach addresses establish the locations of these entities relative to one another within the NHD surface water drainage network, much like addresses on streets. Once linked to the NHD by their reach addresses, the upstream/downstream relationships of these water-related entities--and any associated information about them--can be analyzed using software tools ranging from spreadsheets to geographic information systems (GIS). GIS can also be used to combine NHD-based network analysis with other data layers, such as soils, land use and population, to help understand and display their respective effects upon one another. Furthermore, because the NHD provides a nationally consistent framework for addressing and analysis, water-related information linked to reach addresses by one organization (national, state, local) can be shared with other organizations and easily integrated into many different types of applications to the benefit of all.
i. NHD_unnamed
j. WildScenicRiv_GrandeR

        i. Wild and Scenic rivers of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\region.

14. Landscape
    a. Contour200ft
        i. Created from a cont200_ne coverage at I:\Depts\gis\data\contour\or\, clipped to the Grande Ronde Basin. Does not include WA portion of the Grande Ronde Basin. Reprojected to the project's UTM projection. See the or_cont100_metadata.htm for info on the data.
15. LandUse
    a. Allstatehwy_GR
        i. State highways from the Western US, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    b. Allushwy_GR
        i. US highways in the Western US, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    c. BLM_Vale_GR
        i. This is a BLM roads layer from the Vale District. It has been clipped to the Grande Ronde watershed and reprojected to the project's UTM projection. Original data stored in CRITFC's GIS data sets. This roads layer seems to be the most complete set of data. A Transportation geodatabase was downloaded from USFS site of the Wallowa/Whitman NF, but the data was not as detailed as the BLM layer and only covers the NF. The one layer saved from this Transportation geodatabase was the Trails (NF Trails) which the BLM layer does not have.
    d. Dams
        i. Dam layer, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://rainbow.dfw.state.or.us/nrimp/information/damdata.htm
    e. Dynaroads_GR
        i. This data set displays road names and was clipped to the Grande Ronde and reprojected to the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    f. GR_Hwys_all
        i. This is a combination of several layers of roads and Hwys to show all Hwys (US and State) within the Grande Ronde Basin. This was created

mostly for mapping. The data was reprojected in to the project's UTM projection.

g. LandOwners
    i. Landowners of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data setsI:\Depts\gis\data\boundary
h. NF_Trail
    i. Trail Routes of the Wallowa Whitman National Forest and surronding areas
i. Quad24K_GrandeR
    i. USGS 24k Quad map boundaries, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k24/quadindex7_5.html
j. Towns_GrandeR
    i. Towns of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\base\region.

16. Monitoring Sites
    a. Coopmon
        i. Sent to us on July 22, 2009 from Coby Menton coby@grmw.org. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.
    b. CTUIR_ODFW_Temp_logger
        i. Sent to CRITFC on August 26, 2009 from Leslie Naylor, Assistant Fish Habitat Biologist, CTUIR Grande Ronde Fish Habitat Project, 1-541-215-2245, LesNaylor@ctuir.com. Original name of shapefile was CTUIR_ODFW_Temperature_Loggers2009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
    c. DEQambsites
        i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was DEQambsites.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
    d. GRBstreamgage

i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was GRBstreamgage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.

e. SA_CTUIR_ODFW_Temp_logger
   i. Sent to CRITFC on August 26, 2009 from Leslie Naylor, Assistant Fish Habitat Biologist, CTUIR Grande Ronde Fish Habitat Project, 1-541-215-2245, LesNaylor@ctuir.com. Original CTUIR_ODFW_Temperature_Loggers2009.shp has points located outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data was already in the correct projection.
f. SA_DEQambsites_pro
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is DEQambsites.shp and has points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
g. SA_GRBstreamgage_pro
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is GRBstreamgage.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
h. SA_UnionSWCDmon_pro
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is UnionSWCDmon.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
i. SA_WQ_LaGrandeRD_pro

i. Past and Present Water Quality Monitoring Stations of the Blue Mountains of North East Oregon and South East Washington. Shows spatial location of Monitoring stations. CRITFC received this dataset from Kayla Moringa on July 30, 2009. Fisheries Technician, La Grande Ranger District, Wallowa-Whitman National Forest, 541-962-8536, kmorinaga@fs.fed.us. Original shapefile was wqms_check_shapefile_07302009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites is within the CRITFC study area and has been reprojected to match Watershed Sciences projection.

j. SA_wwwatermonpoints_pro
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is wwwatermonpointclp.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
k. Streamflowgage
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was streamflowgage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.
l. Temperaturegage
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was temperaturegage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.
m. UnionSWCDmon
   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was UnionSWCDmon.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
n. WQ_sites_LaGrandeRD

i. Past and Present Water Quality Monitoring Stations of the Blue Mountains of North East Oregon and South East Washington. Shows spatial location of Monitoring stations. CRITFC received this dataset from Kayla Moringa on July 30, 2009. Fisheries Technician, La Grande Ranger District, Wallowa-Whitman National Forest, 541-962-8536, kmorinaga@fs.fed.us. Original name of shapefile was wqms_check_shapefile_07302009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites is outside of the CRITFC study area.

o. Wwwatermonpoints

   i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was wwwatermonpointclp.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.

17. Photos
18. RestProjects
19. SubPlan_Data

   a. Obstructions_edt

      i. This data set includes a spatial representation of obstructions to fish passage and descriptions that were modeled for Ecosystem Diagnosis and Treatment (EDT) for the 2002-2004 Subbasin Planning effort. The obstructions include both natural and manmade barriers, and may be either partial or full obstructions depending on life stage, time of year, and species. The GIS representation of these obstructions were developed by the local Subbasin Planning team along with the EDT Habitat reaches. In Oregon teams coordinated with the Technical Outreach and Assistance Team (CRITFC; sponsored by the Columbia River Inter-Tribal Fish Commission). The reaches were created to spatially define habitat units to be processed by Mobrand Biometrics' Ecosystem Diagnosis and Treatment (EDT; http://www.mobrand.com/MBI/edt.html) model as part of the Subbasin Planning effort mandated by the Northwest Power and Conservation Council (NPCC) in 2003. (http://www.nwcouncil.org/fw/subbasinplanning/Default.htm). Supplementary Information. This dataset is intended to be used by local Subbasin Planning team members as spatial reference for rated reaches and identified obstructions as has been required by the EDT model. Reaches that do not correspond with the available hydrography have been

digitized according to stream locations depicted on the 1:24,000 (24K) USGS DRG quadrangles.

b. Reach_edt
    i. This spatial dataset includes linear aquatic habitat reaches ("reaches") and descriptions primarily based on the available Oregon 1:100,000 scale routed hydrography for the specified subbasin (or partial subbasin). Each reach was defined as such because it has unique aquatic habitat characteristics which separate it from surrounding aquatic habitat, such as temperature, gradient, water quality, etc. The dataset also includes obstruction reaches, which may partially or fully impede focal species passage. The reaches were originally developed during the 2002-2004 Subbasin Planning effort to define habitat units to be attributed, rated, and processed by the Ecosystem Diagnosis and Treatment (EDT) model (see details below). Many of the EDT ratings and results attributes are available in a separate table (edt_reach_attributes.dbf) that can be appended to the reaches via the unique item, REACHNAME. It is strongly recommended that data users consult the Mobrand Biometric, Inc. EDT website (http://www.mobrand.com/MBI/edt.html) and the related Guidelines for Rating Selected Level 2 Environmental Attributes (http://www.mobrand.com/MBI/pdfs/AttributeRatings-June2004.pdf) to fully understand the EDT process and attribute definitions presented in this shapefile.

20. WatershedSciences
    a. MonSites
        i. Data from Watershed Sciences. Indicates where they believe Temperature monitoring should occur for temperature modeling with the FLIR flight data.
    b. TIR_Recommended
        i. Data from Watershed Sciences indicating where they recommend that FLIR flights should occur to cover Spring Chinook Spawning areas.

Appendix R

Quantifying Available Spawning Habitat

Quantifying Available Spawning Habitat

We will conduct field surveys to document the location and quantity of all available spawning habitat within our sample reaches in order to provide a sampling frame from which to randomly select spawning sites for collection of sediment samples. In addition, estimates of available spawning habitat can be used in our population modeling work to estimate carrying capacity for adult spring Chinook salmon and to track trends in spawning habitat over time.

Various methods are commonly applied to quantify spawning habitat in streams including Physical Habitat Simulation (PHABSIM), two-dimensional hydrodynamic modeling (i.e., 2-D modeling), and habitat criteria mapping. Perhaps most common is the PHABSIM model, a component of the Instream Flow Incremental Methodology (IFIM; Bovee 1998). PHABSIM estimates the area of "usable" stream habitat (i.e., weighted usable area) for fishes at different life stages and discharge levels by evaluating the area of overlap of between suitable habitat conditions and available habitat area. Suitable habitat is defined by habitat suitability curves for depth, velocity, or other physical habitat features (Bovee 1986). Habitat conditions are evaluated at selected cross sections within a stream reach and extrapolations are made between cross sections to estimate habitat conditions for the total reach. Unfortunately, PHABSIM has been shown to grossly overestimate salmon spawning habitat in some cases (Shirvell 1989).

Another commonly used method to estimate the area of available spawning habitat in streams is two-dimensional hydrodynamic modeling (Nelson 1996, Steffler and Blackburn 2002, Hardy et al. 2006, Bovee et al. 2008). Two-dimensional modeling utilizes 3-dimensional streambed topography along with information about flow rate and downstream stage (i.e., water surface elevation) boundary conditions to predict velocities, water surface elevations, and boundary shear stresses in the stream channel. Predicted depths and velocities as well as instream cover information are then used to predict the area of suitable habitat over a range of flows using habitat suitability criteria similar to PHABSIM. Because the entire 3-dimensional surface of the stream channel is known, it is not necessary to extrapolate between cross sections, often resulting in improved model performance. However, development of a 2-D hydrodynamic model for the entire upper Grande Ronde and Catherine Creek basins would be extremely time intensive and cost prohibitive. Additionally, 2-D modeling has been criticized for not providing accurate estimates of suitable habitat along channel margins, where course substrates and woody debris increasingly influence water velocity and sediment deposition (Stillwater Sciences 2006).

A more recent approach used to quantify usable fish habitat is known as habitat criteria mapping (Stillwater Sciences 2006, R2 Resource Consultants 2003, McBain and Trush 2003). In this method, habitat criteria for each fish species and life stage of interest are developed based on literature review, expert judgment, or site-specific habitat use studies. Habitat variables such as water depth, velocity, and substrate size are evaluated, and a range of criteria are defined for each variable which determine whether the habitat is suitable for use. Once habitat criteria are defined, high resolution aerial images of the stream channel are produced using low elevation aerial photography (LEAP) or other methods. Researchers then conduct stream surveys in which habitat areas that meet the criteria for suitable

habitat are delineated into polygons and drawn directly onto the aerial photographs. Total usable habitat area for each species and life stage is then calculated by digitizing the polygons in a geographical information system (GIS) and summing the area of the polygons within the study reach. This procedure can be replicated over a range of different discharge levels to calculate the effect of discharge on habitat quantity.

Schuett-Hames et al. (1999) described a variation of the habitat criteria mapping method for quantifying available spawning habitat for the Timber-Fish-Wildlife (TFW) monitoring program. Their approach, coined the "patch method", involves delineating habitat patches that meet pre-defined criteria for spawning, and measuring the area of each patch in the field (Figure 2). The key difference between the patch method and habitat criteria mapping is that patch locations and areas are defined and measured without the aid of aerial photographs of the stream channel or GIS tools. Owing to its relative simplicity of implementation, and lack of reliance on technology such as LEAP or 3-D models of streambed topology, the patch method is considerably less costly than the other methods described here. However, it requires diligent note taking and careful field measurements to accurately map and quantify available spawning habitat.

We propose a modified version of the TFW patch method to quantify available spawning habitat in the Upper Grande Ronde River and Catherine Creek basins. Specific methods for measurement of habitat characteristics and mapping of spawning patches are provided in Schuett-Hames et al. (1999). Modifications to the TFW protocol pertain primarily to differences in the criteria used to define suitable spawning habitat. Habitat criteria were based on an extensive literature review of the physical habitat conditions that characterize Chinook spawning habitat including water depth, velocity, dominant substrate size, and minimum redd area (Table 1). Our literature review focused on stream-type Chinook salmon such as spring- and summer-run Chinook, and excluded ocean-type fish which typically spawn in larger rivers with deeper habitat and coarser substrate. From the broad range of values for each habitat parameter documented in the literature, we developed habitat criteria that were generally very liberal (Table 2). Our intention was to select criteria that encompassed the high degree of variability in physical habitat characteristics observed in Pacific Northwest streams.

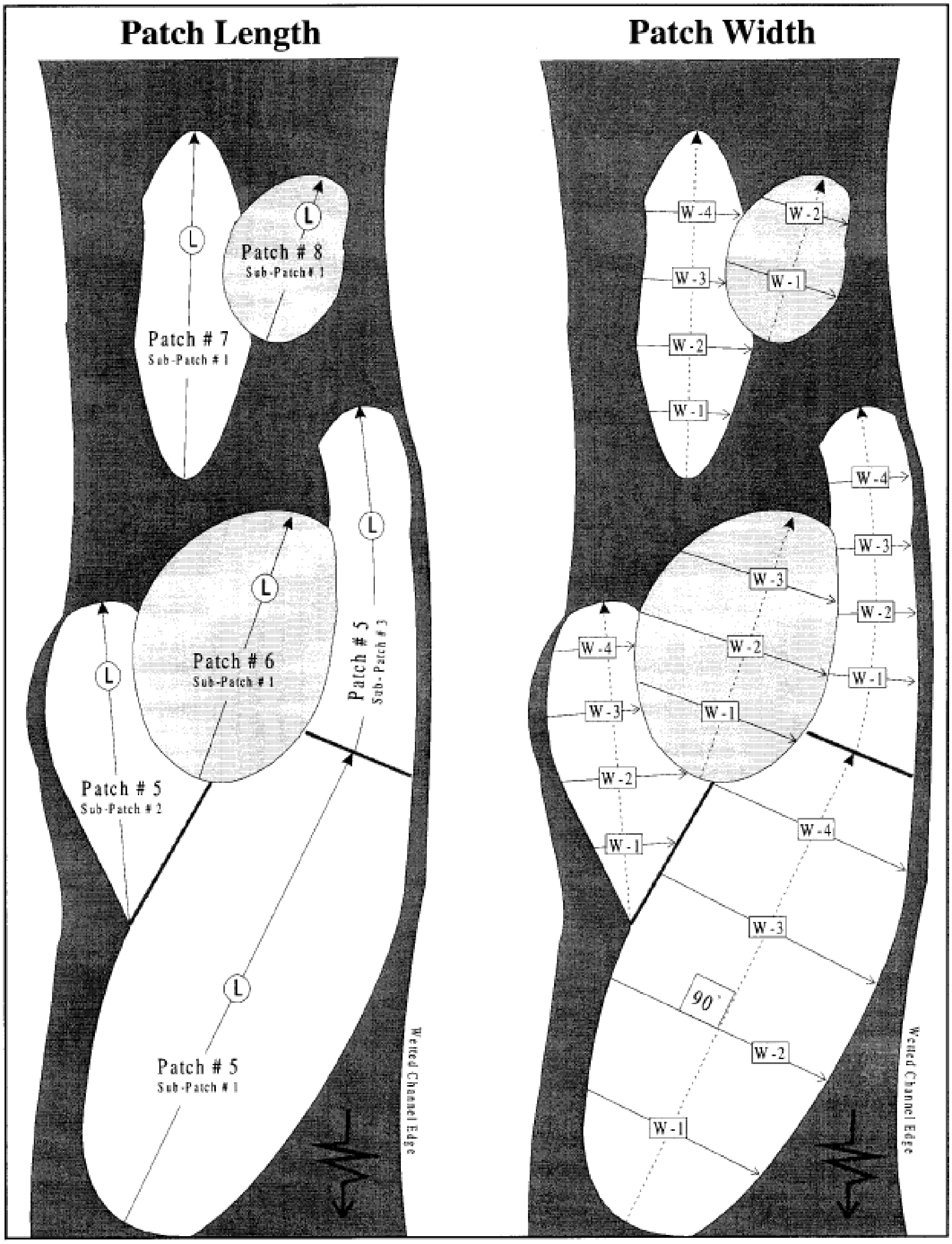


Figure 1. Example of spawning patch measurement techniques from Schuett-Hames et al. (1999).

Table 1. Physical characteristics of Chinook salmon spawning habitat summarized from the literature.

		Redd area (m²)			Substrate (mm)		Water velocity (m/s)		Water depth (m)		
Species	Location	Min	Max	Avg	Min	Max	Min	Max	Min	Max	Reference
Chinook salmon	Unspecified (lit review)	1.3			10[a]	50[a]	0.20	0.80	0.20	none	Stillwater Sciences (2006)
Chinook salmon	Coquille R., OR						0.31		0.24		Hamilton and Remington (1962) cited in Reiser and Bjornn (1979)
Chinook salmon	Unspecified				25.4[a]	76.2[a]	0.31	0.92	0.31	0.92	Flosi et al. (1998)
Chinook salmon	Various Streams (lit review)				10.8[a]	78[a]					Kondolf and Wolman (1993)
Chinook salmon	Unspecified				13	102					Bell (1986) cited in Bjornn and Reiser (1991)
Large Salmonids	Unspecified (lit review)	2.0			16[a]	128[a]	> 0	none	0.15	none	Schuett-Hames and Pleus (1996)
Sping Chinook	Unspecified			6.0							Reiser and White (1981) cited in Bjornn and Reiser (1991)
Spring Chinook	Ohanapecosh R. and Nason Cr., WA			3.2[b]			0.15	1.07	0.06[b]	0.69[b]	Burner (1951)
Spring Chinook	Columbia R. and tribs, WA						0.53	0.69	0.46	0.53	Unpublished data cited in Reiser and Bjornn (1979)
Spring Chinook	3 Willamette R. tribs, OR						0.08	0.85	0.18		Unpublished data cited in Reiser and Bjornn (1979)
Spring Chinook	Various Oregon streams						0.30	0.91	0.24		Thompson (1972) cited in Reiser and Bjornn (1979)
Spring Chinook	5 small Idaho streams						0.14	0.69	0.15		Unpublished data cited in Reiser and Bjornn (1979)
Spring Chinook	Various Oregon streams						0.22	0.64	0.18		Smith (1973)
Spring Chinook	Yakima River, WA						0.27	1.01	0.24	1.25	Bovee et al. (2008)
Summer Chinook	Entiat R., Wenatchee R., White R., WA			5.3[b]			0.31[b]	0.80[b]	0.13[b]	0.71[b]	Burner (1951)
Summer Chinook	Salmon R., ID						0.25	1.09	0.30	0.85	Unpublished data cited in Reiser and Bjornn (1979)
Summer Chinook	Unspecified						0.32	1.09	0.30		Reiser and White (1981) cited in Bjornn and Reiser (1991)
Stream type Chinook	Kamchatka R., Kamchatka	4	15				0.3	1.5	0.13	7.2	Vronskiy (1972) cited in Groot and Margolis (1991)
Stream type Chinook	Various Washington streams						0.52	0.68	0.45	0.52	Collings et al. (1972) cited in Groot and Margolis (1991)
Stream type Chinook	Unspecified						0.1	1	0.1	0.7	Bovee (1978) cited in Groot and Margolis (1991)
Stream type Chinook	Unspecified	0.5	27.5				0.15	1			Neilson and Banford (1983) cited in Groot and Margolis (1991)

[a]Refers to dominant substrate size (D_{50})

[b]Calculated as weighted average where weights were given by the number of redds measured per stream

Table 2. Habitat criteria used to define suitable spawning habitat.

Habitat Parameter	Criteria
Redd area	1.3 m^2
Dominant substrate size	11-90 mm
Water velocity	0.10 - 1.10 m/s
Water depth	0.15 - 1.0 m

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Appendix S

Draft Conceptual Framework and Methods for Stream Classification in the Grande Ronde River Basin

Conceptual framework and methods for stream classification in the Grande Ronde River basin

DRAFT REPORT

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March 31, 2010

Introduction

A robust stream classification is an integral component of this project as it provides a basis for comparing units for analysis, facilitates understanding of ecological processes that vary under different watershed conditions, and creates common ground for administering management activities and communicating findings. Stream classification has a long history of use in aquatic ecology (e.g., Frič 1872; Strahler 1952; Huet 1959; Warren 1979; Vannote *et al.* 1980; Frissell *et al.* 1986; Hawkins *et al.* 1993; Rosgen 1994; Montgomery & Buffington 1997). Classification systems are used, among other reasons, to identify sample units of similar zoogeographic and physio-chemical nature for comparison of site characteristics across broad regions (Stoddard 2004) and for guiding restoration efforts in geomorphically-similar river sections having the capacity to respond to treatments in a similar manner (Ebersole & Liss 1997).

In this project, a hierarchically-nested stream classification (*sensu* Frissell *et al.* 1986) will be used to guide site selection and analyses of key limiting factors of Chinook salmon at multiple life history stages (Figure 1). EMAP's rotating panel design using GRTS (Stevens 1997) also recommends the use of a stream classification system—Montgomery and Buffington's (1997) delineation of gradient and bed-form types—in order to stratify ecologically-comparable sites. Later as this project evolves, various classification systems can be overlaid on an initial, simple classification scheme to examine how model output changes under different classification scenarios. Because this project aims to describe the relative influence of anthropogenic factors (e.g., the cumulative effects of land use *vs.* restoration) on key limiting factors for Chinook salmon using a transparent and reproducible stream classification, findings could later be extrapolated to other basins with similar physio-chemical properties and anthropogenic impacts. This classification using intrinsic watershed characteristics will replace the land use classification previously reported in the project proposal, and will provide strata for estimating the amount of available habitat for Chinook salmon life history stages and eventually setting parameters for a life history model.

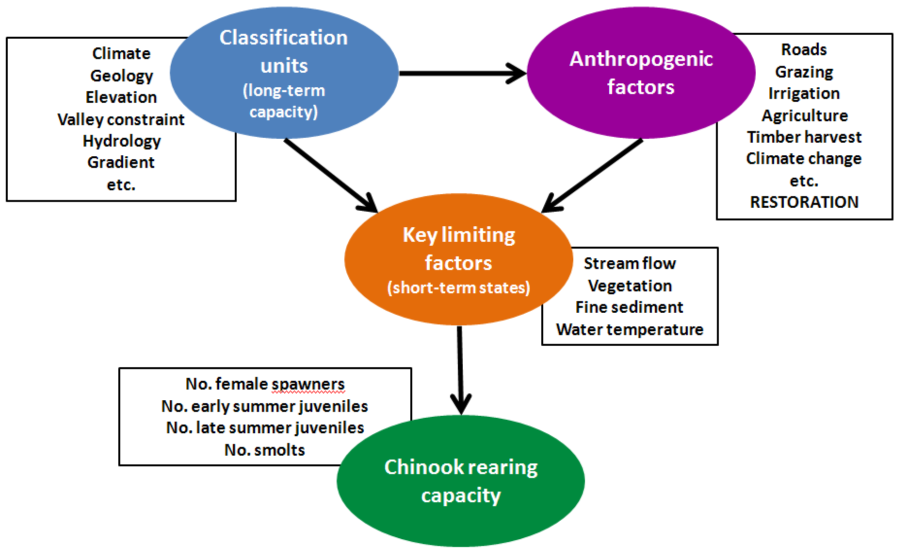

Figure 1. A conceptual framework for modeling spring Chinook rearing capacity. The classification units describing long-term capacity are meant to factor out natural variability from anthropogenic factors so that key limiting factors, which affect fish rearing capacity, can be adequately described.

Development of classification system

Steps towards classification include reviewing published literature on classification systems, deciding on a conceptual framework for classification, generating an accurate stream layer at the appropriate level of resolution, modeling and verifying watershed attributes, using those attributes to group stream reaches into classes (which will be used as strata for probabilistic distribution of sampling locations) and field verification of classification system. This section documents our methods and decision-making processes while developing a conceptual framework for stream classification.

Conceptual framework for classification

Our general approach was to create an *a priori* segment- and reach-scale classification composed of a minimal number of classes expected to explain variation in measured habitat metrics. We adopted the perspective introduced by Warren (1979) that the most useful type of classification system describes long-term capacities of watersheds, versus short-term states that either change relatively quickly due to natural processes—as in a classification based on channel planform and local morphology (Rosgen 1994)—or can be modified by land use practices. As an example of the latter, Rieman *et al.* (2000) classified Pacific Northwest watersheds based on distribution of forest and fish communities, a perspective that proved useful for describing consistent trends among terrestrial communities. However that classification did not provide consistently comparable units for analysis because sites could conceivably change classes if, for example, a fire burnt through extensive forest or if fish populations declined due to parasites.

Useful classifications also encompass broad spatial and temporal scales, integrate structural and functional characteristics under various disturbance regimes, convey information regarding mechanisms controlling instream features, and are created at low cost and high understanding (Naiman 1992). Furthermore, a hierarchical framework provides ecological understanding of watershed-stream relationships that interact at various spatial and temporal scales (Frissell *et al.* 1986). Therefore, our proposed classification system includes spatial scales ranging from landscapes to channel units and encompasses watershed characteristics that can be gathered throughout the entire Grande Ronde basin (and conceivably other basins) using low-cost, publically-available software and data.

Generation of hydrography layer

A preliminary step in attaining attributes for classifying streams was to generate a new, digital steam map (hydrography). Our rationale for creating a new hydrography was that currently available stream layers typically range in scales from 1:24,000 to 1:100,000, even within a given watershed, and therefore do not consistently represent network densities across large spatial extents (Clarke *et al.* 2008). Furthermore, existing stream networks vary in their accurate representation of river channel location as determined from simultaneous examination of aerial photographs and hydrography layers (Figure 2).

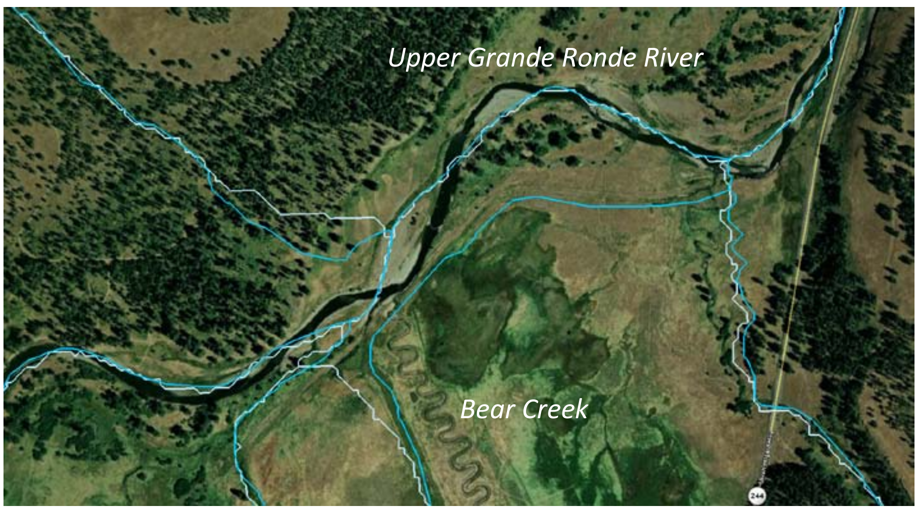

Figure 2. Two hydrographies for the Bear Creek confluence area of the upper Grande Ronde River, modeled from the USGS National Hydrography Dataset (NHD) (blue line) and from a 10-m digital elevation model using ESRI's ArcHydro tool (white line). From this figure the hypothetical nature of a stream network becomes apparent.

We wanted to begin this project with an accurate stream layer having consistent network densities across the entire study area. We used the program NetStream (Miller 2008) to generate a synthetic hydrography from a 10-m digital elevation model (DEM), which was later incorporated into a geographic information system (GIS) for visualization and analysis (Figure 3). We generated hydrography layers for the project core watersheds (upper Grande Ronde River and Catherine Creek) beginning at their confluence at the state ditch, and for two candidate reference streams (Wenaha and Minam Rivers). Because the existing USGS National Hydrography Dataset (NHD) stream network was verified using aerial photographs and expert opinion and therefore represented more accurately the lowest-gradient river valleys with extensive irrigation canals, we used the NHD layer as a mask to guide the newly-

modeled Catherine Creek from above the town of Union downstream to its confluence with the Grande Ronde River at the state ditch (Figure 3). In all other cases stream networks were generated from the 10-m DEMs alone.

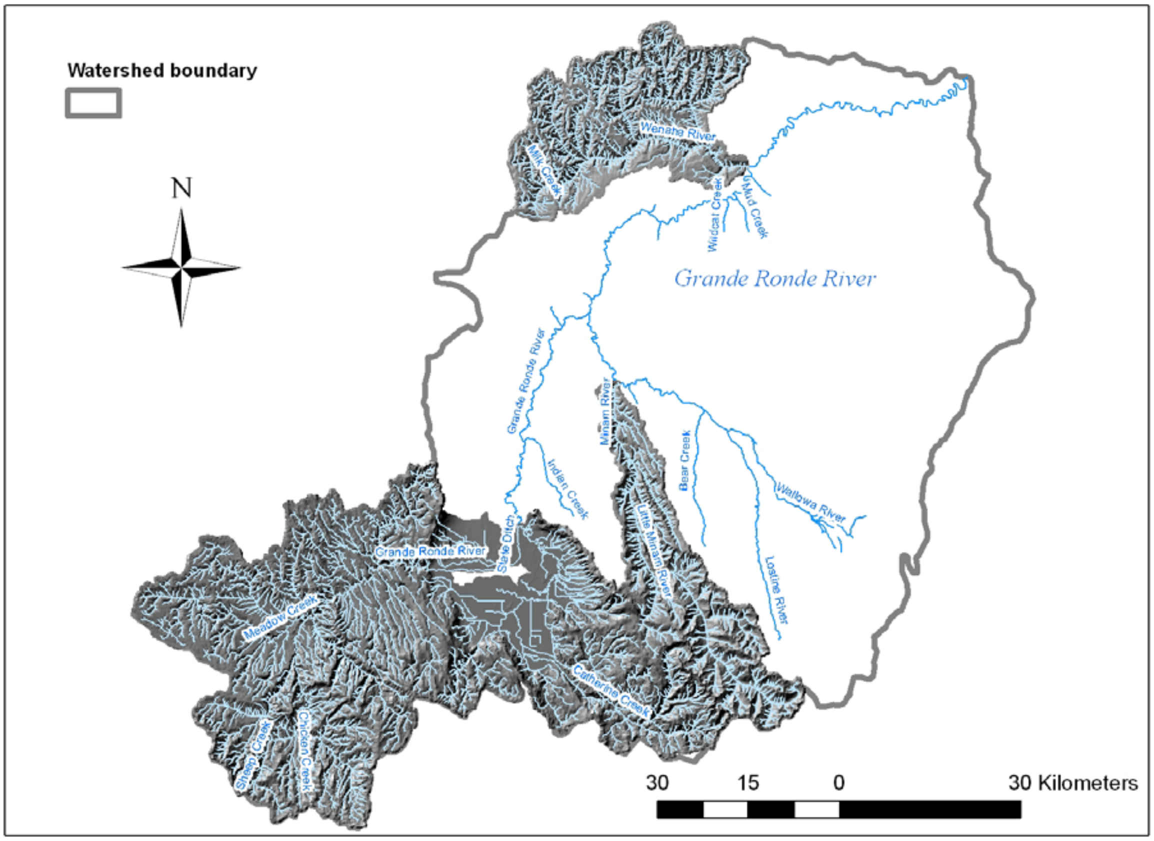

Figure 3. New hydrography layers for the upper Grande Ronde River, Catherine Creek, Minam and Wenaha Rivers derived from 10-m digital elevation model (DEM) using the NetStream software (Miller 2008).

Spatial hierarchy and extent of stream classification

Our proposed classification system encompasses the following spatial scales: landscape, segment, reach, and channel-unit (Table 1), similar but not identical to the hierarchical organization proposed by Frissell *et al.* (1986) and adopted by Cupp (1989). A new hierarchical organization and associated terminology was justified because we wanted to test various classification templates at the smallest scale (landscape) whose spatial extents and resolution did not correspond with one another. For example, we are interested in testing the relative explanatory power of Omernik level IV ecoregions versus watershed identity, and the combination of the two. Since ecoregions often span watersheds, defining a rigid spatial extent is meaningless. In a similar manner, the spatial scale of increasingly larger scales (Table 1) is modified from Frissell *et al.* (1986) to match the specific needs of our project.

We designed the spatial extent of our classification system to match the extent of expected use of spring Chinook salmon in the study watersheds. We used criteria adopted by the Interior Columbia River Recovery Team (ICTRT 2007) for spawning spring Chinook to limit stream extent: channel gradient greater than 20% for at least 200 m, wetted-channel width less than 3.6 m, and weekly maximum average temperature (WMAT) less than 22 degrees Celsius. We additionally limited the extent above natural barriers such as waterfalls identified in the StreamNet database (http://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishbarrierdata) and in the Grande Ronde Subbasin Plan (http://www.nwcouncil.org/fw/subbasinplanning/granderonde/plan/). Stream sections will not excluded if they were used by spring Chinook salmon at any life history stage by ODFW and StreamNet (http://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata), with the exception of lower river areas excluded by the MWAT limit.

Attributes for stream classification

Attributes for classifying streams at the segment scale (watershed area, stream order, elevation, mean annual precipitation depth) and reach scale (channel gradient and channel constraint) (Table 1) were derived using the same NetStream software as generating hydrography layers (Miller 2008) using the methods described by Clarke *et al.* (2008). Reach breaks will be additionally enforced at major tributary junctions, as tributary additions are known to have a major influence on the geomorphic characteristics of mainstems (Rice 1998; Benda *et al.* 2004). Although this phase of classification is in progress, preliminary hierarchical clustering analysis (Lance & Williams 1967; McCune & Grace 2002) suggests grouping of stream segments into two groups (large high-order and small low-order watersheds) and stream reaches into three groups (low-gradient valleys, low gradient canyons, and steep canyons), yielding a total of six *a priori* classification units.

After initial designation of reach-scale classification, several landscape-scale classifications will be tested in a *post hoc* fashion with the goal of further reducing variance in measured habitat metrics (*sensu* Dovciak & Perry 2002; Pyne *et al.* 2007). Candidate attributes for landscape-scale classification come from existing GIS maps of geology, ecoregions, hydrologic landscape regions, and watershed identity (Table 1). Currently unmapped landscape-scale attributes include hydrology and geographic distance between sites. We hypothesize that not any one landscape-scale classification will explain all measured metrics (e.g., distribution of fine sediments, large woody debris, stream temperature, macroinvertebrate index, fish production, and several others) with a high degree of precision, but that some classifications will explain a larger amount of variance in all the metrics on average. *Post hoc* landscape-scale classifications will be examined in context of the *a priori* segment and reach classification (e.g., Figure 4).

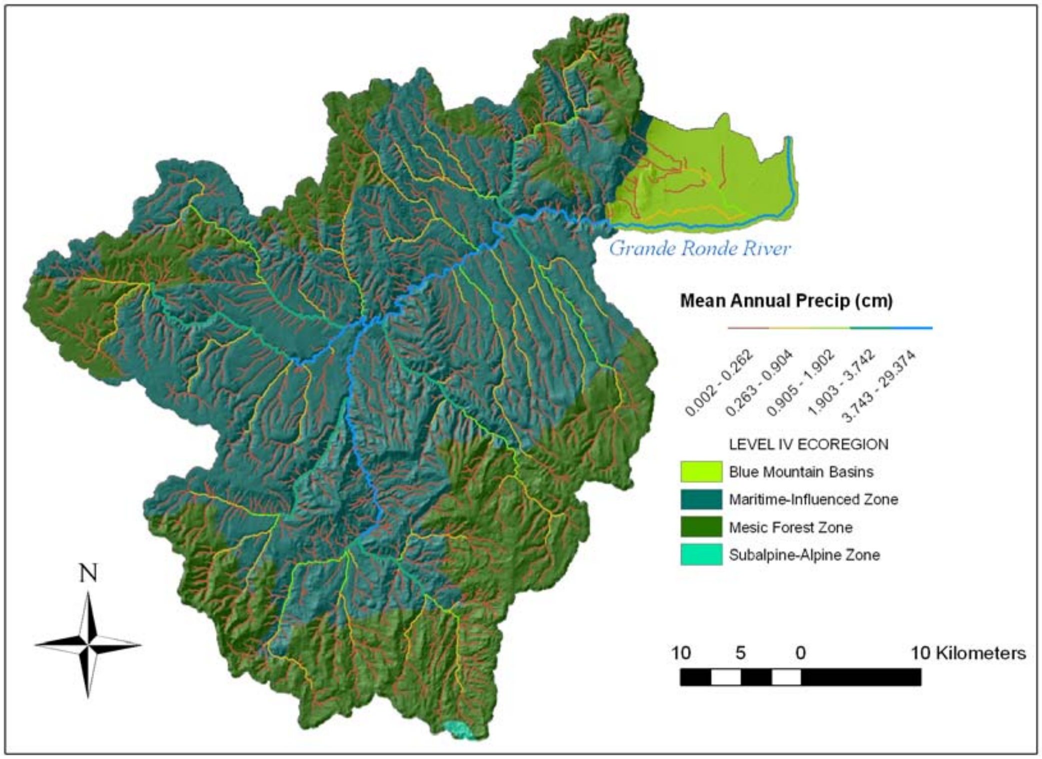

Figure 4. Upper Grande Ronde River hydrography layer generated from a 10-m DEM, with example attributes for use in river classification system. Mean annual precipitation depth (derived from PRISM data) of stream segments are shown with Omernik level IV ecoregions. See Table 1 for other stream classification attributes.

Because of the ephemeral nature of channel units (*sensu* Bisson *et al.* 1982; Hawkins et al. 1993), they will not be used in *a priori* classification. Rather, channel units will be measured in the field and their relative distribution within segment/reach-scale classification will be used to scale production estimates of spring Chinook salmon in the life history model.

Verification of classification system

We envision the three phases of verification of the classification as (1) preliminary testing of GIS-based attributes, (2) field verification of reach delineations, and (3) final testing and application of classification system:

1) *Preliminary testing of correspondence between segment and reach-scale attributes using only GIS-derived variables from the synthetic hydrography.* This phase of classification is meant to refine the mid-scale classification units so that they provide reasonable strata for apportioning sample effort (see Appendix K: Survey Design). This exercise will involve testing whether groupings from cluster analysis at the segment explain variance in attributes at the reach scale.

2) *Field verification of reach delineations.* Beechie & Sibley (1990) state that a useful classification should be recognizable from maps and/or to observers in the field. We expect that because of the necessary inaccuracy of modeling watershed conditions from digital data, even at the relatively high resolution of a 10m DEM, identification of errors in reach delineations will be required—for example, where changes in gradient indicated by GIS modeling do not correspond with actual locations. This will involve noting corrections to reach delineations to a map and recording correct coordinates of reach breaks using a GPS.
3) *Final testing and verification.* This phase is determined by how well variance in the response variables of interest are explained by the classification system (Beechie & Sibley 1990; Hubert & Young 1996; Dovciak & Perry 2002; Pyne *et al.* 2007). In our case measured response variables include the distribution of channel units within classification strata and measures of key limiting habitat factors for spring Chinook salmon.

A final word on our philosophy of classification systems: as classification systems are often based on poorly-understood notions of how the natural world works (Goodwin 1999), they are best perceived hypotheses rather than representations of an ultimate reality. Therefore, we regard our proposed classification as a question (rather than an answer) that can be tested against empirical data, and modified for future applications. The ultimate goal of our classification system is to help describe the variability in life history parameters for spring Chinook salmon by accounting for intrinsic watershed factors and anthropogenic change (Figure 1). The degree to which our classification meets that goal is the ultimate test of its validity.

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Table 1. Variables for landscape, segment, reach, and channel-unit classification.

Classification phase	Spatial scale	Variables	Explanation	Selected references
Domains	Landscape	Geology	Erodible versus resistant parent material	Walker 1990; Richards *et al.* 1997; Montgomery 1999; DOGAMI 2009
		Ecoregion (Omernik level IV-V)	Expert opinion classification incorporating climate, geology, soils, potential vegetation, and geomorphology relevant to aquatic habitat	Bryce & Clarke 1996; Clarke & Bryce 1997; Stoddard 2004
		Hydrologic landscape region	Incorporating climate, runoff seasonality, aquifer permeability, soil permeability, and topography	Wigington, Leibowitz, Comeleo & Ebersole, unpublished map
		Hydrology	Dimensionless ratios describing characteristic low, average, or bankfull flows of watersheds	Orsborn 1990
		Watershed identity	Including upper Grande Ronde, Catherine Creek, and a reference watershed (Minam or Wenaha River)	Omernik & Bailey 1997
		Geographic distance between sites	Used as a null model to compare against all other candidate domains	Pyne *et al.* 2007
Strata	Segment	Watershed area	Drainage area upstream	Warren 1979; McCullough 1987
		Stream order	Definition of stream size based on tributary hierarchy	Strahler 1957
		Elevation	Downstream elevation of a reach scaled to downstream-most elevation of each watershed	Huet 1959; Grenouillet *et al.* 2004
		Precipitation depth	Mean annual precipitation depth of upstream watershed area, derived from PRISM climate data	Daly *et al.* 2002; Paulsen & Fisher 2005; Golian *et al.* 2010
	Reach	Channel gradient	Mean gradient (% slope) from upstream to downstream stream reach	Frissell *et al.* 1986; Cupp 1989; Rosgen 1994; Lunetta *et al.* 1997; Montgomery & Buffington 1997; Burnett *et al.* 2007
		Channel constraint	Ratio of the width of the active channel to the width of the valley floor, averaged by reach	Frissell *et al.* 1986; Cupp 1989; Burnett *et al.* 2007
Field testing	Channel unit	Pools, riffles, glides, etc.	Identified in field and used to scale Chinook salmon spawning and rearing estimates	Bisson 1982; Hawkins *et al.* 1993; Bisson *et al.* 2006

Appendix T

Selectivity of Spawning Spring Chinook Salmon, Representativeness of Survey Reaches, and Land Use Disparity in The Upper Grande Ronde River and Catherine Creek

Selectivity of spawning spring Chinook salmon, representativeness of survey reaches, and land use disparity in the upper Grande Ronde River and Catherine Creek

DRAFT REPORT

Seth White, Casey Justice, and Dale McCullough

March 30, 2010

Introduction

The Interior Columbia Technical Recovery Team (ICTRT), using model predictions based on spawning habitat relationships in various Pacific Northwest watersheds, identified areas of intrinsic spawning potential for Spring Chinook salmon throughout several interior Columbia River basins, including the primary areas of interest for this project: the upper Grande Ronde River and Catherine Creek (Figs. 1-2). To our knowledge, the ICTRT classification of intrinsic spawning habitat potential has not been ground-truthed using field data. The present analysis aims to fill that gap by evaluating whether spring Chinook spawning site selection, as determined from Oregon Department of Fish & Wildlife (ODFW) spawning surveys, occurs in higher or lower than expected frequencies in designated intrinsic potential classes. Additionally, our observations in the field while conducting spawning surveys indicated that while ODFW spawning index reaches seemed to be in less than optimal spawning habitat, private land ownership seemed to be in the best available spawning habitat. We evaluated each of these questions using habitat selectivity analysis, which compares the amount of resource selected while taking into account its availability.

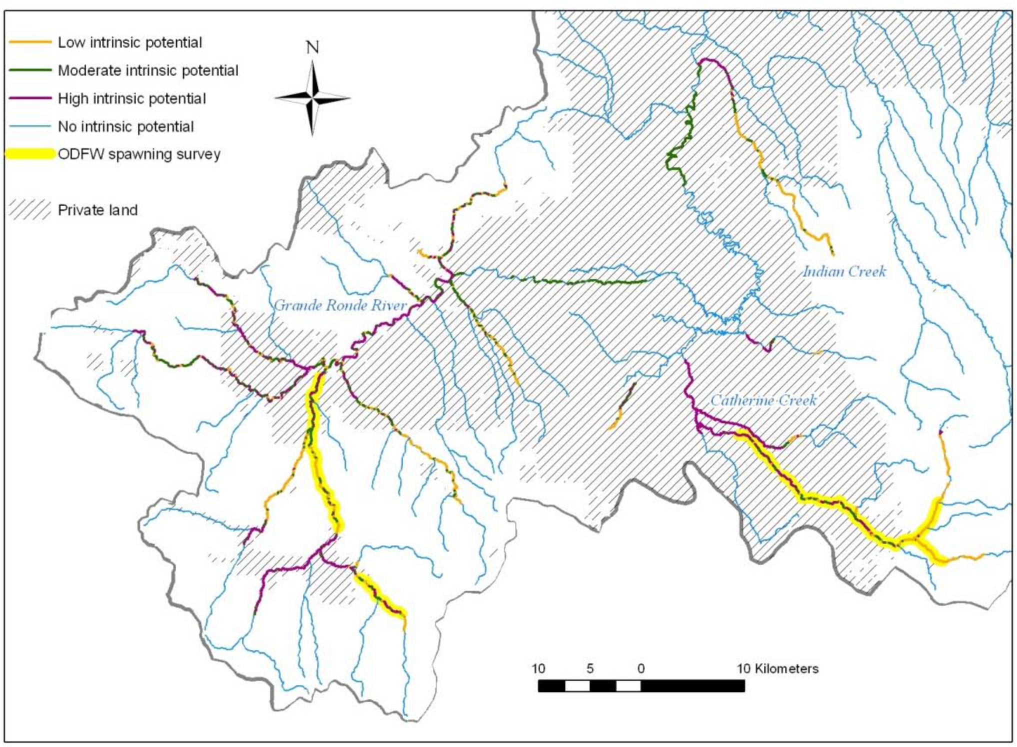

Figure 1. Intrinsic potential of spring Chinook spawning habitat, ODFW spawning index reaches, and private land ownership in the upper Grande Ronde basin above Indian Creek.

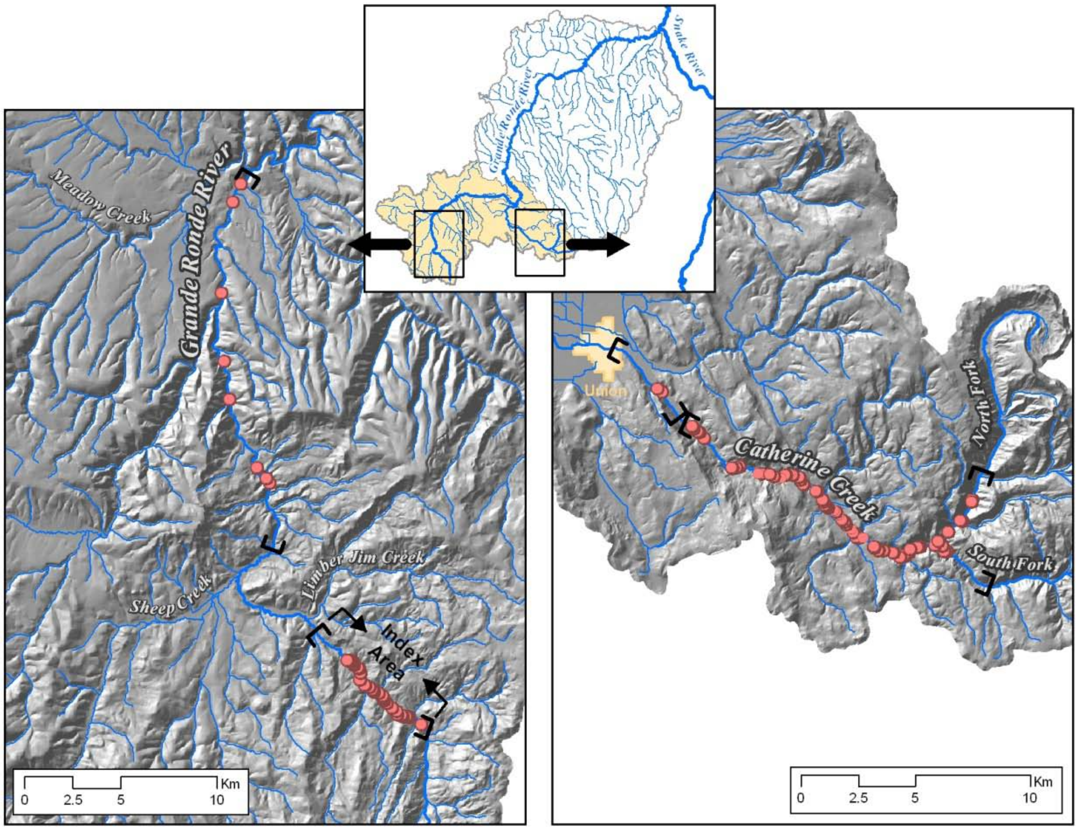

Figure 2. Locations of individual spring Chinook spawning redds (circles) in the upper Grande Ronde River (left) and Catherine Creek (right), 2009. Upstream and downstream extents of ODFW spawning index reaches are enclosed in brackets.

Spring Chinook spawning habitat selection

In late August of 2009, individual spring Chinook salmon redds in the upper Grande Ronde River and Catherine Creek were located using standard ODFW spawning survey protocols and georeferenced using a hand-held GPS. A map of spawning redds, ICTRT-designated intrinsic potential (IP) reaches, and start and end points of ODFW spawning index surveys was created in a geographic information system (GIS) (Figs. 1-2). Potential spawning reaches, each approximately 200 m in length, were rated into IP classes (none, low, moderate, or high) by ICTRT based on literature-derived relationships between spawning and juvenile rearing densities and stream width, valley width, valley constraint, and channel gradient. Other limits to spawning distribution included areas with high weekly maximum average temperatures (WMAT > 22°C) and areas above natural barriers to anadromous salmonids; these details are explained further in ICTRT (2007). The WMAT limits imposed on intrinsic potential represent a combination of natural thermal potential and the effects of anthropogenic impacts. To assess whether the individual redds occurred more or less frequently than expected in intrinsic potential classes, we conducted type I habitat selectivity analysis (after Manly 2003). Selection ratios (*W*) were calculated as:

$W_i = u_i/a_i$

where the proportion of observed use of a resource (*u*) is compared to its relative availability (*a*) for habitat *i*. The number of redds occurring in each IP class (u_i) was compared to the relative proportions

of each IP class (a_i) occurring within the boundaries of ODFW spawning index reaches. While we did not account for the possibility that multiple redds at individual sites could have been created by single spawning females—thereby potentially overestimating spawning site selection—we considered our designation of individual redds as independent samples a useful measure of spawning intensity because higher local redd abundance indicates more intense habitat selection by spawners. For the 139 redds located in 2009, spawning site selectivity for IP classes was highly significant ($p < 0.005$). This relationship was driven by the strong and highly significant ($p < 0.001$) avoidance of spawning in low IP reaches. Despite the lack of a significant relationship, we also noted a non-significant ($p = 0.058$) trend of selection by spawners of high IP reaches (Table 1, Fig. 3).

Table 1. Ratios of resource use (W_i or Manly selectivity measure) of spawning redd occurrence versus availability of reaches in intrinsic potential (IP) classes within ODFW spawning index reaches. Lower than expected ratios ($W_i < 1$) indicated avoidance of a resource, while higher than expected ratios ($W_i > 1$) indicated a preference. Significance of p-values (*) should be compared with Bonferroni level = 0.017.

IP Class	Prop. used	Prop. avail	W_i (SE)	P-value
Low	0.216	0.34	0.635 (0.103)	< 0.001*
Moderate	0.396	0.35	1.131 (0.119)	0.271
High	0.388	0.31	1.253 (0.253)	0.058

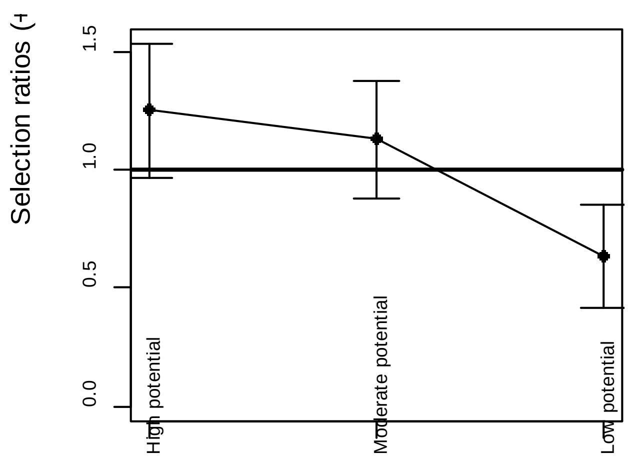

Figure 3. Manly selectivity measure (W_i) of redd site selection of IP classes in ODFW spawning index reaches. Error bars are 95% confidence intervals with Bonferroni adjustment.

Representativeness of ODFW spawning index reaches

To evaluate whether ODFW spawning index reaches were representative of the potential habitat available for spawning (regardless of land ownership or anthropogenic migration barriers), we

conducted an identical habitat selection analysis using all IP classes equal to or greater than those designated as “low” in the upper portions of the Grande Ronde River and Catherine Creek. We included Indian Creek and all areas upstream within the area of potential spawning in this analysis because the spring Chinook subpopulation there is considered part of the larger Catherine Creek population (ICTRT 2003). We evaluated the number of reaches occurring in each IP class (u_i) as a ratio of the relative proportions of each class within the ODFW index reaches (a_i). A sum of 271 reaches totaling approximating 54 river kms of available spawning habitat were included in ODFW spawning index reaches, as compared to 1,587 reaches approximating 318 river kms of available spawning habitat in the landscape. The ODFW spawning index reaches comprised 17% of available spawning habitat. Selection of IP classes by ODFW spawning index reaches was significant (p = 0.03), with the relationship driven by the significant (p = 0.013) avoidance of ODFW surveys in high IP reaches and the non-significant (p = 0.049) trend of selection of low IP reaches (Table 2, Fig. 4) (significance of p-values should be compared with Bonferroni level = 0.017).

Table 2. Ratios of resource use (W_i) of ODFW spawning index surveys versus availability of reaches in intrinsic potential (IP) classes throughout the upper Grande Ronde River basin. Lower than expected ratios ($W_i < 1$) indicated avoidance of a resource, while higher than expected ration ($W_i > 1$) indicated a preference. Significance of p-values (*) should be compared with Bonferroni level = 0.017.

IP Class	Prop. used	Prop. avail	W_i (SE)	P-value
Low	0.339	0.283	1.20 (0.102)	0.049
Moderate	0.347	0.333	1.041 (0.087)	0.640
High	0.314	0.384	0.817 (0.073)	0.013*

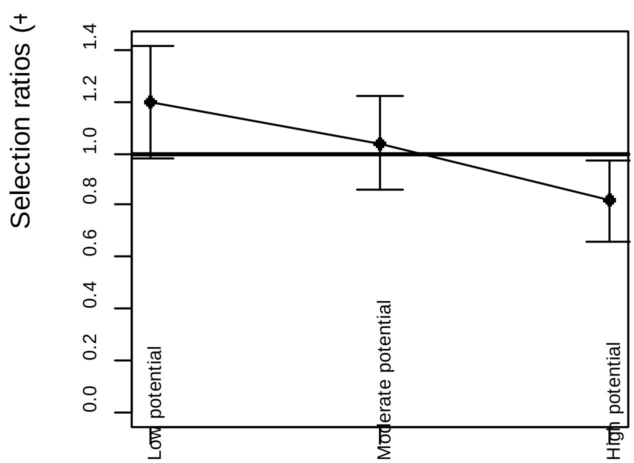

Figure 4. Manly selectivity measure (W_i) of ODFW spawning index survey selection in IP classes available in the upper Grande Ronde basin. Error bars are 95% confidence intervals with Bonferroni adjustment.

Representativeness of private land ownership

To evaluate whether private land ownership was representative of the potential habitat available for spawning, we used habitat selection analysis in an identical fashion to evaluate the number of reaches in each IP class (u_i) as compared to its relative availability within private land ownership (a_i). Maps of land ownership were provided by the Interior Columbia Basin Ecosystem Management Project (ICBEMP). A total of 1,029 reaches approximating 206 river kms of available spawning habitat were included in private land, comprising 65% of available spawning habitat. Representation in higher IP classes in private land ownership was highly significant ($p < 0.0001$); with the relationship driven by the highly-significant ($p < 0.01$) and very strong avoidance of low IP reaches, the trend of non-significant ($p = 0.02$) avoidance of moderate IP reaches, and the highly-significant ($p < 0.01$) selection of high IP reaches (Table 3, Fig. 5).

Table 3. Ratios of resource use (W_i) of private land versus availability of reaches in intrinsic potential (IP) classes throughout the upper Grande Ronde River basin. Lower than expected ratios ($W_i < 1$) indicated avoidance of a resource, while higher than expected ratios ($W_i > 1$) indicated a preference. Significance of p-values (*) should be compared with Bonferroni level = 0.017.

IP Class	Prop. used	Prop. avail	W_i (SE)	P-value
Low	0.158	0.283	0.560 (0.040)	< 0.01*
Moderate	0.368	0.333	1.105 (0.045)	0.02
High	0.473	0.384	1.233 (0.041)	< 0.01*

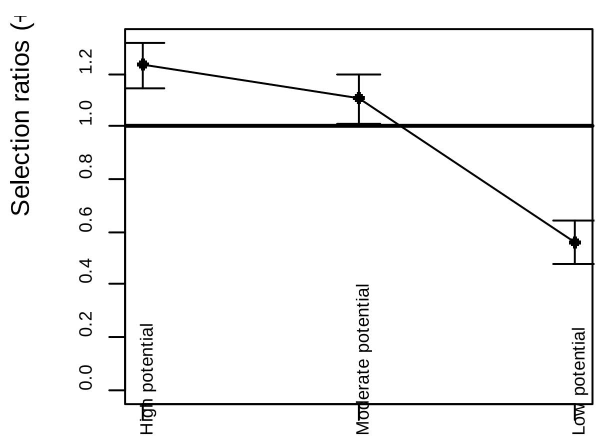

Figure 5. Manly selectivity measure (W_i) of habitat selection by private land ownership in IP classes available in the upper Grande Ronde basin. Error bars are 95% confidence intervals with Bonferroni adjustment.

Conclusions

Spawning site selection by spring Chinook salmon tended to favor reaches identified by ICTRT as high IP, while significantly avoiding reaches of low IP (Fig. 3). This finding, though based on a single year of spawning data from two sub-watersheds, lends credence to ICTRT's designation of intrinsic spawning potential. However, we also found that ODFW spawning index reaches do not adequately represent the distribution of intrinsic spawning potential for spring Chinook in the upper Grande Ronde basin, though that does not imply ODFW surveys do not encapsulate the best available current spawning habitat. The ODFW spawning surveys tend to over-represent reaches with low IP while significantly under-representing high IP reaches (Fig. 4). In a restoration monitoring context, extrapolations of basin-wide spawning densities from ODFW index reaches would therefore tend to under-represent the intrinsic potential for spring Chinook spawning, thus underestimating the degree of possible recovery of spawning. Finally, we found that private land ownership enjoyed the lion's share of high quality spawning habitat (Fig. 5), with strong selection for high IP reaches, a trend towards selection of moderate IP reaches, and strong avoidance of low IP reaches. With private land ownership occupying 65% of potential Chinook spawning habitat, these findings are not trivial. Access to private land for research and monitoring purposes is time consuming but well worth the effort. Furthermore, activities of landowners such as poor riparian management practices or conversely, conservation measures to improve fish habitat, have a higher potential to impact spring Chinook populations than do activities on public lands.

Acknowledgments

Denise Kelsey provided invaluable GIS support.

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Appendix U

Habitat Project Data Management/Goals

Habitat Project Data Management/Goals

Tribal Data Network (TDN)

The required data management chapter of the Habitat Project is described herein. This description includes the following:

1. Proposed roles of the core group of individuals assisting with the management of data gathered by CRITFC.
2. Current managed data and tools.
3. Goals for future data management.

Funding for the TDN is provided primarily by the Memorandum of Agreement (MOA) signed by three of the four CRITFC-member tribes and CRITFC. The MOA provides certain data requirements and guidelines. The TDN provides tools, assistance, and best practices protocols for data collected by CRITFC-staff, CRITFC-member tribes, and other agencies to comply with these data requirements and guidelines. A subset of this collected data will be used to fulfill the Habitat Project's management goals.

Proposed Roles of Core Group

At the present time, the TDN's core group consists mainly of computer programmers, GIS Specialists, and technical staff. Henry Franzoni is the TDN's Principal Investigator responsible for the design, implementation, data dissemination, configuration, security, maintenance, license agreements, and hardware/software distribution, web service agreements, and data reporting. The following paragraphs present an introduction to the data management protocols for the Habitat Project.

Metadata

The TDN will not only store data, but store metadata and data dictionaries, which can be utilized to guide the interpretation of comprehensive data collections. Currently, Henry Franzoni is meeting with the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) to assist with the development of a metadata guidance document, and a regional data management road map. At this time, CRITFC will utilize the FGDC Metadata Standard and develop tools for reporting this metadata. The FGDC Metadata Standard is the Content Standard for Digital Geospatial Metadata (CSDGM) Version 2 (FGDC-STD-001-1998) standard for all U.S. Federal agencies, as per Executive Order 12096 (Rentmeester et al. 2010). Data management for habitat data will include elements in the Pacific Coast Salmon Recovery Fund (PCSRF) metrics: fish data will address the VSP (viable salmonid population parameters) as requested by National Oceanic Atmospheric Administration (NOAA) in the Draft-Guidance for Monitoring and Recovery of Pacific Northwest Salmon and Steelhead (Crawford and Rumsey 2010).

Data Infrastructure

The TDN data infrastructure system is a distributed model. One server will serve as the main controller accepting many operations from clients. Security will be maintained with logins and passwords. Data will be initially housed in SQL Server 2008 and periodically backed up to other servers and backup media. These media and servers will be deployed in a secured facility. Quality Assurance and Quality Control procedures are in place and will be added to the metadata. User processes will involve the development of software applications using programming languages such as PHP, ASP, JSP, C#, VB, Transact SQL, HTML, Apache, and Python. Several examples of user processes are listed below:

1. Automatic download and validation of data sets.
2. Automation of QA/QC protocols.
3. Analysis of data.
4. Development of metadata and data dictionaries.
5. Administration of logins and passwords to maintain reliability of data.

Current Managed Data and Tools

For this Habitat Project, temperature and flow data sets have been validated and summarized for over 100 USGS and Forest Service gauges. Some of the gauges included 20+ years of collected data.

Additionally, several tools for monitoring and evaluation of fish populations have already been developed by the TDN and are currently being utilized by CRITFC-staff and member tribes. A list of a portion of these tools is shown below:

1. Lamprey population estimator pilot for Confederated Tribes of the Warm Springs (CTWS).
2. Lamprey data collection pilot software for Yakama Nation / Klickitat River
3. Smolt monitoring data collection, storage, and dissemination software used at Imnaha Fish Trap.
4. FPC32.Net Smolt monitoring data collection software for Grand Ronde, Snake, Salmon River, Clearwater fish traps, as well as mainstem dams. (Endangered Species Act (ESA) handling issues, minimization of stress issues).
5. Regional data management support for Hood River Basin CTWS.
6. Written data sharing agreements.

These tools and more are consistently being updated, shared, and developed with advances in technology.

Goals for TDN

At this stage in data infrastructure development the goals for the TDN are summarized below:

1. To assist with the attainment of the Habitat Project's management goals to timely and consistently report data collected.
2. To use the data gathered from the Habitat Project to inform and guide CRITFC's member tribes in the useful collection of key habitat monitoring parameters to assist in fish management.
3. To develop more tools and analyze existing tools for rapid input and management of collected data and share these useful tools with CRITFC- staff and member tribes.
4. Assist in training of CRITFC-staff and member tribes in implementation of data management tools.

Additionally, LIDAR data will be used to compare the accuracy of the data collected. The 96 GB data set will be stored and accessed through a remote connection. FLIR data will also be added to the server after data collection.

Data can be provided in various standard formats for harvesting by portals, catalogs and search engines dependent on what the goals are for CRITFC-member tribes. The TDN and CRITFC-member tribes have experimented with numerous methods for analyzing, gathering, and reporting data and CRITFC will ensure the most useful and secure tools are being utilized.

These goals will be modified and added to as the project progresses.

Citations

Crawford, B., and Rumsey, S. 2010. Draft. Regional Guidance for Monitoring and Recovery of Pacific Northwest Salmon and Steelhead. Salmon Recovery Division.: US Dept. of Commerce NOAA's National Marine Fisheries Service- Northwest Region, 2010.

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