Columbia Habitat Monitoring Program: 2013—Third Year Lessons Learned Project Synthesis Report

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Prepared by:

CHaMP | Columbia Habitat Monitoring Program

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LIST OF ACRONYMS

AEM	Action Effectiveness Monitoring
BiOp	Biological Opinion [FCRPS]
BPA	Bonneville Power Administration
CHaMP	Columbia Habitat Monitoring Program
CRB	Columbia River Basin
CRITFC	Columbia Inter-Tribal Fish Commission
CWA	Clean Water Act
DEM	Digital Elevation Model
DoD	DEM of Difference
DPS	Distinct Population Segment
EDT	Ecosystem Diagnosis and Treatment
EMAP	Environmental Monitoring and Assessment Program
EPA	US Environmental Protection Agency
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
GCD	Geomorphic Change Detection
GUT	Geomorphic Unit Tools
GIS	Geographic Information System
GRTS	Generalized Random-Tessellation Stratified
ICRB	Interior Columbia River Basin
IMW	Intensively Monitored Watershed
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISRP	Independent Science Review Panel
PIBO	Pacfish/Infish Biological Opinion
NOAA	National Oceanic and Atmospheric Administration
NWFSC	Northwest Fisheries Science Center
NPCC	Northwest Power and Conservation Council
NREI	Net Rate of Energy Intake
ODFW	Oregon Department of Fish and Wildlife
PIBO	PACFISH/INFISH Biological Opinion
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
QA	Quality Assurance
QC	Quality Control
RBT	River Bathymetry Toolkit
USBR	US Bureau of Reclamation
USGS	US Geologic Society
UTM	Universal Transverse Mercator
VSP	Viable Salmonid Population

EXECUTIVE SUMMARY

Background

The Columbia Habitat Monitoring Program (CHaMP; BPA Project No. 2011-006-00) is designed to collect information on tributary habitat attributes that can be used to predict the freshwater productivity of anadromous salmonids reliably. The Integrated Status and Effectiveness Monitoring Program (ISEMP; BPA Project No. 2009-f) began development of the CHaMP pilot in 2010 and it was implemented in 2011. The CHaMP sampling design calls for nine-years of data collection, in watersheds that represent a range of environmental conditions in the Columbia River Basin (CRB) to produce traditional and novel habitat metrics. that can be "rolled-up", that is, used to describe fish-habitat relationships relevant to three key management questions (KMQs) posed by BPA:

- **KMQ 1:** What are the tributary habitat limiting factors or threats preventing the achievement of desired tributary habitat performance objectives?
- **KMQ 2:** What are the relationships between tributary habitat actions and fish survival or productivity improvements, and what actions are potentially most effective? Which actions are most cost-effective to address habitat impairments?
- **KMQ 3:** Are tributary actions achieving the expected biological and environmental improvements in habitat [and improving survival of specific fish life-stages through species growth or habitat capacity]?

In 2013 CHaMP completed the first of the first three-year cycle of its nine-year rotating panel design. This is an important milestone because three years of data supports the first robust estimate of habitat status and enables an in-depth evaluation of the reliability of CHaMP metrics. Our ability to detect short-term temporal patterns is encouraging and suggests that CHaMP metrics are both informative and precise. CHaMP's capability to detect trend will improve substantially after the next three-year sampling panel is completed in 2016, per the study design.

The CHaMP protocol capitalizes on numerous preexisting survey efforts, resulting in substantial compatibility of metrics across regional and national habitat survey initiatives. It is also designed to incorporate emerging remote sensing techniques such as Light Detection and Ranging (LiDAR) and aerial photography, enabling swift data acquisition at relatively large spatial scales. These features allow the development of fish/habitat relationships at multiple spatial scales, provide the basis for detailed restoration design, support evaluations of habitat restoration, and place changes into the context of natural processes that constantly alter in-stream habitat.

CHaMP's standardized metrics and documentation of physical changes from habitat restoration can ultimately be used to predict fish response. Beginning with the 2015 report, the relationship between habitat restoration actions and changes in the freshwater productivity of salmon and steelhead will be projected and reported using empirical models such as ODFW's HabRate model and ISEMP mechanistic bioenergetics model, NREI.

While CHaMP data is key to supporting these models, ultimately an important use of CHaMP data is to understand high-level (watershed, ESU, and Basin-wide) habitat status and trends that can be used for management decision-making (i.e., the KMQs). In addition to requiring extensive and reliable datasets, such reporting usually requires an ability to summarize the data using threshold values –good, marginal or poor habitat and/or habitat trends, compared to a base condition. CHaMP is working with PNAMP and others to develop an online interface that will provide access indicators and summary reporting products to support management decision-making. To facilitate reader review of the habitat status and trends section on the next page, Figure 1 and the text box present a primer on viewing and understanding boxplots.

UNDERSTANDING BOXPLOTS

- The line in the box shows the median value: half (50%) of the values fall above this line and half fall below it.
- The lower quartile value (Q1, 25%), and the upper quartile value (75%, Q3) are shown as the top and bottom lines of the box.
- In the Figure 1 example, an outlier is any value that is greater than or less than 1.5 multiplied by the Inter Quartile Range (IQR; Q3-Q1), away from the max and min values. The IQR is the black box and outliers are represented with dots.
- A symmetric distribution is shown (i.e., the median is near the "middle" and the whiskers—the lines above and below the box that indicate variability outside the upper and lower quartiles of the dataset —are roughly the same length. A skewed distribution would have the median value off center and/or whiskers of different lengths and/or many outliers far from the IQR box.

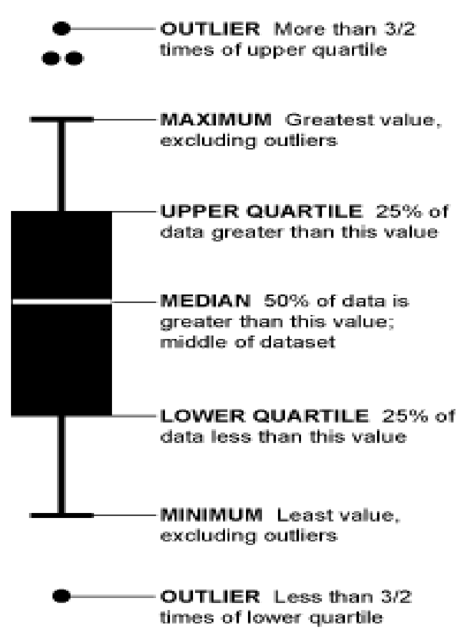


Figure 1. Boxplot example

Habitat Status & Trends

CHaMP is able to produce robust estimates of habitat status. Status for key metrics from the 2011-2013 dataset in each watershed is depicted on the next pages using Box and Whisker plots. These plots can be used to convey information about the distribution of a measured attribute, and show largely the same information that is seen in a histogram. Boxplots are especially useful for comparing multiple distributions. In CHaMP, for example, we are often interested in comparing distributions of habitat attributes across watersheds. The boxplots in Figure 2(a-d) show the status of select CHaMP metrics and the distribution of these metrics' values within each CHaMP watershed. The watershed median is shown by the solid line in the middle of each boxplot. The blue boxes indicate a range in which the middle 50% of the data are contained for each watershed. The dotted lines ("whiskers") show the extent of the rest of the data, excluding outliers, and the individual points describe outlier points – individual sites where the measured value falls well outside the range of the rest of the data within that watershed.

In many cases, habitat status findings align well with *a priori* assumptions. For example the frequency of large woody debris in the Secesh River is generally higher than in other locations, as might be expected for a watershed that is identified as a reference stream in many regional programs (Figure 2a). Similarly, the Secesh River also exhibits relatively low levels of fine sediment (D50) relative to other watersheds (Figure 2b).

The process of summarizing status information has underscored the value of stratification. The CHaMP survey design is stratified by valley class (i.e., broken out by material source, transport, and depositional zones) and land ownership (public versus private). While it is

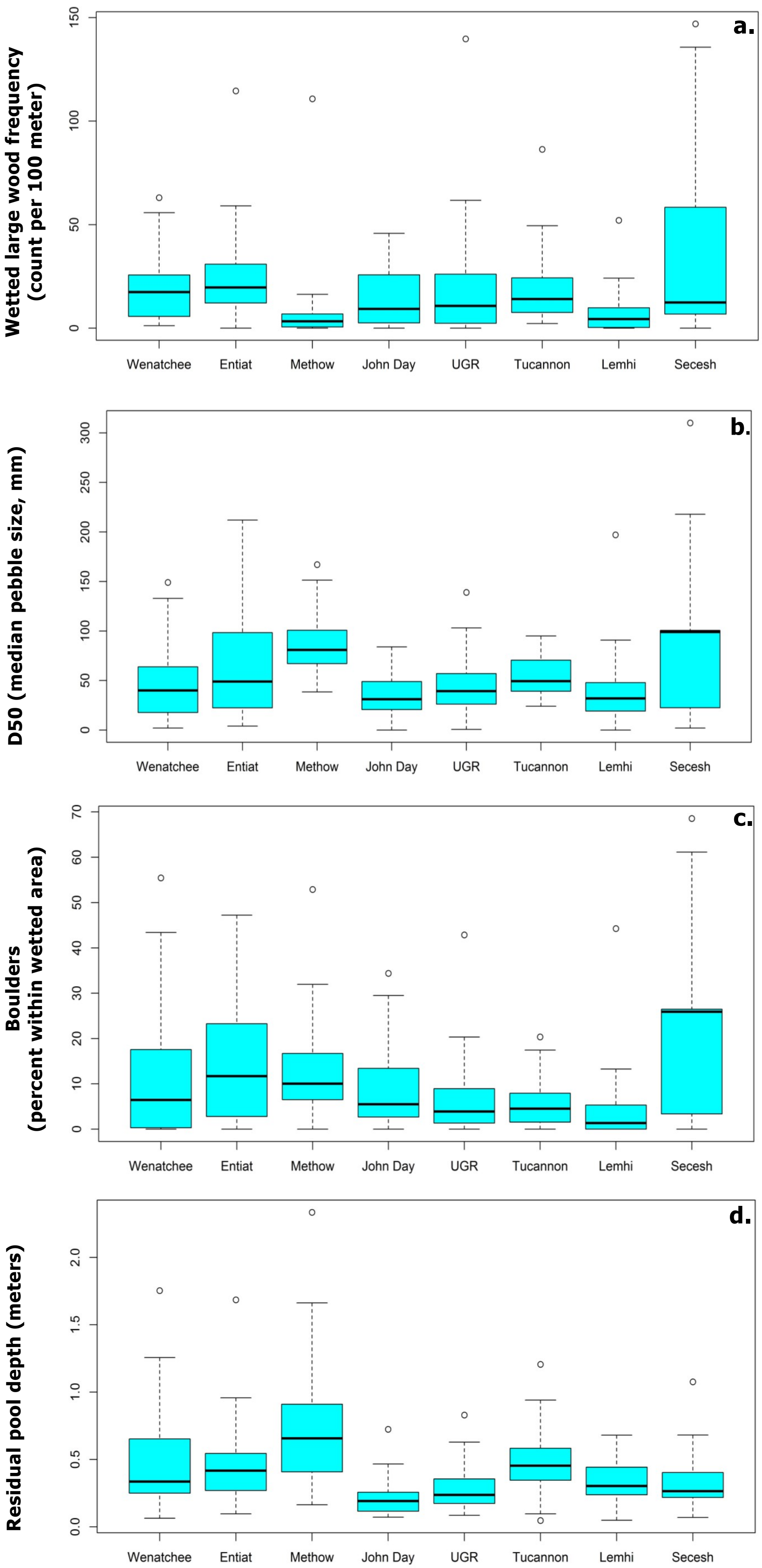


Figure 2(a-d). Watershed level summaries of select metric values, average of 2011-2013.

—-After completion of CHaMP's first three year panel of its nine year rotating panel design, CHaMP can produce robust estimates of habitat status in all watersheds.

reasonable to expect that land ownership is associated with, and perhaps in some cases a direct driver of, many of the metrics collected by CHaMP, perhaps less obvious is that metrics vary significantly by valley class due to the geomorphic processes that shape the landscape. For example, variance in the amount of large woody debris is substantially influenced by both land ownership and valley class, whereas the frequency of fast turbulent habitat is explained best by valley class alone. Detail on CHaMP's survey design and the role and value of stratification is provided in Chapter V.

In addition to estimates of status, CHaMP is designed to provide meaningful estimates of temporal trends, should they exist, after nine years (three, three-year panels) of sampling. Currently, CHaMP is able to estimate temporal patterns at annual CHaMP sites only. This is because annual sites have been revisited (3x). Temporal change estimates are made by fitting a linear regression line to the site level metric value versus time. With only three years of data we are not able to differentiate short-term temporal variability from long-term linear trends in metrics in a statistically sound manner. Nonetheless, we can produce statistically significant watershed level summaries of year-to-year change at annual sites. (Figure 3a-c). By 2019, at the end of the nine-year design, CHaMP annual sites will have been visited 9x and all rotating panel sites will have been visited 3x, so all sites can be used in long-term temporal pattern (i.e., trend) estimation.

The plots on this page and in Appendix A depict watershed summaries of site-level change for select metrics at annual sites sampled from 2011-2013. These plots are included here only as examples of our ability to estimate change, but not as evidence of statistically significant long–term linear trends. Positive values indicate increases in the site-level average of each metric over the three years, while negative values indicate decreases. Boxplots spanning both positive and negative values reveal that some sites within that watershed showed

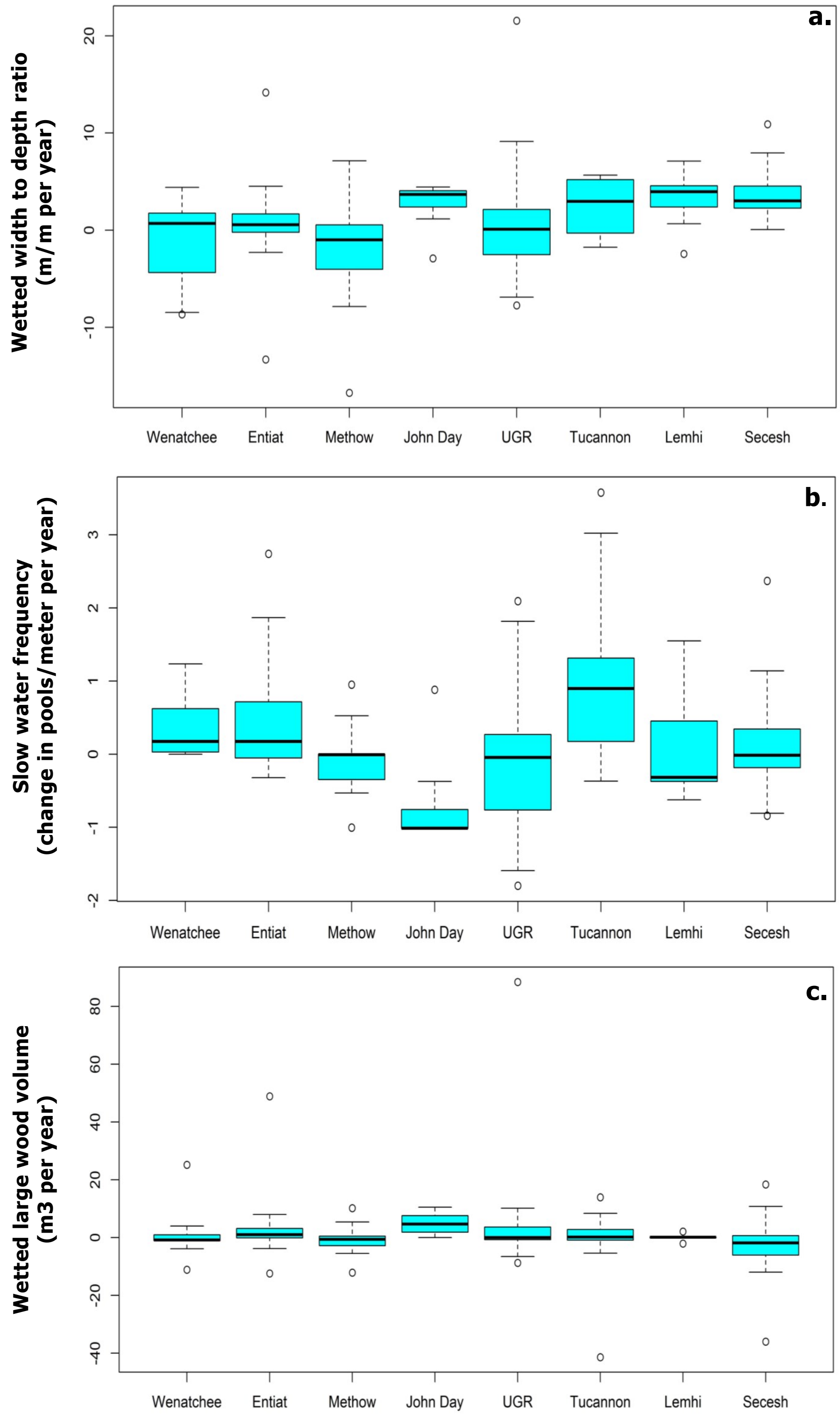


Figure 3(a-c). Watershed level summaries of site-level change for select metrics across CHaMP watershed annual sites, 2011-2013.

—-Given the highly imprecise nature of estimating trends with only three years of data, caution should be exercised in making inference from these boxplots. Increases or decreases may or may not be indicative of long term trends, but could well be simply year-year variability, measurement noise, etc.

CHaMP's ability to precisely identify meaningful, long-term trends will increase substantially after additional years of data collection per the nine-year study design.

increases in the metric, while others showed decreases.

Broadly speaking, some metrics appear to have moved in the direction expected for habitat restoration actions in IMWs. For example, the IMWs in the John Day, Lemhi, and Tucannon focus, in part, on increasing floodplain connectivity and/or reductions in channelization; whereas actions in the Entiat are focused on the placement of instream structures to provide flow refugia. Statistically significant year-to-year changes toward increased wetted width to depth ratios in the John Day and Lemhi (Figure 3a) may be early indicators that restoration actions are decreasing the prevalence of incised or channelized reaches. The Entiat and Tucannon exhibit positive short-term changes in the frequency of slow water habitat Figure 3b), potentially creating flow refugia for juvenile salmonids. The volume of large woody debris within the wetted channel width (Figure 3c) shows significant positive changes in both the John Day and Entiat, increasing channel complexity and providing the means for juvenile salmonids to escape predation.

Confidence in these changes and an evaluation of linear trend can only be established over a longer time-series. After 2017 and completion of the second three-year panel, our ability to differentiate trends from random change over time will become more precise. Nonetheless, preliminary metric change results are encouraging and, within the context of IMWs, illustrate how CHaMP habitat metric change information might be used to inform habitat restoration effectiveness monitoring.

How the Region is Using CHaMP Information

Although CHaMP is producing reliable habitat data (see Metrics discussion) that information is of little value unless it is used in an applied manner. The BPA's Integrated Status and Effectiveness Monitoring Project (ISEMP; Project No. 2003-017-00) relies on CHaMP to support habitat restoration effectiveness monitoring. Additionally, standardized CHaMP metrics are being actively used by the Columbia River Inter-Tribal Fish Commission (CRITFC), the Oregon Department of Fish and Wildlife (ODFW) and other collaborators.

In support of KMQ 1 (Status & Trends of habitat limiting factors), CHaMP's standardized metrics have been leveraged by ISEMP, CRITFC, ODFW and others in the development of continuous estimates of habitat quality and life-stage specific limiting factors models such as HabRate to inform recovery planning in the upper Grande Ronde through BPA's Restoration Atlas planning process, and the validation of life cycle model components. Technical input from Expert Panel members and others is required to develop qualitative threshold values and ratings that can be used in conjunction with CHaMP's habitat metrics to generate and display summaries at different scales.

CHaMP is helping to address KMQ 2 (Effectiveness of habitat restoration actions). Topographic survey data from annual sites in multiple watersheds have been used within Geomorphic Change Detection (GCD) software to evaluate pre– and post-project conditions. As a specific example, in 2013 CHaMP survey data and DEMs of Difference (DoDs) were used in the Asotin IMW to provide a detailed mechanistic explanation of how and why restoration can benefit salmon and steelhead. Outputs were used to evaluate habitat change between and among years, and to test design hypotheses to inform strategic project planning and effectiveness evaluations (Figure 4 and inset box). The application of CHaMP surveys in the Asotin IMW example shows how CHaMP data have been used for both planning and effectiveness evaluations. Similar applications of CHaMP data to help answer KMQ 2 have occurred in other watersheds as well, such as the Entiat and Tucannon.

ASOTIN CREEK IMW

- CHaMP surveys are being used in the Asotin IMW to identify limiting factors (KMQ1; lack of channel complexity and flow refugia), plan a restoration action (KMQ2), and evaluate the response of large woody debris (LWD) additions on juvenile steelhead and their habitat (KMQ3).
- CHaMP DEMs were modified to reflect the predicted physical change expected from LWD additions (Figure 4). These data were then used to develop a hydraulic model across the project reach in order to generate 0.1m precision depth and water velocity field estimates based on both the actual and modified DEMs. Finally, the depth and velocity changes were used in a net rate of energy intake (NREI) model to estimate the expected change in fish capacity resulting from the restoration action (Predicted, Top row)
- Pre- and post-implementation CHaMP surveys conducted on the same reaches were used to compare the predicted response to the actual physical and biological changes resulting from implementation of the restoration plan (Actual, Bottom row). After only one year, physical and biological responses were evident and in the direction expected.

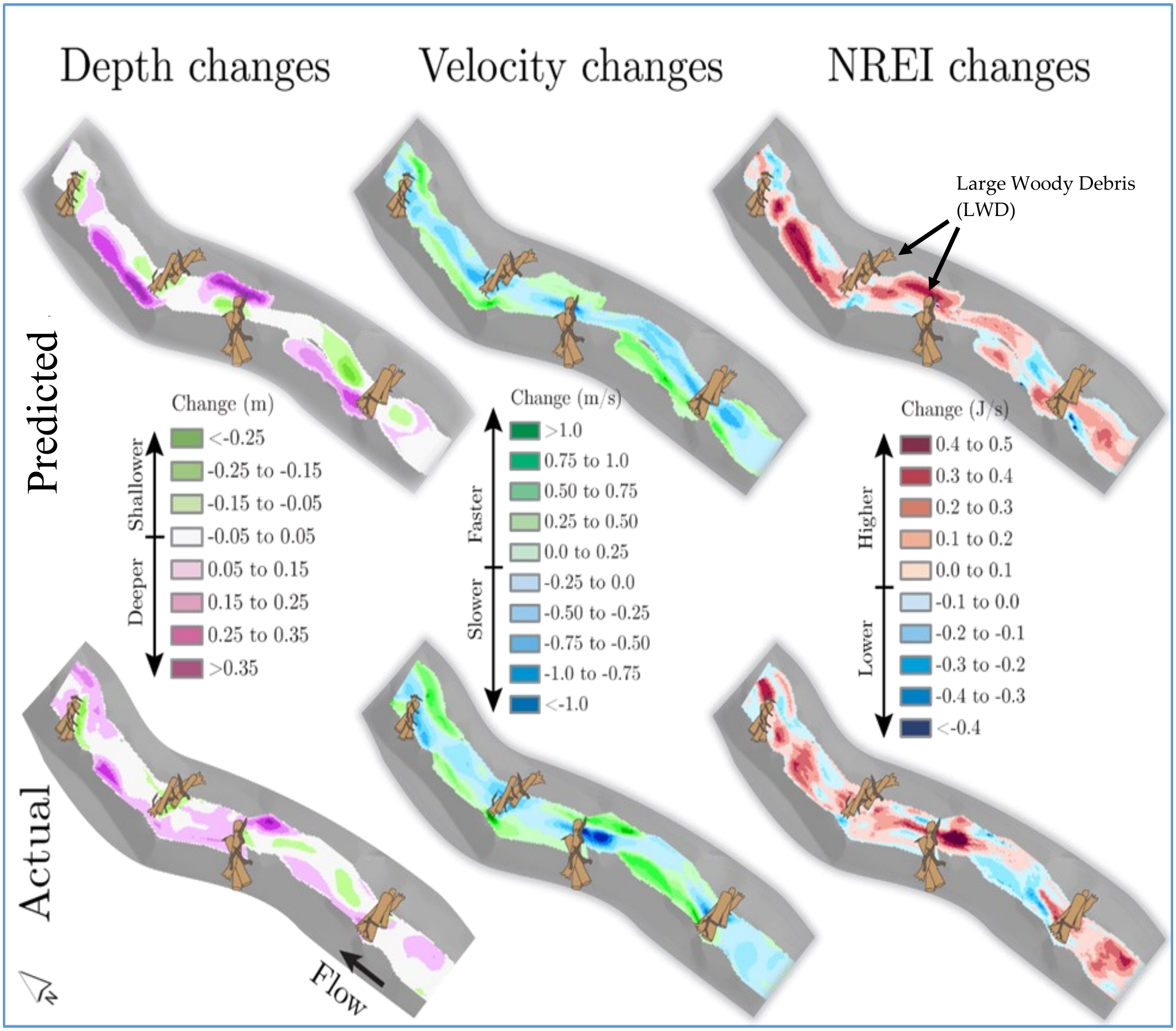
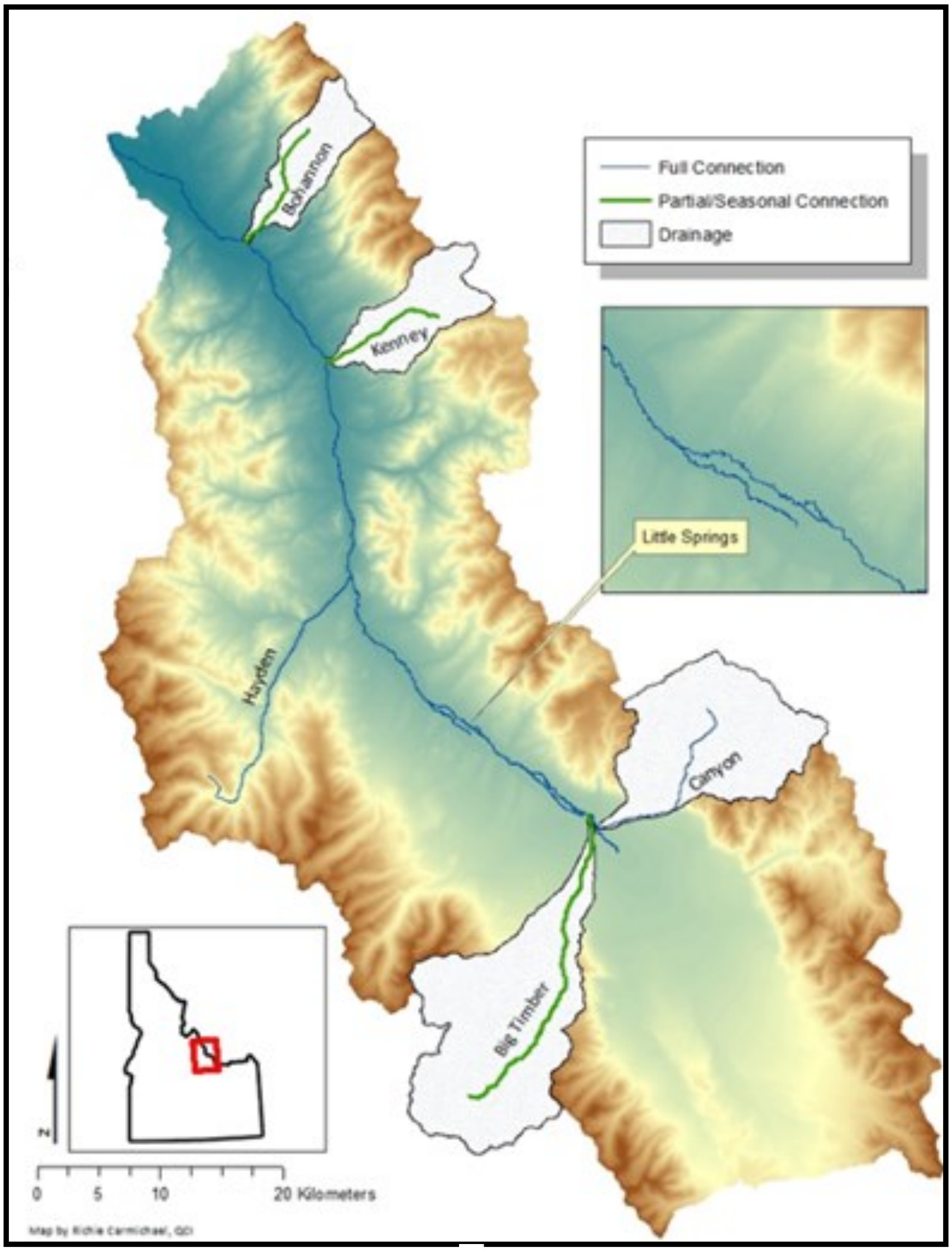


Figure 4. CHaMP metrics are being used in the Asotin IMW and other watersheds to model expected changes in depth, velocity and Net Rate of Energy Intake (an indicator of fish carrying capacity) from installing wood structures) (Predicted, Top row). Data collected just one year after project implementation (Actual, Bottom row) show there were physical and biological responses and in the direction expected.

CHaMP habitat data have also been used in conjunction with ISEMP data to help answer KMQ 3. A number of habitat restoration actions have been implemented in the Lemhi IMW in an attempt to meet the 4% and 7% freshwater productivity (smolts/adult) improvements identified in the 2008 BiOp for steelhead and spring/summer Chinook salmon, respectively. Habitat restoration actions have included tributary reconnections (highlighted in white in Figure 5, including Little Springs Creek, shown as an inset), in-stream habitat improvements, and changes in water diversion practices to increase instream flow and reduce peak water temperatures. CHaMP data have been leveraged within a watershed model to evaluate the effectiveness of restoration actions completed through 2012. The model estimates that actions completed through 2012 (Figure 6) will likely be sufficient to achieve the productivity targets for steelhead but are not likely to achieve productivity improvement targets for spring/summer Chinook salmon.

In 2013 CHaMP-ISEMP staff collaborated with co-managers to simulate a series of additional habitat restoration actions, using the watershed production model, that would be likely to achieve the 7% productivity improvement for spring/summer Chinook salmon. One scenario, the reconnection of Texas Creek, is illustrated in Figure 6 (lower left-hand corner) .

Currently, CHaMP data are being used to parameterize the watershed production model for the Wenatchee, Entiat, and Lemhi. CHaMP metrics could also be used in the region to inform the work of non-CHaMP watersheds. For example, watersheds that have developed Ecosystem Diagnosis and Treatment (EDT) model outputs may wish to explore the utility of metrics and network map products for validation of existing EDT products, such as mapped estimates of habitat quality or recovery potential. Preliminary CHaMP-ISEMP map products for non-CHaMP watersheds that are using EDT, such as the Okanogan, will be available in fall 2015.



Baseline

Wetted area: 1.27 km^2

Pool area: 0.37 km^2

Tributary reconnection

Wetted area: 1.55 km^2 **(22%)**

Pool area: 0.44 km^2 **(19%)**

Steelhead

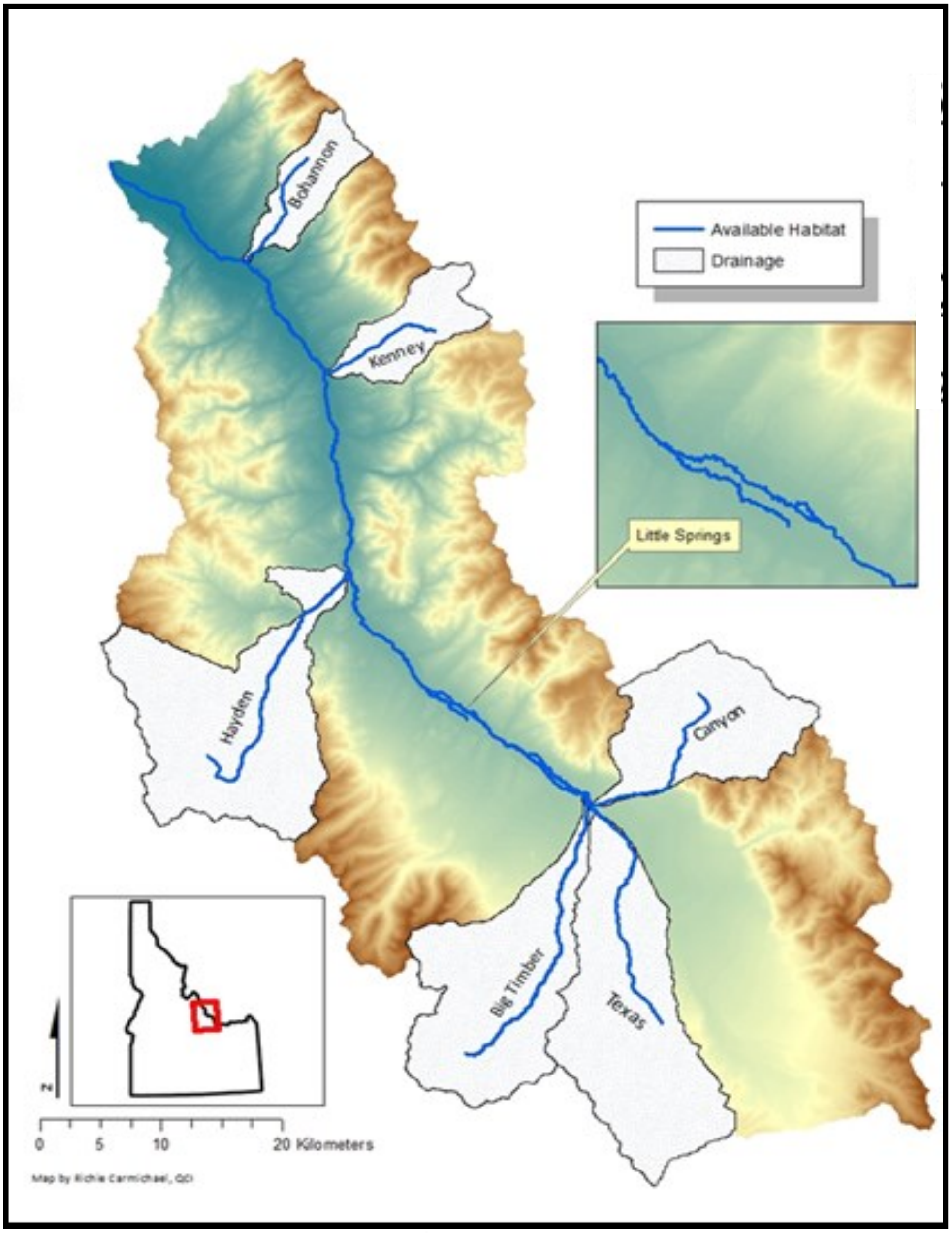
164 smolts/adult (**10% increase**)

Chinook

19.3 smolts/adult (**3% increase**)

Figure 5. Percentage increase in habitat available to anadromous salmonids due to tributary reconnections (highlighted in white, including Little Springs Creek shown as an inset) in the Lemhi River through 2012 and the predicted changes in freshwater productivity (smolts/adult) estimated to occur as a result of those actions.

Productivity improvements for steelhead are estimated to exceed the 4% target identified in the BiOp. The 7% productivity improvement target for spring/summer Chinook salmon is unlikely to be achieved.



Baseline
Wetted area: 1.27 km²
Pool area: 0.37 km²

Tributary reconnection
Wetted area: 1.7 km² (**34%**)
Pool area: 0.46 km² (**24%**)

Steelhead
167 smolts/adult (**12% increase**)

Chinook
20.1 smolts/adult (**7% increase**)

Figure 6. Estimated incremental change in habitat availability and steelhead and spring/summer Chinook salmon productivity due to the simulated reconnection of Texas Creek.

Under this scenario, estimates suggest that 7% freshwater productivity targets for spring/summer Chinook salmon would be met *and* result in an additional 2% improvement in steelhead productivity.

Lemhi River

CHaMP data in the Lemhi River are being leveraged in a watershed production model to evaluate the effectiveness of completed restoration actions and types and extents of additional restoration actions that may be necessary to achieve freshwater productivity targets identified in the 2008 Biological Opinion (KMQ2). Restoration actions in the Lemhi include in-stream restoration actions as well as the addition of tributary habitat via the reestablishment of flow and removal of migration barriers.

CHaMP habitat data and ISEMP fish data were used to evaluate the quantity and quality of habitat available to anadromous salmonids from all restoration actions completed through 2012 and to predict accompanying changes in adult and juvenile abundance and freshwater productivity (smolts/adult; Figure 5). Results suggested that restoration actions completed through 2012 would be likely to achieve freshwater productivity improvement targets for steelhead, but not the seven percent target for spring/summer Chinook salmon.

CHaMP data from remaining disconnected tributaries were used to simulate a suite of additional tributary reconnections and targeted in-stream restoration actions that would be capable of meeting productivity targets for spring/summer Chinook salmon. An example of one such scenario, which also provided greater benefits for steelhead, is illustrated in Figure 6.

Coordinating Metrics Across Other Habitat Programs

CHaMP is not the only program collecting habitat survey data in the interior Columbia River Basin. Accordingly, CHaMP was designed to create methods that could be exported to other monitoring programs and metrics that could be leveraged in the efforts of others. In 2013 collaboration between CHaMP and the BPA's Action Effectiveness Monitoring (AEM) grew the CHaMPMonitoring.org data management system to support and serve data from the AEM effort. Collaboration with the AEM project has also furthered regional monitoring program metric standardization, as the AEM protocol was built to incorporate and leverage CHaMP's metrics and data management tools.

Until recently, data from other preexisting habitat survey efforts such as PACFISH/INFISH Biological Opinion (PIBO) have not been evaluated to identify common metrics, nor has any attempt been made to report those common metrics in a single location.

Recognizing the value in identifying common metrics among the multitude of habitat survey initiatives, and reporting those metrics in a single accessible location, in 2013 BPA tasked CHaMP with expanding its database to store and serve information collected by PIBO.

By the end of 2014, the CHaMP database will be modified to provide access to common metrics between PIBO and CHaMP. Generally, these metrics fall into two categories (see Table 1):

- Metrics that are interchangeable with limited manipulation and
- Metrics that can be made compatible via "crosswalks;" requiring adjustments or statistical transformations.

Beyond simply reporting common metrics, database information can provide spatial aggregation of data to better extend site-based results to progressively larger spatial scales (equivalent to Evolutionarily Significant Units (ESUs)) and ICRB domains of interest for anadromous salmonids.

The 2014 database effort is limited to:

1. CHaMP and PIBO data – recognizing that successful completion of this effort opens the door to inclusion of additional data streams (e.g., the Aquatic and Riparian Effectiveness Monitoring Program and the Environmental Monitoring and Assessment Program).
2. Three univariate metrics: stream temperature, pool frequency, and large woody debris frequency.

Information from the 2014 effort will be made available in formats designed to support a wide range of users. Expert Panels may elect to define threshold values, allowing data to be summarized in a "stoplight" fashion, wherein green values identify good habitat, yellow marginal, and red poor. Alternatively, "raw data" for standardized metrics will be accessible to support others' efforts such as watershed model parameterization, among others.

Table 1. CHaMP-PIBO metrics identified as the same or requiring a linear transformation only (22), or similar (need to be constructed from measurements (2).

Directly Exchangeable (10)—Same Metrics (No cross-walk necessary)*	*Requires Crosswalk (12)—Same Metrics (Regression correction necessary)*
Conductivity	Pool Percent
Temperature	Pool Frequency
Site Length	Substrate: D16
Gradient	Substrate: D50
Site Sinuosity	Substrate: D84
Bankfull Width	Average Thalweg Depth
Wetted Width	Wetted Width to Depth Ratio
Pool Tail Fines <2 mm	Residual Pool Depth
Pool Tail Fines < 6mm	Bankfull Width CV
Bankfull Large Wood Frequency	Bankfull Width to Depth Ratio CV
Similar Metrics (2)—CHaMP can generate (algorithm-based crosswalk)	Bankfull Width to Depth
Percent Undercut Banks	Bankfull Large Wood Volume
Bank Angle	

*quantitative criteria for regression parameter and r2 have not yet been set.

The Reliability of CHaMP Habitat Metrics

The CHaMP 2013 field sampling effort expanded the number of annual and unique sites surveyed using the CHaMP protocol (Table 2). The completion of the 2013 sampling season, and the first three-year panel, resulted in additional site visits and measurements for the CHaMP team to use scrutinize every aspect of its program. This concerted effort to improve sampling efficiency and metric quality has occurred annually after every field season since the start of CHaMP implementation in 2011. As specific examples, refinements to the undercut bank protocol have increased measurement repeatability and metric content, and an innovative water temperature quality assurance/quality control tool developed in 2013 has increased the efficiency of identifying data errors. CHaMP's evaluations and adaptive management have resulted in a suite of metrics that are reproducible and are accompanied by very low measurement error, represented in pink in Figure 7.

In 2013 CHaMP also made substantial improvements in the precision and repeatability of measuring macroinvertebrate drift. It was of special interest to CHaMP to address questions from BPA about the value of its drift metric because drift is especially important when compared to measures of benthic macro-invertebrates: it is a direct measure of food availability for juvenile salmonids, can be more precisely estimated, and is far more cost-efficient to collect and process. As importantly, the CHaMP drift metric is a key component in multivariate bioenergetics models that explicitly link habitat to capacity and growth potential for juvenile stream-rearing salmonids.

A table summarizing key CHaMP metrics (singular and multivariate based on syntheses, model outputs) and their utility for summary indicator and product development, is presented in Chapter VI, CHaMP Metric Assessment..

Table 2. Summary of unique sites surveyed by regional collaborators using the CHaMP protocol, 2011-2013.

	2011	2012	2013	Total Unique Sites Surveyed Using CHaMP *
Methow	25	19	25	49
Entiat	76	60	79	94
Wenatchee	23	22	25	43
Tucannon	24	29	29	49
South Fork Salmon	33	25	25	55
Lemhi	42	48	48	109
Minam	-	-	10	10
John Day	59	73	77	188
Upper Grande Ronde	56	56	54	129
Yankee Fork	-	-	25	25
AEM	-	-	29	29
BPA-Funded Total**	335	344	429	780

*These totals count, only once, annual sites that were sampled in 2011-2013. Altogether, 513 visits conducted in 2013 and 1394 visits were conducted from 2011-2013.

** Non-BPA-funded sites = 75 total. 18 sites in the Asotin were funded/surveyed by Washington SRSRB, 22 sites were surveyed in California by state Department of Fish and Game - Coastal Watershed Planning and Assessment Program, 3 sites by Confederated Tribes of the Warm Springs, 3 sites surveyed for USBR in Methow, and 29 sites in Bridge Creek.

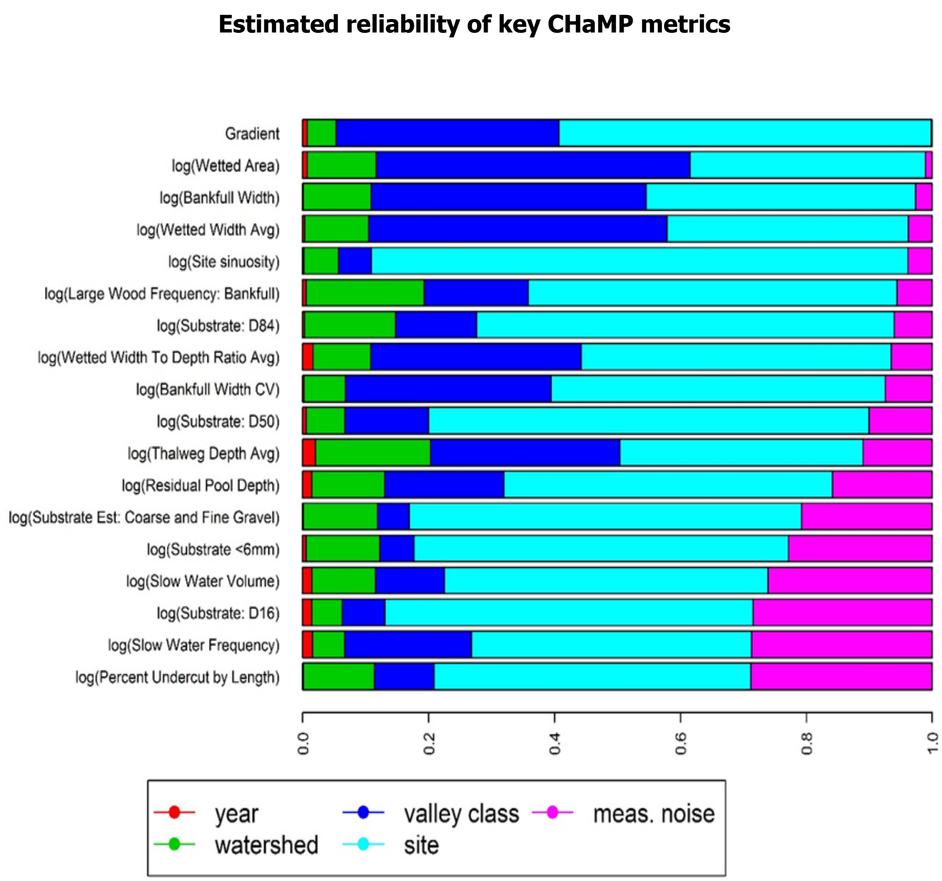


Figure 7. Refinement of CHaMP protocols and metrics from 2011-2013 has minimized measurement noise (pink) and improved metric reliability. Depending on the metric, CHaMP sampling strata (site--public versus private; valley class—material source, transport or deposition) explain an important part of the overall metric variation within each watershed.

The Future of CHaMP / Concluding the Pilot

CHaMP (and CHaMP-ISEMP) products are being developed on a timeline to support two major decision-making processes: the Expert Panel process (2016) and the BiOp (2018). Table 3. describes these and other milestones.

The CHaMP project was initiated under a "pilot" designation given Council concerns and ISRP questions regarding the development of a new regional-scale habitat monitoring program.

Very generally speaking, the "CHaMP-specific" questions that were raised (i.e., questions relating specifically to CHaMP project development and implementation, not the integration of CHaMP and ISEMP data in fish-habitat relationships), can be summarized as:

1. Are the metrics generated by the CHaMP protocol reliable and useful?
2. How will CHaMP make progress towards standardization and unified metric reporting across other habitat survey programs?
3. Are CHaMP methods, metrics and tools compatible with, of value to, and usable by other regional programs?
4. How does CHaMP's study design support regional management decision-making, especially extrapolation to unmonitored watersheds?
5. Does the current suite of watersheds monitored by CHaMP adequately represent habitat conditions across the Columbia River Basin?

After three complete years of monitoring, extensive annual QA/QC and adaptive management to continuously improve all aspects of the program, we assert that CHaMP meets the technical expectations of a robust, dependable stream habitat monitoring protocol and that the information presented herein, and previously in Ward et al. (2011) and CHaMP (2012), has answered many of the questions (generalized above) that were asked by the BPA, Council, and ISRP over the 2011-2013 period.

Table 3. CHaMP product milestones and long-term timeline.

Year	Milestone
2011	Pilot Implementation (Entiat, Wenatchee, Methow, Grande Ronde, Tucannon, John Day, Lemhi, and Secesh)
2013	End of first three-year cycle in the nine-year rotating panel design– status and trend info available. End of "Pilot." Implementation in Yankee Fork and Minam.
2014	Integration with the AEM project.
2015	Integrated CHaMP PIBO database. Development of material by fall 2015 to support 2016 Expert Panel summaries.
2016	End of second three-year cycle in the nine-year rotating panel design. Expert panel summaries complete.
2017	Long-term trends can be statistically identified. Development of material using 2011-2016 data set to support development of BiOp data summaries.
2018	BiOp process
2019	End of third three-year cycle in the nine-year rotating panel design. Design evaluation.

Work is ongoing to address Question 5, that is, the degree to which "... the current suite of watersheds monitored by CHaMP adequately represent habitat conditions across the Columbia River Basin". Selection of watersheds for the CHaMP program was non-random in that watersheds were explicitly adopted to span a range of estimated decreases in the freshwater productivity of anadromous salmonids; however, slightly less than half of the originally proposed CHaMP watersheds were implemented. Nonetheless, we feel that the current range of CHaMP implementation in the Columbia River Basin strikes a pragmatic balance amongst the uncertainties of data requirements, the ability of the program to meet them, and finite funding resources.

Lastly, ISEMP and others have demonstrated the utility of CHaMP tools and metrics by using them in independent efforts to resolve critical tributary habitat and salmonid population management uncertainties. Accordingly, we recommend that the Pilot designation be removed from the CHaMP project and that its implementation as proposed be supported through the end of its nine-year design.

An in depth discussion of criteria beyond the KMQs that were considered as part of this proposal to remove the pilot designation from CHaMP is presented in Chapter VIII.

What are CHaMP expectations moving forward?

CHaMP is a habitat monitoring protocol explicitly designed to collect information to link habitat attributes in a predictive manner to the freshwater productivity of anadromous salmonids. The distribution of CHaMP watersheds across the range of environmental conditions in the Columbia River Basin is intended to maximize the extension of results to un-sampled watersheds.

Analytical functions of CHaMP are limited to habitat survey protocol improvements to maximize reliability, ensure repeatability, and increase efficiency, and data service to support existing and new initiatives, such as the Expert Panel process and AEM. As proposed and implemented, CHaMP is not configured to independently develop fish/habitat relationships. While CHaMP is fully capable of documenting the physical changes resulting from habitat restoration actions, CHaMP is collaborating

with a wide range of regional partners to relate those changes to the freshwater productivity of anadromous salmonids. We feel that this report fully demonstrates the relevance of CHaMP in that regard.

This report is the final contribution to the trilogy of CHaMP pilot "Lessons-Learned Project Synthesis Reports." Beginning after the 2014 sampling year, CHaMP and ISEMP will produce an integrated annual report. The unification of annual reporting from these two BPA programs will streamline the structure and flow of information going forward into upcoming policy and management processes. The ISEMP-CHaMP 2014 integrated report will complete the process of addressing Council and ISRP questions posed during the CHaMP pilot that primarily relate to KMQ 3 and the development of fish-habitat relationship models. In addition, the 2014 report will respond in a comprehensive manner to more recent questions raised by the ISRP about the interaction among the ISEMP, CHaMP, and AEM projects. Specifics on 2014 CHaMP-AEM and CHaMP-PIBO collaboration that occurred during the 2014 sampling year will also be presented in the integrated report. Many CHaMP reporting requirements will be primarily fulfilled through the provision of data and information via CHaMP-Monitoring.org together with the content in the 2014 ISEMP/CHaMP report.

The CHaMP team looks forward to supporting new and existing mandates that rely on a proven, field-tested protocol that delivers reliable, repeatable, and relevant habitat status and trend data. Moving forward, CHaMP data will be employed in a number of settings and will remain accessible through CHaMP-Monitoring.org. Protocol refinements, and annual field implementation summaries will be incorporated in joint ISEMP/CHaMP reports, as will advances in data services. We envision the delivery of a CHaMP summary report in 2019, with accompanying recommendations on CHaMP survey design changes prior to field survey implementation in 2020.

I. INTRODUCTION

Background to this Report

The Columbia Habitat Monitoring Program (CHaMP; BPA Project 2011-006-00) is the culmination of the Integrated Status and Effectiveness Monitoring Program's (ISEMP; BPA Project Number 2003-017-00) work to develop and export a standardized regional habitat monitoring program designed to support overall policy and management decision-making. ISEMP began CHaMP project development in 2010 across the three pilot subbasins and Intensively Monitored Watersheds (IMWs). Although CHaMP was implemented as a separate project in 2011, it was originally conceived to enable synthesis of fish and habitat data to help answer BPAs Key Management Questions (KMQs), which were posed in response to the 2008 Federal Columbia River Power System Biological Opinion (FCRPS; NMFS 2008).

In 2013 coordination between the CHaMP and ISEMP projects increased again in response to the maturation of CHaMP's metrics and their applicability to ISEMP fish-habitat product development. The CHaMP 2013 post-season workshop, held on December in Boise, Idaho, was restructured to one day to focus discussion with crews and maximize feedback on field implementation, identification of protocol development, and QA improvements for 2014. This restructuring was possible because as of 2013, the CHaMP protocol and tools were more stable and required less discussion. A separate presentation to managers designed to highlight how CHaMP data are being used by ISEMP and others to help answer the KMQs, specifically fish-habitat relationship questions, occurred on February 15-16, 2014 in Portland, Oregon. This important update presentation to managers was deferred to the start of CY14 to facilitate comprehensive project reporting based on all information from the 2011-2013 pilot period.

CHaMP provides standardized habitat monitoring data for use in answering three important Key Management Questions (KMQs) and to support regional policy and management decision making:

- *KMQ 1: What are the tributary habitat limiting factors or threats preventing the achievement of desired tributary habitat performance objectives?*
- *KMQ 2: What are the relationships between tributary habitat actions and fish survival or productivity, and which actions are most cost-effective at addressing habitat impairments?*
- *KMQ 3: Are tributary actions achieving the expected biological and environmental improvements in habitat [and improving survival and/or habitat capacity of specific fish life-stages?*

Day 1 of the workshop had a management focus and described CHaMP-ISEMP products, and collaborator efforts that are utilizing CHaMP data to help answer KMQs. Day 2 of the workshop had a more technical focus and described the science that underpinned many of the analyses and synthesis products that were presented on Day 1. February 16 Day 2 topics included CHaMP metric assessment, and discussion of potential criteria and rationale for removal of the pilot designation from the project based on 2011-2013 implementation.

CHaMP 2013 Report Structure

Over the past three years CHaMP annual report structure has evolved to address topics of interest or address particular policy and management staff questions. Overall, the structure and content (Table 4) have been designed to achieve a number of goals including:

- Summarize CHaMP-specific contributions to answering policy and management questions from the BPA, Council, ISRP and others over the pilot period.

Table 4. CHaMP 2013 report overview

Chapter II	CHaMP products to support the assessment of tributary habitat limiting factors (KMQ 1)
Chapter III	Informing implementation of effective and cost-effective habitat actions (KMQ 2)
Chapter IV	Assessment of effectiveness of restoration strategies on habitat and salmonid populations (KMQ 3)
Chapter V	Supporting habitat management decision making through CHaMP's survey and response design. *Related BPA, ISRP and Council questions about CHaMP's design are presented in this chapter.*
Chapter VI	CHaMP metric assessment and discussion.
Chapter VII	Summary of 2013 program and field implementation. Information and recommendations in this chapter are largely based on feedback from crews at the one day December 2013 CHaMP post-season workshop and the post-season survey.
Chapter VIII	Proposed criteria and rationale for concluding the Pilot

- Continue topic threads that were included in the 2011 and 2012 reports, for example, Study Design and Metrics Diagnostics.
- Provide updates to/conclude answers to many of the Council and ISRP questions posed to the CHaMP team during the period of the project (2011-2013). When a logical crosswalk is present, *such questions are listed in italics at the start of related chapters.*
- Outline rationale for removal of the pilot designation from the CHaMP project in light of the information presented in this and previous reports, and the upcoming 2014 integrated report.

Supporting a BPA Framework to Help Meet Regional Salmonid Management equirements

As mentioned previously, CHaMP is designed as a Columbia River basin-wide habitat status and trends monitoring program built around a single protocol with a programmatic approach to data collection and management. Since 2011, CHaMP sampling has been conducted at sites within CHaMP watersheds funded by BPA, at CHaMP sites within other watersheds and through other sources of funding, and at sites that are also shared with BPA's AEM program. With revisits to sites included, crews using the CHaMP protocol conducted 513 visits in 2013 and 1394 visits over the 2011-2013 period (see Table 5).

Implementation in 2013 again resulted in the collection and analysis of systematic habitat status information that is being used to assess basin-wide habitat conditions. CHaMP is also working to identify long-term trends information but ultimately monitoring must occur per the study design for three cycles of a sampling panel, at least nine years, for this to occur. When coupled with biological response indicators, CHaMP status and trends information will be used to evaluate habitat management strategies.

Table 5. Unique sites surveyed by regional collaborators using the CHaMP protocol, 2011-2013.

	2011	2012	2013	Total Unique Sites Surveyed Using CHaMP *
Methow	25	19	25	49
Entiat	76	60	79	94
Wenatchee	23	22	25	43
Tucannon	24	29	29	49
South Fork Salmon	33	25	25	55
Lemhi	42	48	48	109
Minam	-	-	10	10
John Day	59	73	77	188
Upper Grande Ronde	56	56	54	129
Yankee Fork	-	-	25	25
AEM	-	-	29	29
BPA-Funded Total***	335	344	429	780

*These totals count, only once, annual sites that were sampled in 2011-2013. Altogether, 513 visits conducted in 2013 and 1394 visits were conducted from 2011-2013.

**Through ISEMP, BPA also funded 29 sites in Bridge Creek.

*** Non-BPA-funded sites = 46 total. 18 sites in the Asotin were funded/surveyed by Washington SRSRB, 22 sites were surveyed in California by state Department of Fish and Game - Coastal Watershed Planning and Assessment Program, 3 sites by Confederated Tribes of the Warm Springs, 3 sites surveyed for USBR in Methow.

CHaMP efforts are integrated with ongoing Pacific Northwest Aquatic Monitoring Program (PNAMP) recovery planning efforts and part of the collaborative process across Columbia Basin fish management entities, tribes and other state and federal agencies that are monitoring anadromous salmonids or their habitat. Through CHaMP implementation, we are characterizing stream responses to watershed restoration and/or management actions, ideally in at least one population within each steelhead and spring Chinook Major Population Group (MPG) that have, or will have, "fish-in" and "fish-out" monitoring (identified in RPA 50.6), thereby meeting the requirements of RPA 56.3, RPA 57, and RPA 3. For more information on the protocol see: Scientific Protocol for Salmonid Habitat Surveys within the Columbia Habitat Monitoring Program (CHaMP) v4.0

https://www.monitoringmethods.org/Protocol/Details/2020

Figure 8, above right, depicts the relationship between CHaMP and ISEMP program workflows from data collection to a description of a population-level response. A feedback loop results from validating predictions made by the various products, leading to further refinement of, and confidence in, the protocol, fish-habitat analyses and synthesis products.

CHaMP-ISEMP Tasks and Timelines

In 2014 CHaMP and ISEMP efforts will continue to focus on translating the data and metrics from each project into formats that are salmon-centric but biophysically informed, and that are built upon more direct linkages, consistencies and efficiencies to help answer KMQs. Specific CY14 areas of focus include:

- Continuing habitat data collection to support status and trends detection, especially as it relates to habitat change resulting from restoration actions;

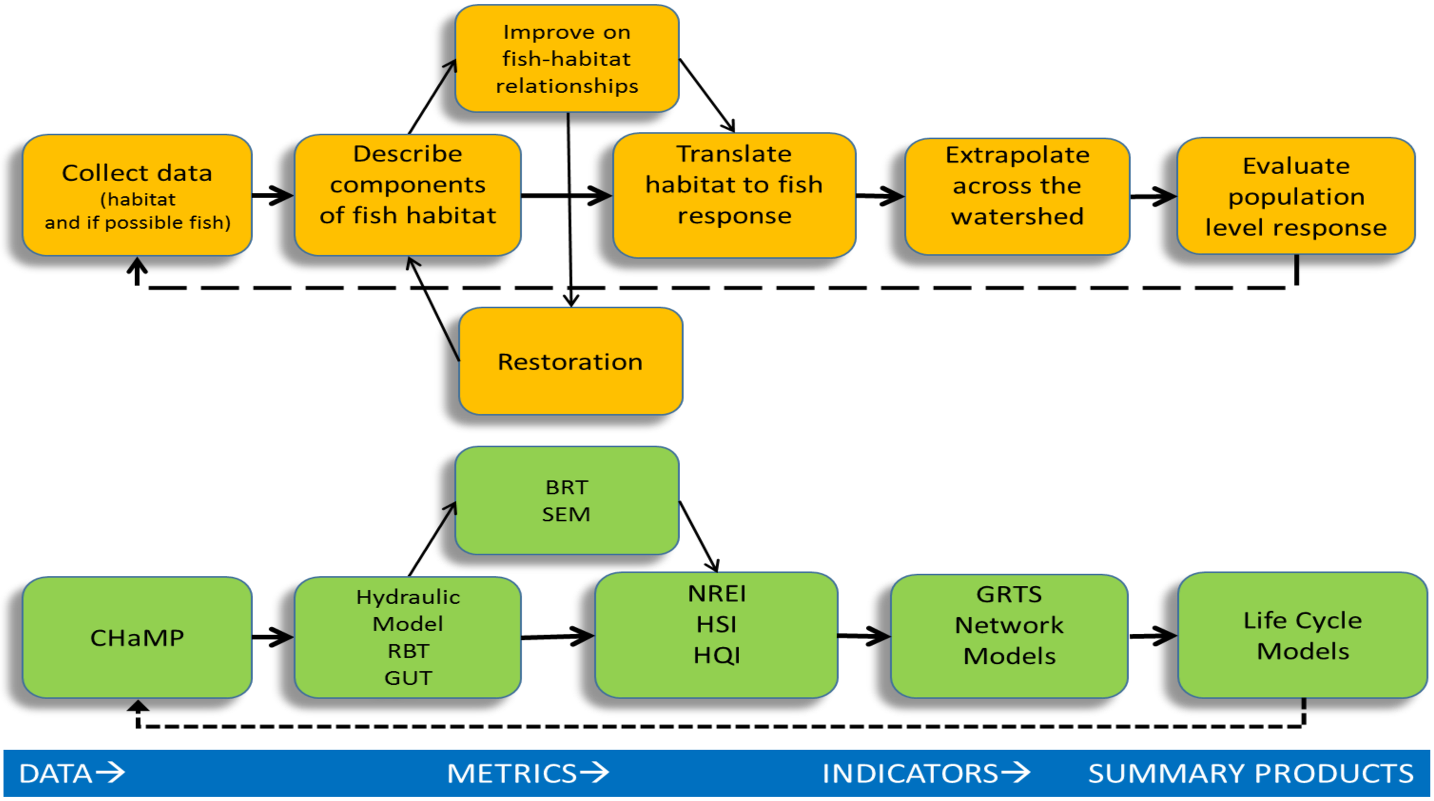


Figure 8. A step-wise process is used to meld the CHaMP and ISEMP workflows from data collection through the development of summary products to describe fish population response. The top panel (yellow) shows how the effects of habitat restoration are linked to an evaluation of fish response. The bottom panel (green) depicts the corresponding tools and products that have been developed or are under development to support answering the KMQs and other regional policy questions of interest.

- Refining tools to automate metric generation and analyses;
- Advancing the CHaMPMonitoring.org data management system to incorporate and share other types and sources of habitat metrics, and exploring the utility of integrated data sets and other metrics in fish-habitat relationship model development and to help answer KMQs;
- Piloting rapid geomorphic assessment tools and evaluating metrics to improve inputs to ISEMP's continuous models, and the ability to extrapolate to unmonitored areas.

Neither CHaMP nor ISEMP is purporting to be able to answer all of the KMQs. Some are being answered by the Expert Panels, while others need technical expert, stakeholder and decision-maker input as well as scientific interpretation. Projected timelines for products to support regional decision-making processes are presented in Table 6.

Table 6. CHaMP pilot product milestones and long-term development timeline.

Year	Milestone
2011	Pilot Implementation (Entiat, Wenatchee, Methow, Grande Ronde, Tucannon, John Day, Lemhi, and Secesh)
2013	End of first three-year cycle in the nine-year rotating panel design– status and trend info available. End of "Pilot." Implementation in Yankee Fork and Minam.
2014	Integration with the AEM project.
2015	Integrated CHaMP PIBO database. Development of material to support Expert Panel data summaries
2016	End of second three-year cycle in the nine-year rotating panel design.
2017	Long-term trends can be statistically identified. Development of material using 2011-2016 data to support BiOp data summaries.
2018	New FCRPS BiOp with updated Habitat Strategy
2019	End of third three-year cycle in the nine-year rotating panel design. Design evaluation.

CHAPTER II: CHAMP PRODUCTS TO SUPPORT THE ASSESSMENT OF TRIBUTARY HABITAT LIMITING FACTORS (KMQ 1)

KMQ 1: What are the tributary habitat limiting factors or threats preventing the achievement of desired tributary habitat performance objectives?

CHaMP generates the majority of the site-scale habitat information used by ISEMP for status and long-term trends detection, and supports the development of multivariate, continuous displays of habitat condition and limiting factors. Examples illustrating how CHaMP data were used by ISEMP and other collaborators in 2013 to address KMQ 1 are presented in the sections that follow.

Continuous Modeling of Geomorphic Classification and Condition

CHaMP habitat data are feeding ISEMP's development of a continuous classification of the geomorphic and habitat condition along the stream network (Figure 9). The purpose of this is to create a "global attribute" to support extrapolation of site-based CHaMP data to larger "rolled-up" scales and unsampled watersheds. The CHaMP-ISEMP "River Styles" geomorphic classification work is complementary to that being performed by NOAA and is designed to help support extrapolation and continuous map product development.

In 2013 CHaMP data were leveraged in ISEMP a geomorphic condition assessment in the Middle Fork John Day watershed, which was based on the River Styles framework (Brierly and Friers 2009; see CHaMP (2012) for background on River Styles and 2012 ISEMP efforts). Geomorphic classification was performed to provide geomorphic context (character and behavior) throughout the

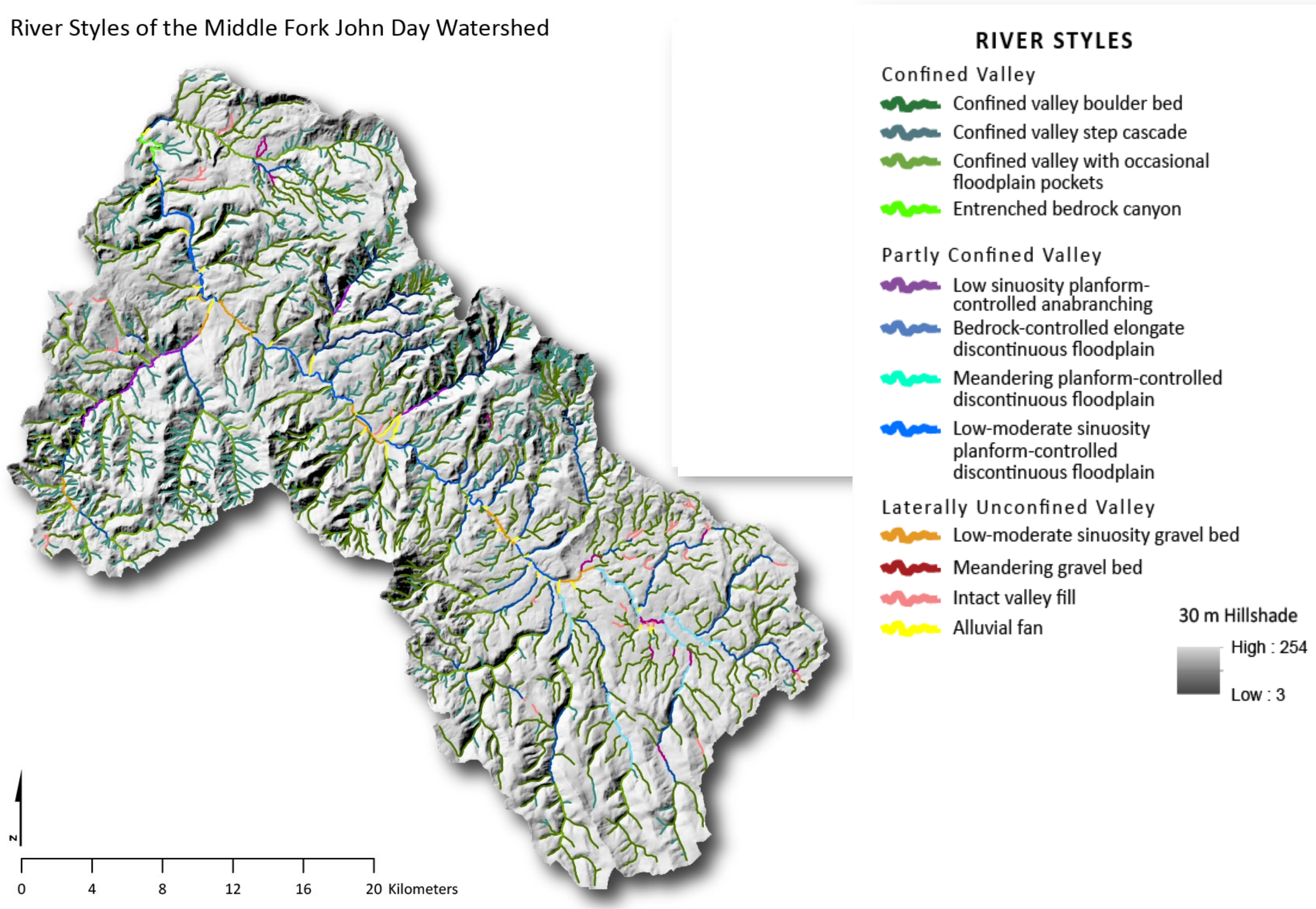


Figure 9. A River Styles (Brierly and Friers 2009) framework was applied in the John Day watershed to assess geomorphic condition and with this information, develop continuous maps of geomorphic potential across the stream network for use by managers to facilitate strategic restoration design and planning.

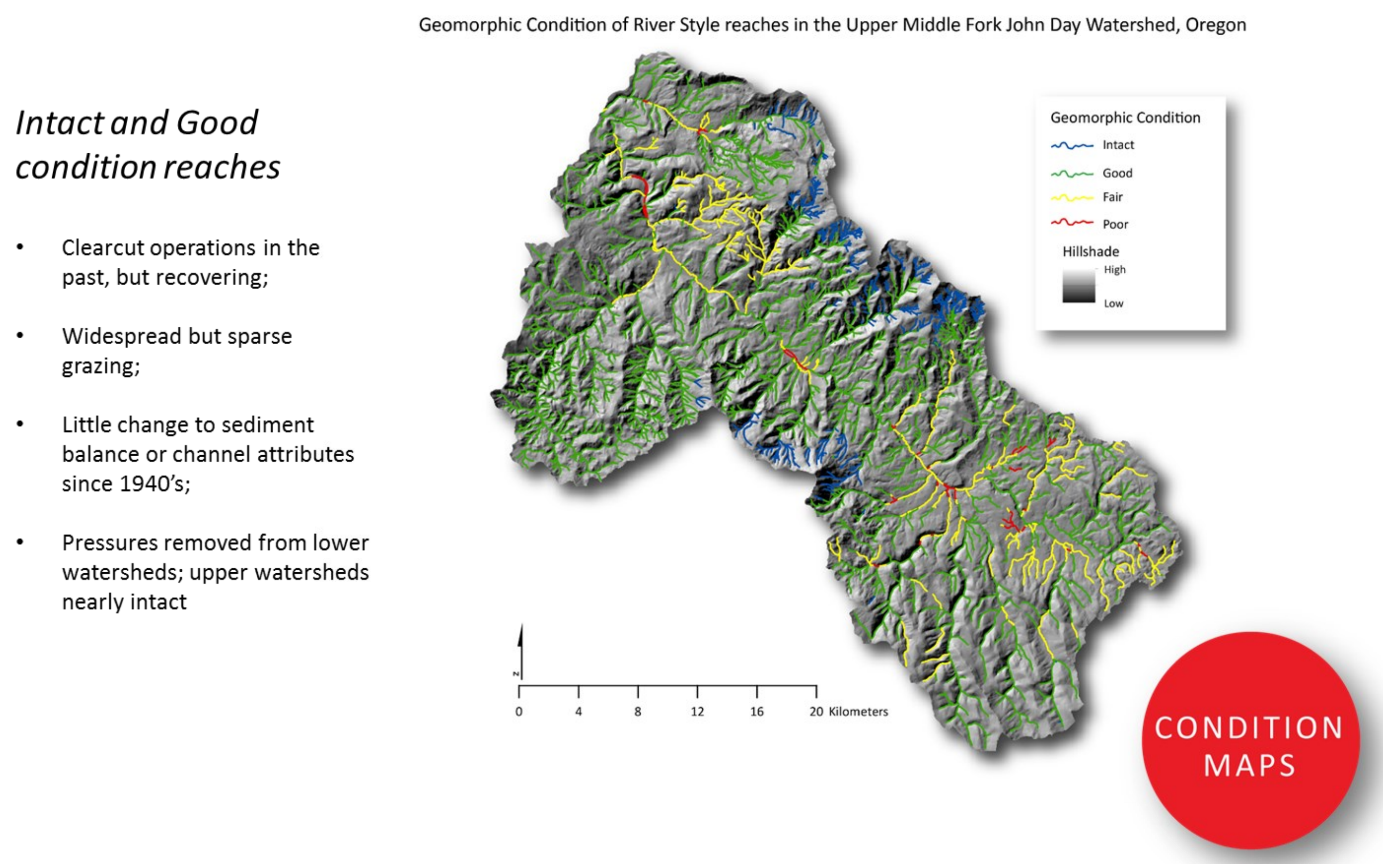


Figure 10. Continuous geomorphic classification and comparison to reference condition along a network paves the way for the development of geomorphic condition maps, by reach, to inform discussion about recovery potential by restoration planners.

catchment area (Figure 9). Each reach was evaluated within the context of reference condition and ranked to develop geomorphic condition information, by River Style reach, for streams in the watershed (Figure 10). Geomorphic condition assessments set the stage for the creation of geomorphic recovery potential maps along the entire stream network that can be utilized by restoration planners to support development of strategic tributary habitat improvement actions and plans (see Chapter III).

In 2014 the CHaMP-ISEMP team will focus on the development of continuous network map products, such as what have been depicted for the John Day, for other CHaMP watersheds, to meet upcoming regional planning process timelines. Pilot geomorphic condition assessment efforts are planned in the Wenatchee, Entiat, Tucannon, John Day and Yankee Fork watersheds to support development of expected versus observed geomorphic reach data. This work will leverage existing geomorphic and GIS data from sources such as USBR surveys, strategic habitat improvement plan information, etc.

Wider application of this approach in 2015 will inform discussion about its utility and next steps, including how to take the River Styles framework and further adapt it so that it is more useful for examining "fish-centric" management questions.

Mapping life stage-specific habitat limiting factors

In 2014, CHaMP collaborators CRITFC and ODFW continued their efforts to assess the status and trends in key limiting factors affecting ESA-listed spring Chinook in the Grande Ronde watershed. New 2013 CHaMP collaborators, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), provided support to ODFW and CRITFC in this effort. The example that follows shows how CHaMP's quantitative metrics are easily being incorporated with ODFW and CRITFC data into a literature and stream survey based habitat rating model (HabRate) intended to provide a map-based (network) qualitative perspective of reach habitat potential at multiple spatial scales for use by managers and restoration implementers.

CHaMP metric use in ODFW's HabRate limiting factors model

The HabRate model was developed by Burke et al. (2010) for a specific application to the middle Deschutes River basin in Oregon, but was intended for general application to Pacific Northwest basins. ODFW modified the HabRate model specifically for the upper Grande Ronde River basin and to accommodate inputs from ODFW and CRITFC CHaMP surveys from 2011 to 2013. This was done to

support BPA's Restoration Atlas process (described in the next chapter) and help provide an initial assessment of average conditions of the surveyed reaches for each life history stage, by assessment unit. The current distribution of the Chinook salmon spawning and rearing was used to select sites in the Catherine Creek basin for inclusion in the model.

Four classes of data shared between the Aquatic Inventories and CHaMP protocols were integrated into the HabRate model. These were substrate, channel morphology, habitat unit features, and large woody debris. Individual attributes within each category are listed in Table 7. ODFW parameterized the HabRate model using available literature on salmonid habitat requirements and developed values for discrete life history stages (i.e., spawning, egg survival, emergence, summer rearing, and winter rearing). Site-level summaries of stream habitat data used to generate a limiting factor assessment of potential egg-to-fry and fry-to-parr survival for each reach, and to rate the quality of stream reaches as poor, fair, good, or excellent based on attributes relating to stream substrate, habitat unit type, cover, and gradient. Thus CHaMP monitoring site data were leveraged to generate a rating of Chinook salmon habitat quality and potential limiting factors for three life history stages in the Catherine Creek basin.

CHaMP site-level metrics and ratings provide the coarsest resolution (points) to depict the spatial distribution of the HabRate evaluation (Figure 13). Individual metrics (e.g., complex pools, high quality spawning habitat) can also be mapped at a site level. As ODFW's Aquatic Inventories data are collected in a spatially continuous manner, HabRate results can be referenced to spatially-explicit hydrologic datasets and the results may be mapped at all levels, that is, averaged up to multiple spatial scales such as Hydrographic Units (e.g., HUC 6) or geomorphically defined assessment units (Figure 11).

For example, continuous maximum weekly maximum temperature (MWMT) data from CRITFC's heat source model

Table 7. Site (reach) level attributes (averaged values) included in ODFW's HabRate model application.

Substrate	Channel Morphology	Habitat	Wood
Percent fines	Reach length	Number of pools	Pieces of large woody debris (LWD)
Percent gravel	Channel area	Percent pools	Volume of LWD
Percent cobble	Gradient	Scour pool depth	Pieces of LWD per 100m
Percent boulders	Wetted width	Depth of riffles	Volume of LWD per 100m
Percent fines in riffles	Bankfull channel width	Pools per km	Key pieces of LWD***
Percent gravel in riffles	Large boulders*	Pools greater than 1m depth per km	Key pieces of LWD per 100m
Average percent boulders per pool	Large boulders per 100m**	Channel width (bankfull) pools	Average LWD per pool
	Percent open sky****	Number of pools per 100m	Average key pieces of LWD per pool
	Width to depth ratio	Residual pool depth	
		Percent undercut	
		Average percent undercut per pool	

*Numbers of large boulders are not included in CHaMP protocol, so percentages of boulders are used in its place. **Large boulders per 100m is not a metric that CHaMP produces, in its place we use percent boulders. ***Key pieces of LWD is defined as >30 cm diameter and >6 m length located in the wetted channel.

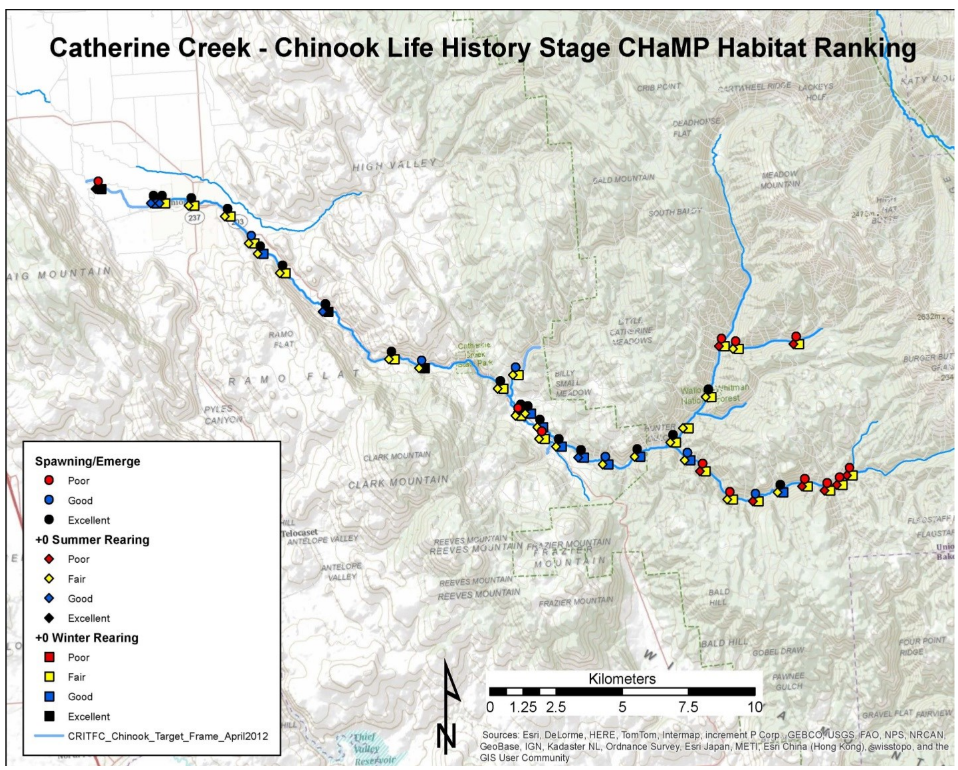


Figure 11. HabRate site level ratings for all three life history stages for Chinook salmon (spawning-emergence, summer rearing, and overwintering) in Catherine Creek.

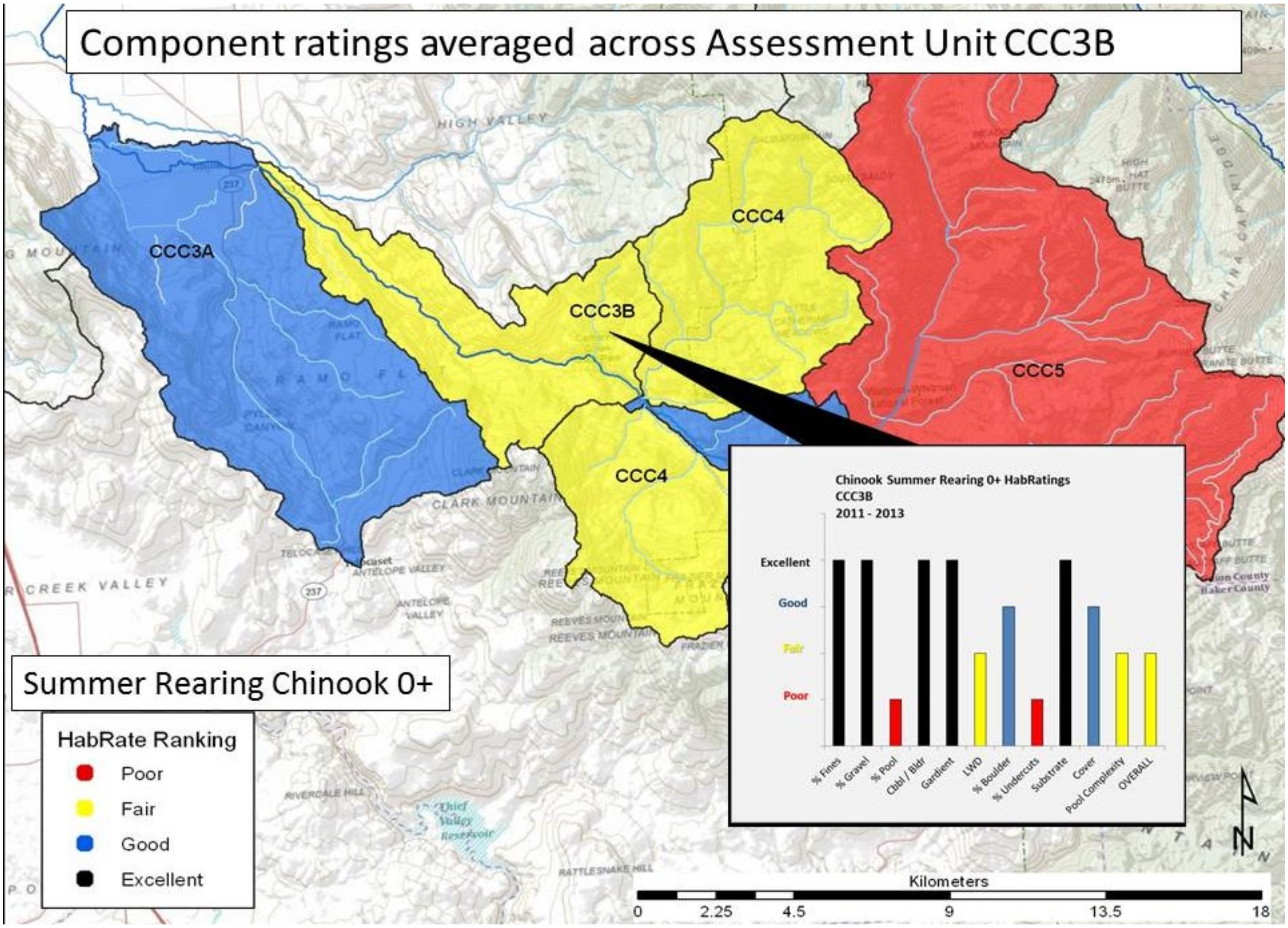


Figure 12. Averaged site level rankings by assessment units in Catherine Creek for summer rearing Chinook salmon parr based on conversion of limiting factors. In CCC3B, component ratings are averaged from all sites within the assessment unit. MWMT data from CRITFC's heat source model were considered as part of polygon (AU) ranking development.

were evaluated alongside HabRate rankings for summer Chinook parr rearing across major assessment units in Catherine Creek. Site-level ratings were averaged and used with temperature and flow information to provide context for limiting factors model outputs, and to generate a rating at a higher (polygon/AU) scale. Ultimately, structurally suitable areas in excellent condition for summer rearing of Chinook parr (e.g., CCC3A) were found to expose them to lethal stream temperatures, thus making survival questionable.

A strength of CHaMP's GRTS-based sampling design is that it also generates data that are appropriate to map and roll-up to multiple scales, and supports extrapolation to unsurveyed areas.

A cautionary approach is necessary during the development and interpretation of "rolled-up", higher-level displays like what is shown in Figure 12. *For Example:*

—Figure 12 displays higher-level ("rolled-up") summaries of habitat condition. The number of sites available to contribute data to the rating for each Assessment Unit might only be two (or less).

—-While CHaMP can make estimates of condition over larger areas to support Expert Panels and others with only two points, the estimates will not be very precise. Similarly, if sites that contribute data to a rating for an area are poorly distributed, they may not accurately represent overall conditions at a larger scale.

—CHaMP's sampling design selects sites randomly at the population scale. This enables site-level metrics to be used with globally available habitat attributes in continuous displays, such as what is presented in Figure 12, to generate metric "roll-ups" and extrapolation to unsampled areas.

—ISEMP has used CHaMP temperature metrics to develop a network model of temperature to support extrapolation within and across watersheds.

CHAPTER III: INFORMING IMPLEMENTATION OF EFFECTIVE AND COST-EFFECTIVE HABITAT ACTIONS (KMQ 2)

KMQ 2: What are the relationships between tributary habitat actions and fish survival or productivity improvements, and what actions are most effective, and cost-effective, for addressing habitat impairments?

Introduction

During Day 1 of the 2014 CHaMP-ISEMP analyses and synthesis workshop it was stated that restoration planners are in search of strategic versus opportunistic approaches to habitat restoration: that is, volumes of raw data (or even measurements or metrics) and abstract models without clear management relevance are not useful. Instead, having information summarized and mapped is what is useful for restoration planners (S. White, CRITFC). Indeed, while individual CHaMP metrics can be utilized in a "stand-alone" manner to help "true up" biological values, raw data and metrics without context and interpretation are likely not of high utility to strategic habitat assessment and restoration efforts. Further discussion about the information content of CHaMP metrics when they are used in combination or in the production of multivariate outputs, rather than alone, may be found in Chapter V.

The synthesis products presented in Chapter II and the ISEMP 2013 report (ISEMP 2014) are being used to help identification of sites that are most suitable for obtaining specific restoration goals, and the development of restoration designs. CHaMP and ISEMP data together have been used to produce recovery potential maps (see ISEMP 2014). Examples of how CHaMP data are being leveraged by ISEMP and other collaborators in the planning, prioritization and implementation of projects are presented in the sections that follow and in ISEMP (2014, 2013) and CHaMP (2012).

Supporting Strategic Habitat Restoration Plan and Project Development

CHaMP continues to use topographic surveys to create DEMs to capture changes in bed elevation, describe erosional and depositional patterns, and provide relative measures of sediment flux in stream reaches throughout the interior CRB. DEMs of difference (DoDs; see CHaMP 2013) are developed and used with Geomorphic Change Detection (GCD) software to calculate both areal and volumetric budgets of erosion and deposition at the site level, and perform inter-site comparisons using normalized change detection metrics. These metrics can also be used to assess net geomorphic change at multiple scales, for example, CHaMP basin-wide, network, reach and site level, and facilitate evaluation of restoration action effectiveness (e.g., Are the predicted responses actually happening?).

Specific examples of how CHaMP employed GCD in 2013 for planning, evaluation and hypothesis testing are presented below. The section that follows highlights how CHaMP data are being used by collaborators for strategic planning and prioritization in BPA's Grande Ronde Restoration Atlas process.

GCD for site context, informing design, and hypothesis testing

In 2013 GCD software and DoD data from the Tucannon watershed were used to assess geomorphic differences in physical fish habitat conditions across three sites, and to quantify changes (actual and modeled) due to restoration activities designed to address habitat limiting factors. The three sites include a highly dynamic and heterogeneous Reference site, a Control site that is less diverse and dynamic, and a Treatment site (levee removal). The Treatment hypothesis is that levee removal to allow channel movement and dynamic material exchange will allow the river to regain its natural capacity for adjustment, and result in the creation of side channels and diverse habitat units that greatly enhance fish habitat at the site.

As part of project hypothesis development and design the River Styles framework, discussed previously, was applied to establish geomorphic context for the sites, that is, habitat restoration potential based on historic and current landscape controls and features. The Treatment site has similar geomorphic context to the Reference site but represents a poor condition variant: a poor condition variant means dynamic behavior is limited and change is relatively static; a good condition variant means dynamic behavior, more complex assemblages of geomorphic units, which is good for fish.

CHaMP reference site data from 2011-2013 and GCD outputs were used to assign pre- and post- Treatment site behavior in terms of a condition variant, i.e., evaluate post-project behavior at the Treatment site. Although DoDs and GCD were able to capture and quantify habitat changes, the years after 2011 levee removal and 2013 LWD installation at the Treatment site were low flow years so not much change in the floodplain has been observed to date. However, development of a conceptual post-treatment survey and DoD allowed CHaMP to quantify expected restoration outcomes over time and a wider range of flow conditions (Figure 13, next page). These data will be used to evaluate actual habitat change from the restoration action(s) at the site over future years, and to inform future project planning and design.

CHaMP has also used GCD ahead of design development and implementation monitoring to test the hypothesis that implementation of beaver structures, such as what ISEMP installed in Asotin Creek (see Ward et al. 2012, CHaMP 2013), would be effective at other

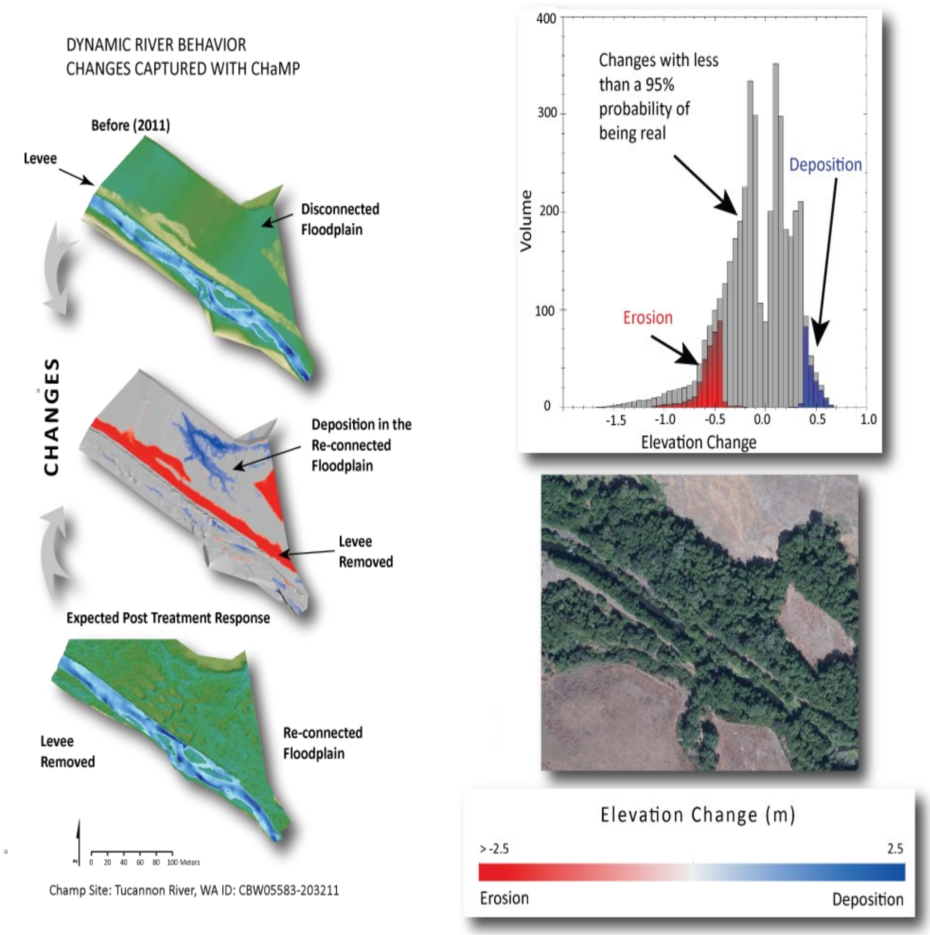


Figure 13. Conceptual repeat topographic surveys and DoD for a Tucannon CHaMP site CBW05583-203211 (treatment site) showing expected change (restoration of poor condition variant site). Levee removal was completed in 2011 and in 2013 LWD structures were introduced at the site to encourage lateral migration onto the floodplain and dynamic behavior (regular erosion and deposition, i.e., good condition variant).

planned restoration sites, and to what degree. This type of evaluation can facilitate identification of the potential outcomes of restoration scenarios well ahead of pre-post project implementation monitoring.

In another example, CHaMP has been collaborating with the USBR in the Methow Watershed on the collection of CHaMP data for use in restoration planning and life cycle modeling efforts. In July 2014, the Carlton Complex fire burned approximately 255,181 acres of the lower portion of the Methow watershed (BAER Briefing). Post-fire rainstorms induced debris flows in several of the tributaries that drain the hills to the east of the mainstem Methow River. In 2014 CHaMP performed an initial GCD assessment to determine the effect of the debris flows on the morphology of the channel and the habitat of the endangered salmonids species that use the lower mainstem Methow River. Data were collected at five mainstem CHaMP sites. The sites are located downstream from several tributaries that experienced debris flows including Beaver Creek; Frazer Creek, a tributary to Beaver Creek; and Benson Creek. The GCD software was used in conjunction with CHaMP topographic data to determine the changes to the channel before and after the debris flows. Additionally, pool tail fines and embeddedness metrics generated from surveys conducted in the three years prior to the disturbance (2011, 2012, 2013), as well as data collected following the disturbance (2014), were analyzed.

Initial results from the GCD analysis indicate that only minor geomorphic changes in the mainstem Methow River were caused by the debris flows in August 2014. The GCD software, however, detected a thin veneer of mud deposited along the banks and on channel bars in places. The majority of the geomorphic changes not influenced by uncertainty, especially interpolation errors, were caused by events prior to the debris flows, most likely the annual snowmelt flood(s) that occurred between surveys. Some of these changes include pool fill and scour, and bar aggradation. Of the three metrics analyzed, the most significant changes were detected in measurements of pool tail fines and embeddedness. There was from 75% to 1,523% increase in the percent of pool tail fines less than 6 mm measured at all five sites. Similarly, there was 1,251% to 2,064% percent increase in average embeddedness measured at two sites.

In general, the analysis of CHaMP data supports some of the preliminary projections stated by the BAER team: "Increased sediment may affect migrating fish in the lower Methow River, but most sediment increase is expected in steep non-fish-bearing streams. Sediment or a debris flow reaching the Methow River is likely (50-90 percent occurrence within 1-3 years), but consequences should be minor and the risk level is low." (From BAER Analysis Briefing: SW Carlton Complex 09/09/2014).

Lessons learned from this preliminary GCD analysis reveal the importance of capturing adequate survey extent and point density in key areas so that interpolation error, which arises when only one or two surveys cover a portion of the area of interest, is limited. After the first pilot year in 2011, CHaMP training emphasized the importance of more points outside of the bankfull area to capture areas that could be affected by larger flows and channel forming processes, such as what was experienced in 2014. Since emphasis on the expansion of survey extent at sites and added emphasis

on capturing all of the important features at a site, including the deepest portions of the channel and places where changes are likely to occur, has improved the quality of CHaMP surveys over the pilot, the addition of future surveys should minimize interpolation error in the production of DoDs and GCD results.

Informing spring Chinook recovery planning in the upper Grande Ronde

In 2013 CRITFC and ODFW continued use of Accords (BPA Project No. 2009-004-00) funds to capitalize on CHaMP topographic data and DEM products, and related ISEMP synthesis products (i.e., HSI, NREI, and flow models that use CHaMP metrics as inputs). CHaMP also supported ODFW's work in 2013 to continue sampling in the Minam River watershed, a collaborative effort between ODFW and CRITFC, so that a wilderness stream could be include to inform estimates of reference condition for the Grande Ronde Restoration Atlas, which is being developed to focus restoration in high priority geographic areas. The Atlas process is supported through a Stakeholder committee and a science technical advisory committee (TAC) composed of multiple agencies (BPA, ODFW, CTUIR, United States Forest Service, US Bureau of Reclamation (BOR), CRITFC, NOAA, Union Soil and Water Conservation District, the Grande Ronde Model Watershed, and others). The Atlas process is working to address critical limiting factors to:

- Develop species and life stage-specific recovery options
- Provide baseline restoration design information
- Inform design in unmonitored areas/sites
- Allow design hypothesis testing prior to restoration project development and implementation.

Figure 14. depicts how CHaMP survey data are being leveraged by Atlas participants to identify specific population-level limiting factors, identify and prioritize restoration activity types, and help predict the outcomes of likely restoration scenarios. To identify relationships among natural conditions, human-caused disturbance and habitat limiting factors (Figure 15, next page), CRITFC is using its fish abundance and benthic macroinvertebrate data along with CHaMP topographic and auxiliary metrics.

In 2013 CRITFC also used CHaMP data to inform Chinook salmon and steelhead life cycle models for fry through smolt life history stages. McNeil core samples and CHaMP pool tail fines data (<6mm) were used to develop a relationship that enabled examination of the proportion of fines, in conjunction literature-derived values of mortality, to derive egg-to-fry survival estimates based on percent fines (Figure 16) not accounting for other sources of mortality.

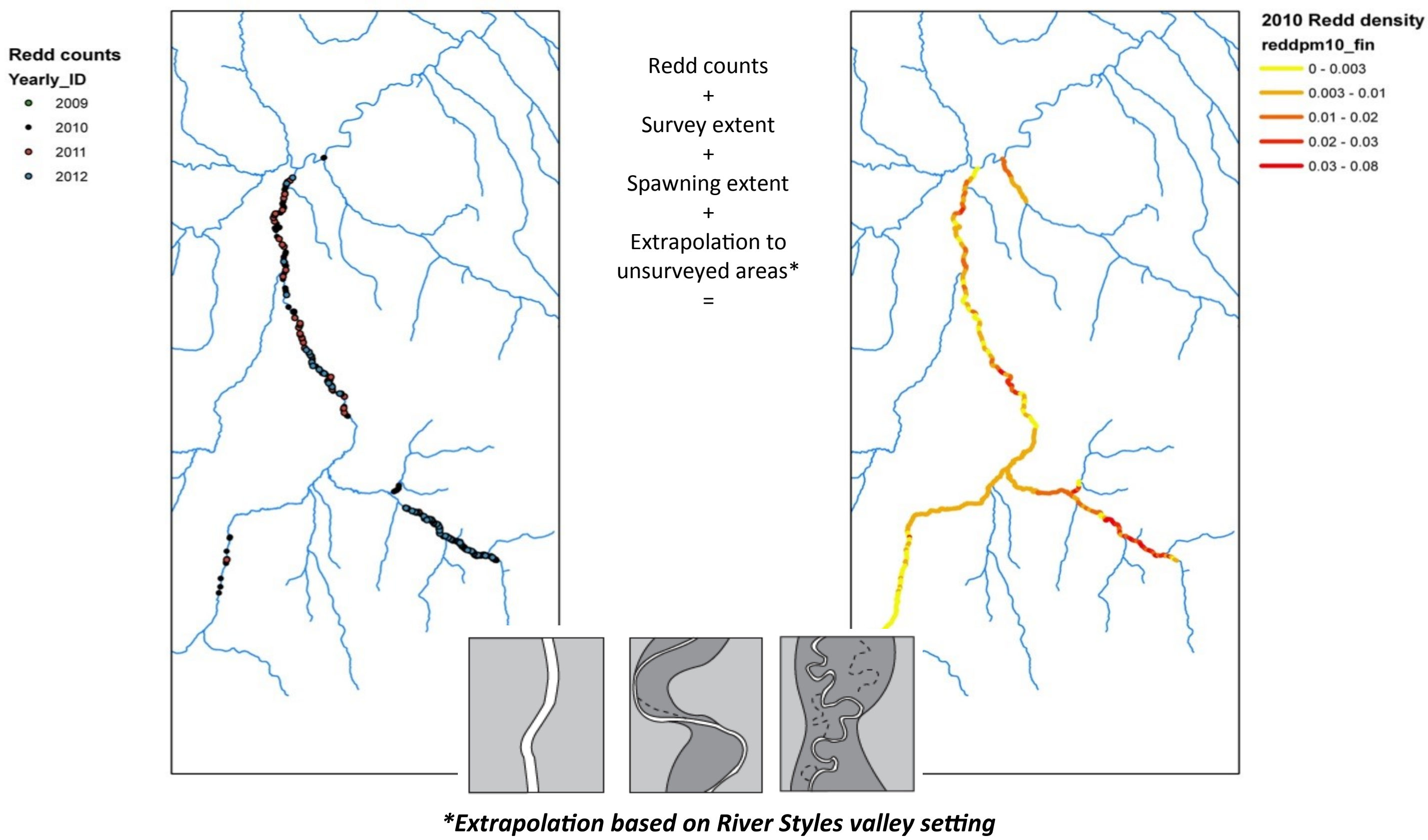
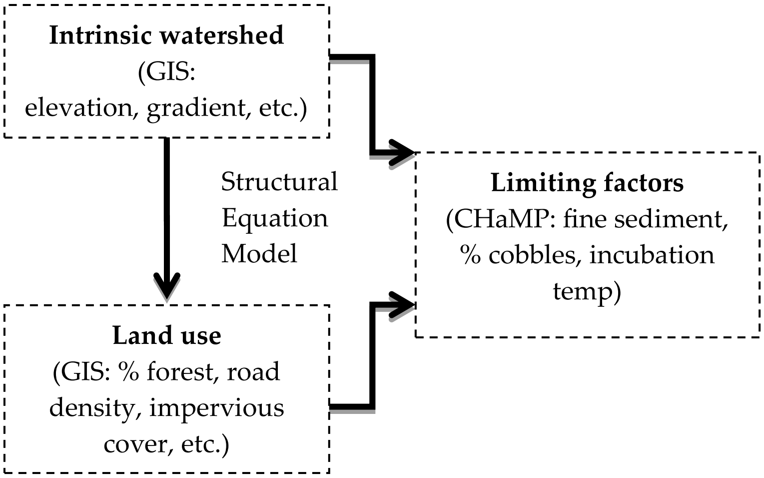


Figure 14. CHaMP survey data were used by CRITFC and ODFW to validate a river classification based on reach-scale valley morphology. This information was used with fish information and professional interpretation to predict areas of Chinook spawning and redd densities in unsurveyed areas of the upper Grande Ronde watershed, OR.



CHaMP's standardized metrics have been used by ISEMP and others to:

- Inform and improve life stage specific habitat limiting factors assessments and benchmarks.
- Assess degree of habitat impairment by comparing current conditions to benchmarks.
- Improve limiting factors assessments at multiple spatial scales (e.g., by using network models)
- Integrate snorkel parr density and habitat data to identify core production areas by habitat type to estimate the proportion of summer Chinook parr produced by each AU in Catherine Creek.

Figure 15. CRITFC is using CHaMP metrics and other information for identification of fry through smolt life stage habitat limiting factors and parameterization of its life cycle model. For detail on the development and application of the Structural Equation Model (SEM), which utilizes CHaMP data, please see Ward et al. (2012) and CHaMP (2013).

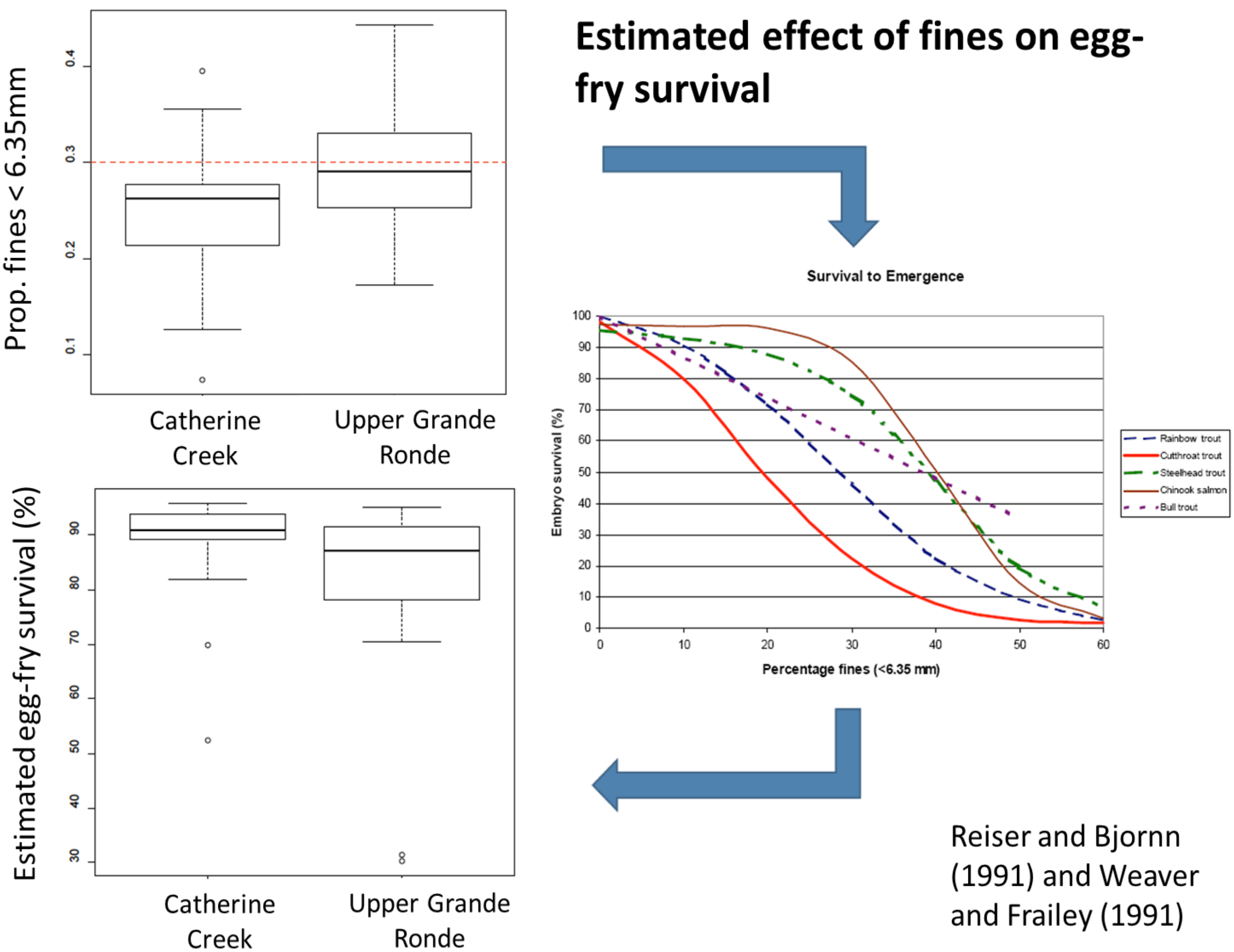


Figure 16. CHaMP pool tail fines data were used by CRITFC to develop preliminary life stage and species-specific survival curves to evaluate habitat limiting factors (fines), not accounting for other sources of mortality (CRITFC).

CHAPTER IV: ASSESSMENT OF EFFECTIVENESS OF RESTORATION STRATEGIES ON HABITAT AND SALMONID POPULATIONS (KMQ 3)

KMQ 3: Are tributary actions achieving the expected biological and environmental improvements in habitat [and improving survival of specific fish life history stages through species growth or habitat capacity]?

CHaMP is *not* configured to independently develop fish/habitat relationships, as it is designed to collect tributary habitat status and trends monitoring data. Therefore, a limited number of "unifying" product examples that the CHaMP-ISEMP team has developed, and which will be automated for use in all interior CRB watersheds, is presented in this report..

Nonetheless, CHaMP's collaboration with a wide range of regional partners is enabling ISEMP and others to relate tributary habitat changes to the freshwater productivity of anadromous salmonids. We feel that this report fully demonstrates the relevance of CHaMP data and products in this regard, as the examples in the Executive Summary and on the preceding page clearly show how CHaMP metrics are being used to parameterize and validate life cycle / watershed production models to elucidate the relationship between habitat change and fish population response—the heart of KMQ 3.

Because ISEMP is the driving force behind the development of fish-habitat relationship syntheses models and products that are fed by CHaMP habitat metrics, integrated reporting on the status of fish-habitat relationship development in the IMWs and other CHaMP watersheds will occur in the 2014 ISEMP-CHaMP report, scheduled for production in Spring 2015. The new integrated report structure will be similar in that it will facilitate comprehensive discussion and presentation of how ISEMP-CHaMP efforts are helping to address all three of the KMQs, as well as other regional salmonid management and policy questions.

CHAPTER V: SUPPORTING HABITAT MANAGEMENT DECISION-MAKING THROUGH CHAMP'S SURVEY AND RESPONSE DESIGN

Background

Since 2011 Council, ISRP and BPA staff members have posed a number of questions about the rationale for, and the pros and cons of, CHaMP's survey and response design. These questions include:

- Examine the difficulties and potential benefits in incorporating *ad hoc* data when trying to extrapolate to other areas;
- Describe how site selection is influenced, if at all, by proximity to ongoing…restoration actions;
- Explain how habitat and fish samples are/should be distributed across watersheds to address KMQs;
- Describe what CHaMP has learned through evaluations of sampling intensity and the number of sites.

Responses to policy and management questions are provided within the discussion that follows.

Evaluating CHaMP's Sampling Design

In order for a monitoring design to be deemed 'successful', objectives must be specified such that design implementation provides the data to meet the objectives. At a coarse level, CHaMP's objectives are to characterize status and trends of a variety of Technical Recovery Team (TRT) salmon and steelhead stream channel habitats in a diversity of interior Columbia River Basin watersheds. CHaMP uses a 'design-based approach' for site selection/sampling, that is, it relies on the concept of statistical sampling by which a subsample of sites is selected using Generalized Randomization Tessellation Stratified (GRTS) techniques to achieve a balance between a design that is optimized for status estimation (the more unique sites the better for status estimation) and a design that is optimized for trend detection (repeating sites over years is best for trend detection). The CHaMP 2011 and 2012 reports contain details on GRTS design and how it balances status and trend objectives using a 3-year rotating panel design, with annual and unique sites within each panel, over its 9-year sampling framework (Ward et al. 2012, CHaMP 2013).

Over the pilot CHaMP has automated the process of GRTS sample weight adjustments using R code to ensure accurate, properly weighted estimates to support status and trend detection. Specifically, the CHaMP design supports estimates of CHaMP metric frequency distributions and related summary statistics (status: means, medians, %-tiles), and their change over time (trend), along with uncertainty estimates (i.e., standard errors). The design allows making estimates by various strata (e.g., by watershed, valley class, or assessment unit) or time scales (by year, or an average across years). These estimates are available as data files or graphic outputs (Figure 17).

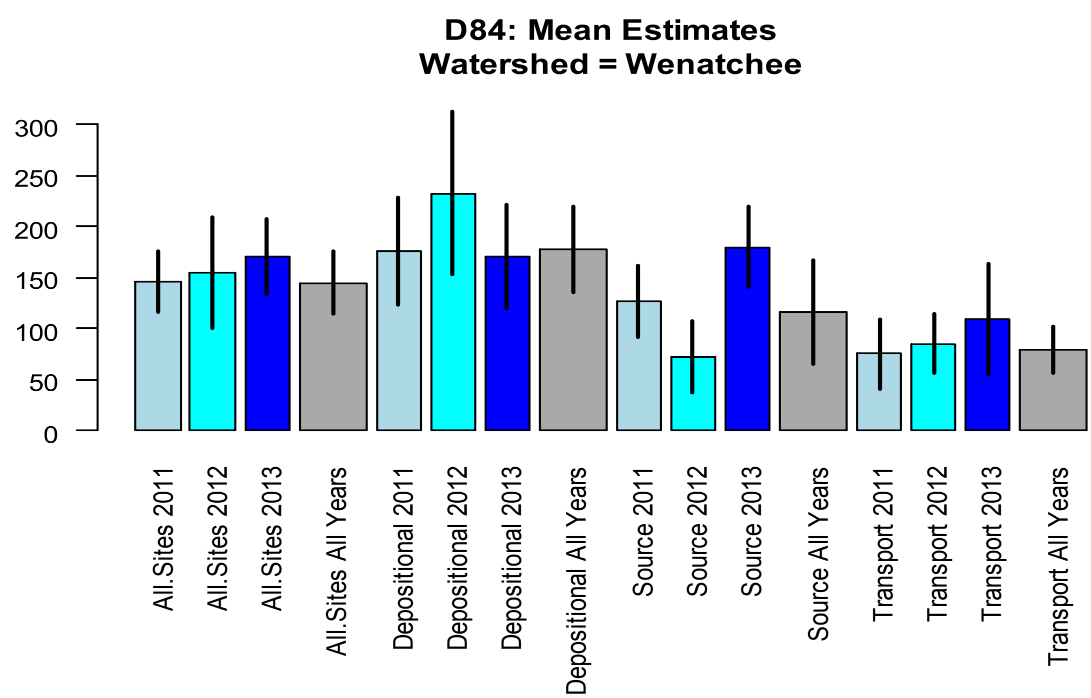


Figure 17. Graphical display of D84 mean estimates from 2011-2013 CHaMP data.

Balancing Program Objectives

Lessons learned from CHaMP project implementation from 2011-2013 have clearly shown that "objectives compete for samples" both with respect to CHaMP's design and with respect to external pressures on project resources. In 2013, BPA requested that CHaMP explore how its sampling effort could be leveraged to meet objectives of other programs and/or effect potential sampling efficiencies. Questions posed to CHaMP included whether CHaMP sites could be used as control sites within the AEM MBACI sampling design in order to reduce sampling effort and the overall number of sites between the two projects. Indeed, select CHaMP sites were able to be incorporated into the new and evolving AEM sampling design(s); however, CHaMP-ISEMP team members advised that efforts to relocate existing CHaMP or ISEMP IMW sites in an attempt to meet sampling location needs of the AEM program (or other programs) could diminish the power of CHaMP's design-based approach to status and trends detection. The range of competing objectives that confronted the CHaMP project in 2013 is presented in Table 8.

The first three years of CHaMP's sampling results can be used to evaluate the extent to which CHaMP's metrics and design can be made more efficient, given the estimated variance structure from 2011-2013. Further discussion is necessary to evaluate whether effort to balance competing monitoring program objectives through sampling design alterations will actually be beneficial.

Please refer to Chapter VI for more discussions of metric interoperability and the need for quantitative comparisons between what would be lost to CHaMP's primary objectives, and what would be gained by competing program objectives, if alterations are proposed.

The Role of Randomization in CHaMP Site Selection

CHaMP's sampling designs are based on a spatially balanced, randomized site selection algorithm (GRTS; Stevens and Olsen 2001) and sample sites are assigned weights to represent the extent of the population represented by the site (for example, the number of stream km the site represents; ; see CHaMP 2013 for more information on sample design and weighting).

The difficulty with including sites that are hand selected (or opportunistically or judgmentally selected) is that unknown bias can be introduced by a site's inclusion in the sample, because of its unknown selection probability. While the addition of ad hoc sites has the potential to increase the number of sites within the CHaMP domain and increase precision at the assessment unit (and CHaMP domain) scale, these additional non-CHaMP sites create the need for a mechanism to assign weights to them. The added value of these non-CHaMP sites might be minimal. For example, it is safest to assign a weight of one to these sites (that is, the represent only themselves). If, for example, each CHaMP site had a weight of 10, it would take 10 non-CHaMP sites for the equivalent value of a CHaMP site for watershed scale status and trends estimates. If ad hoc sites are included, investigators must make implicit assumptions about what the site represents. If such assumptions are valid, the opportunistic site could be assigned more weight; however, challenges still lie in the fact that overall results may be skewed because of where an ad hoc site is located on the landscape, that is, the location of the site was not selected randomly. Further, in some watersheds such as IMWs, sites are deliberately intensified as part of the study design. Therefore, it is imperative that monitoring practitioners understand underlying study objectives when seeking to alter design-based

Table 8. Summary of competing monitoring program objectives and potential outcomes of program modification.

Competing Objective	Comment	Outcome 1	Outcome 2	Outcome 3
Characterize Assessment Units within watersheds (e.g., 5th field HUCs)	Implies increasing sample size within a watershed i.e., increase within CHaMP watershed sample size	Increases precision at assessment unit scale (as well as at CHaMP scale)		
Characterize watersheds outside CHaMP domains	Implies decreasing samples allocated to current CHaMP watersheds	Decreases precision at CHaMP watershed scale, and especially at AU scale		
Reduce or eliminate annual sites		Reduces linkage across years	Reduces ability to increase precision of 3 year panel sites for trend	Reduces ability to estimate 'year' variation and its implications
Alter CHaMP panel structure, e.g., increase to 5-year panels		Extends temporal domain to 15 years	Full trend power not achieved until after 15 years	Reduces sample size for 3 year status estimates
Incorporate sites from other monitoring programs		Creates need for mechanism to estimate non-CHaMP site weights	Potential to increase sample size within CHaMP domains	

sampling. Arguably, a better near-term path is using hand-selected sites in combination with CHaMP's randomly selected sites in a model-based approach, discussed later in this section.

Sample Size Optimization

One way of examining stability of the sample is to evaluate how variance changes as sample size increases. Initially, increases in sample size results in rapid increases in the precision of population variance estimates. For example, for a small sample of 5 – 10, the variation in the metrics among the samples could be quite low, near zero, in which case the sample would indicate that the target population has little variation. On the other hand, a sample could have substantially higher variation. The rapid increase in precision tails off at a sample size of 40-50 sites. The range in variation among samples of size 50 is substantially lower than that seen for sample sizes of 5 – 10. However, adding more sites contributes less and less to improving precision. CHaMP's selection of a target sample size of 45 reflects the balance of a reasonable sample size with the cost of increasing sample size, either through inclusion of more randomly selected sites or ad hoc sites, and further diminishing returns.

Effectiveness of Sample Stratification

CHaMP adopted a coarse geomorphic classification by 'valley class', that is, sampling strata were defined using unique combinations of valley class (source, transport, and depositional) and ownership type (private or public), based on the belief that these two factors would account for significant variation in many important habitat metrics (see CHaMP 2013). Sample stratification is used in most CHaMP watersheds to help improve the precision, for a given sample size, of status and trends estimates where strata-to-strata variation accounts for a significant portion of the overall spatial variation of a metric.

In 2013 a design-based analysis using three years (2011-2013) of CHaMP data was completed, using the spsurvey package in R, in order to check whether valley class and ownership type indeed account for a significant portion of the spatial variation observed in CHaMP metrics. Of particular interest was whether private versus public ownership is a meaningful distinction or not, as there is less certainty regarding this than there is in the impact of valley class. In the analysis, the three year average site-level response was used for annual sites, while a single response was used for rotating panel sites. The effect of year was ignored, since previous analysis has shown year-year variation to be negligible over the three year period in which data have been collected thus far.

Results for three watersheds (the John Day (JD), Lemhi (LEM), and Upper Grande Ronde (UGR)), which were selected because they each contain all combinations of valley class and ownership type, indicate many CHaMP metrics, as expected, vary significantly by valley class. Furthermore, a few key metrics, especially metrics related to large woody debris, appear to vary significantly by ownership type within each valley class. Details from these three watersheds are provided in the discussion that follows.

Figure 18 shows the relative values from the three watersheds for mean fast turbulent frequency by valley class and ownership type. The shade of blue corresponds to valley class, with dark blue, blue, and light blue indicating source, transport, and depositional, respectively. The fill type indicates ownership type, with solid fill indicating private (Pvt) ownership, and hatched fill indicating public (Pub) ownership. For fast turbulent frequency, there is significant variation across valley classes, and the pattern is consistent across each watershed. There is not a strong or consistent pattern seen between public and private ownership classes. Significant variation by valley class is observed again in Bankfull Width Profile Filtered Mean, but very little variation is seen between ownership types within a valley class (Figure 19, next page) .

In both estimated Bankfull Large Wood Frequency per 100m (Figure 20) and Bankfull Large Wood Volume in Fast-Turbulent (Figure 21), significant variation is seen across valley class and between ownership types within a valley class. For the variation by ownership type, we see significantly higher levels of woody debris at publicly owned sites than at privately owned sites. This pattern is observed in most of the large woody debris CHaMP metrics.

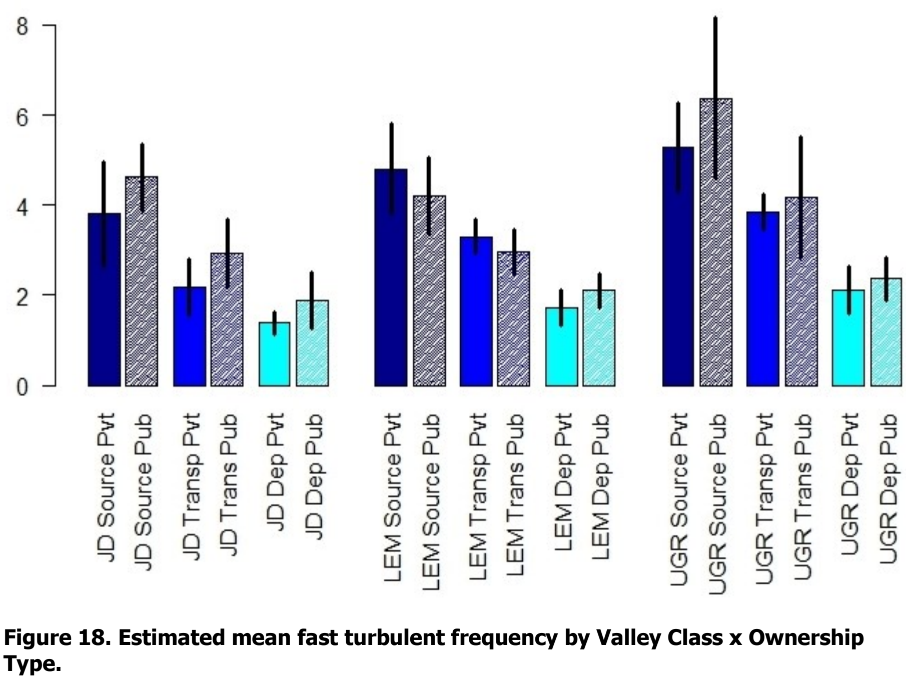


Figure 18. Estimated mean fast turbulent frequency by Valley Class x Ownership Type.

Boulders (i.e., percent substrate of boulder-sized particles) is another key CHaMP metric that appears to vary significantly by both valley class and ownership type within a valley class, as exhibited in Figure 22. Again, we generally see higher levels of the metric in publicly owned sites than at privately owned sites.

It appears that, for at least some key CHaMP metrics, valley class and ownership type can account for an important part of overall variation within each watershed. This suggests that they may indeed be suitable attributes over which to stratify sampling designs, assuming that the metrics that exhibit variation over these strata are important metrics.

More detailed analysis, estimation of power curves, etc., may be useful in optimizing sample sizes per stratum, and/or to examine attributes other than valley class and ownership type as potentially superior strata classifiers, keeping in mind that optimal sampling design must combine robust analysis with an artful balance of: differences in perceived importance across metrics, competing and sometimes shifting objectives, uncertainty (especially in the behavior of temporal trends), and the often under-appreciated value of keeping a design unchanged over time even if the design is less than optimal. The results presented here, as well as examination of plots as shown above across the entire suite of CHaMP metrics, do not suggest the need for any immediate change in how CHaMP designs are stratified.

An interesting topic for future investigation is the possible reasons for observed differences between privately and publicly owned CHaMP sites. Ownership types are not distributed in a spatially random manner within a watershed, and it may be that many of the observed differences are due to inherent

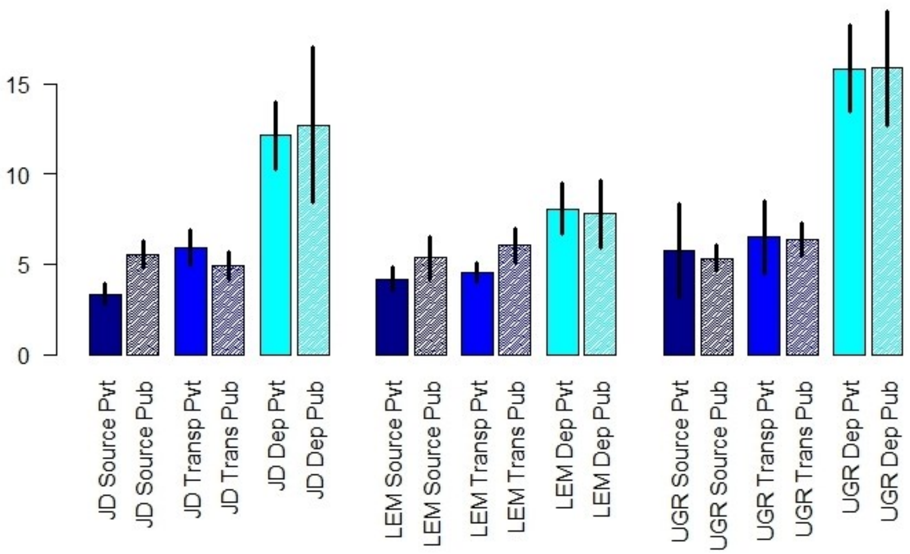


Figure 19. Estimated mean bankfull width profile filtered mean by Valley Class x Ownership Type.

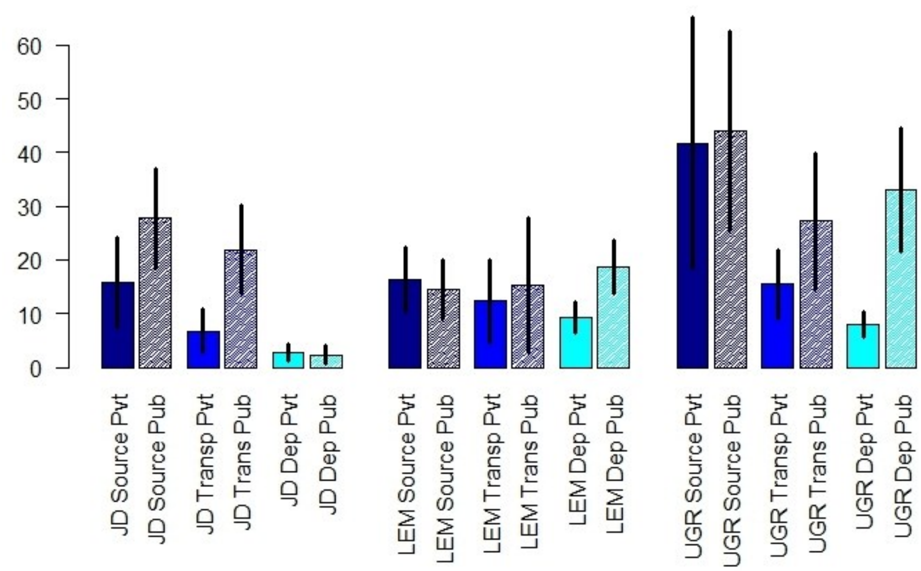


Figure 20. Estimated mean bankfull large wood frequency per 100m by Valley Class x Ownership Type

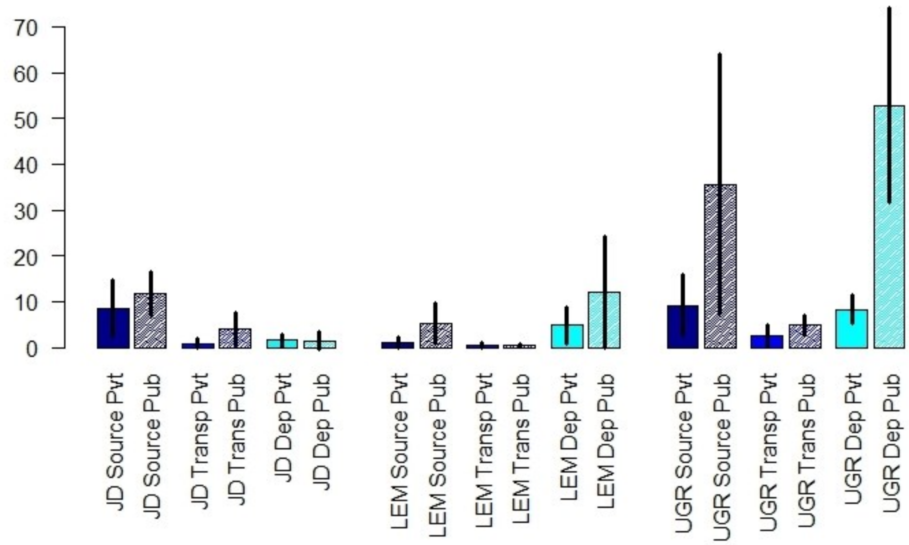


Figure 21. Estimated mean bankfull Large wood volume in fast-turbulent by Valley Class x Ownership Type.

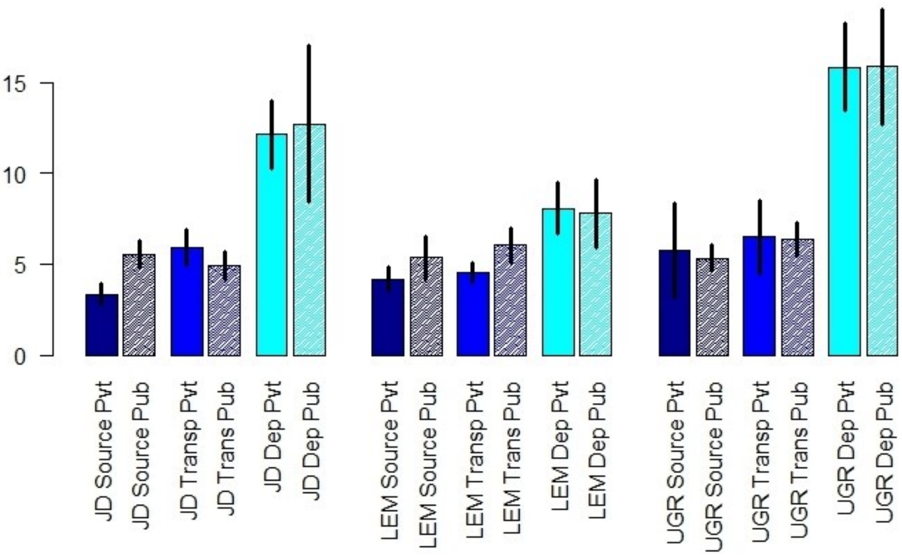


Figure 22. Estimated mean boulders by Valley Class x Ownership Type

habitat characteristics correlated with the likelihood of an area to be publicly or privately owned, rather than, say, direct management of the land. However, since valley class might be expected to account for much of that variation, and ownership differences are still observed within valley classes, it may be of interest to attempt to further understand what drives habitat differences between publicly and privately owned sites.

Linking CHaMP Surveys with Spatially Explicit Models

CHaMP's approach to estimating and summarizing survey data relies on the concept of statistical sampling by which a sample of sites is selected using randomization techniques. The results of a design-based approach are not intended to be spatially explicit but do allow inferences about an attribute's spatial variation across a network of interest, as illustrated by the frequency distribution.

This approach can be contrasted with what is often called a 'model-based' approach or more explicitly in the cases described here: spatially explicit modeling. Spatially explicit models are built to correlate site specific stream attributes with attributes that that can be mapped or determined at all locations in the population domain. Such models allow mapping of the attributes at all locations in the target network.

Results from both design– and model-based approaches can be summarized in a similar way, for example, in popular "stoplight" pie diagrams that might characterize habitat condition as good (green), moderate (yellow), or poor (red); see Figure 23 on the next page. These two different approaches are complimentary in that data produced by CHaMP's sample surveys can be used in the development of such models.

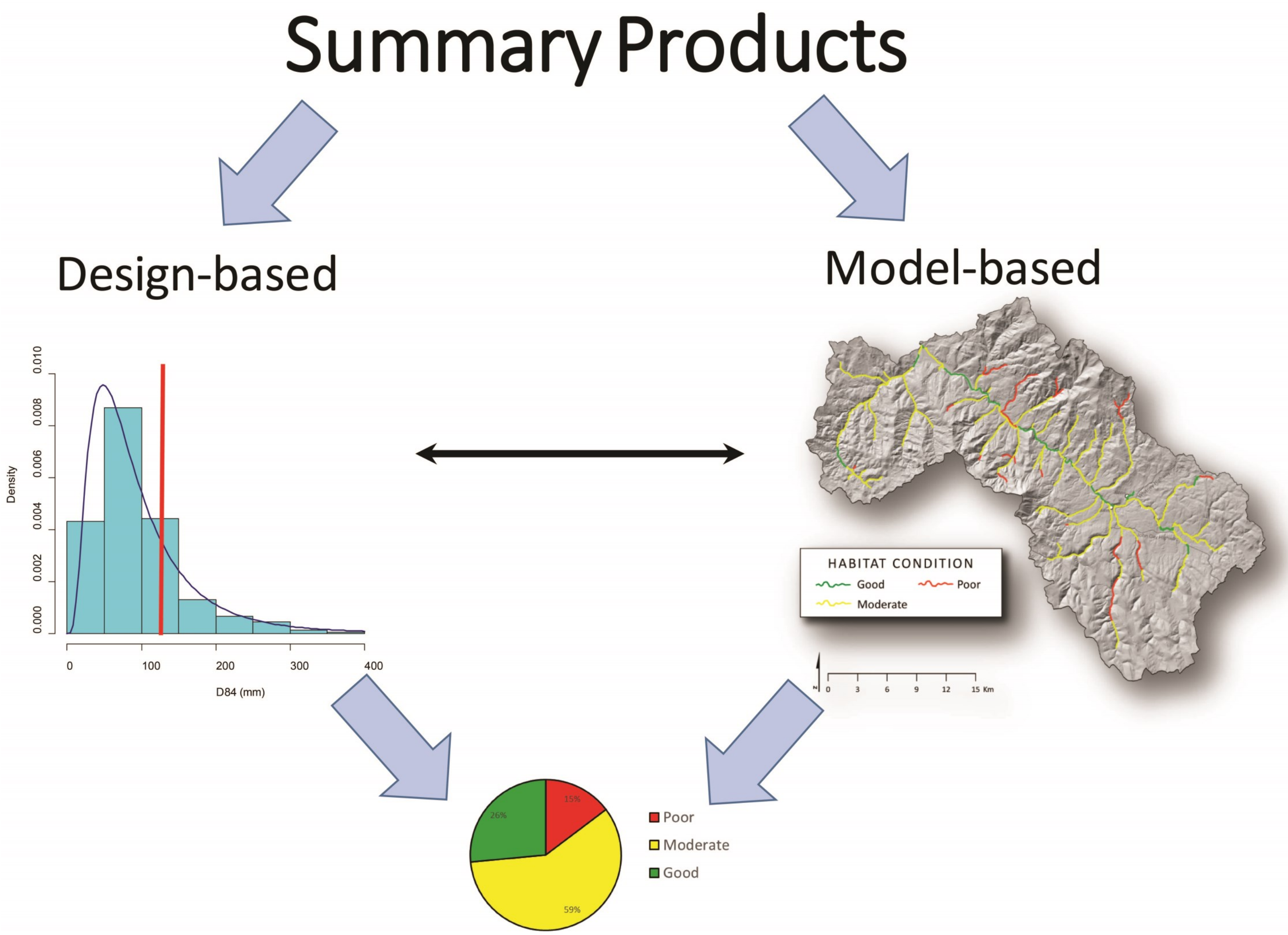


Figure 23. A conceptual illustration of t wo approaches for characterizing the condition of stream networks and the development of summary products.

In Figure 23:

- The results of a design-based approach (on which CHaMP's sampling is structured) allows inference about an attribute's spatial variation across a network of interest, as illustrated by the frequency distribution, and are not intended to be spatially explicit.
- A spatially explicit model relates stream habitat attributes to characteristics that can be described spatially. If adequate models can be developed, the results can be mapped (i.e., the results are spatially explicit).
- In both cases, results can be summarized as frequency distributions or summary statistics like pie diagrams that might illustrate the proportion of the resource that is in good, moderate, or poor condition.

CHAPTER VI: CHAMP METRICS ASSESSMENT

- ***What has CHaMP learned about the appropriateness and value of its protocols and metrics through testing in select basins?***

Introduction

CHaMP has used annual metric diagnostics from 2011-2013 to make specific refinements to its measurement protocols and sampling design after each field season, with changes to metrics primarily aimed at improving the previous year's metric 'performance' and enacting efficiencies. Adjustments continue to be fed forward into the development of indicators, analyses and summary products (see ISEMP 2014) that depend on CHaMP metrics as inputs.

A key part of the metric assessment process is evaluating how well CHaMP is able to characterize variation and whether its metrics are capable for use in ISEMP's and other collaborators' models. In 2013 CHaMP-ISEMP analysts again used variance decomposition to identify how well metrics are performing. As an example, CHaMP channel dimension and profile metrics were assessed graphically to determine if they are performing well (Figure 24). Measurement noise is generally small for these CHaMP metrics, relative to site-site.

In 2013 CHaMP-ISEMP analysts performed follow-up metric evaluations to determine whether protocol changes from 2012-2013 made measurement error better or worse, and to inform future CHaMP-ISEMP efforts to improve the protocol and metric performance. For example, between 2011 and 2012, ISEMP found that sampling 210 particles per site was excessive with respect to required precision. After the 2013 field season, when fewer particles per site were sampled, 2012 and 2013 data were evaluated (Figure 25). Only small (if any) decreases in precision in D84 and related metrics were seen. As expected, there was no apparent reduction in precision of valley class and watershed level estimates.

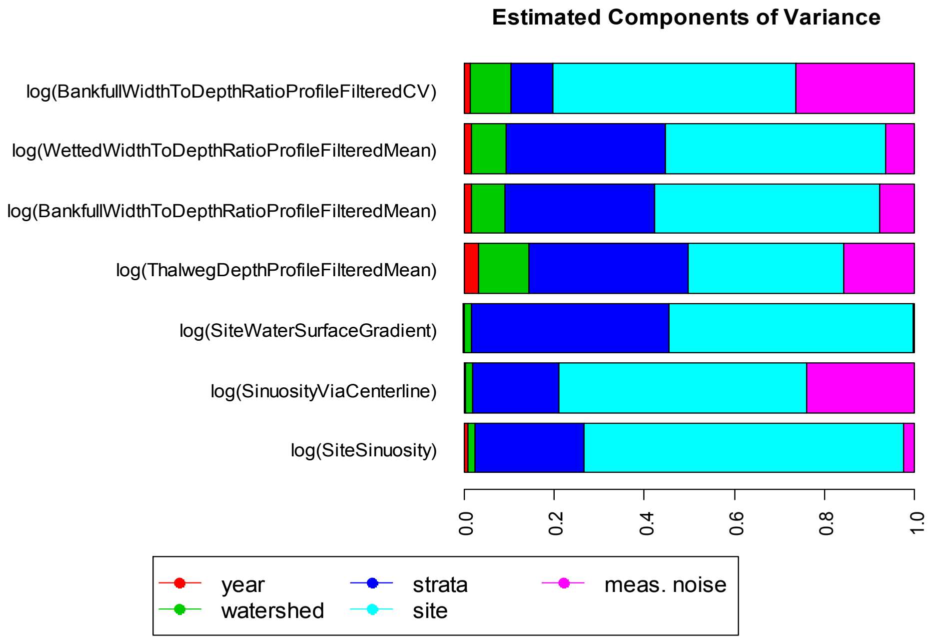


Figure 24. Components of variance in CHaMP depth profile, water surface gradient, and sinuosity metrics. Most variance occurs site to site and across strata, while changes across time are small in comparison.

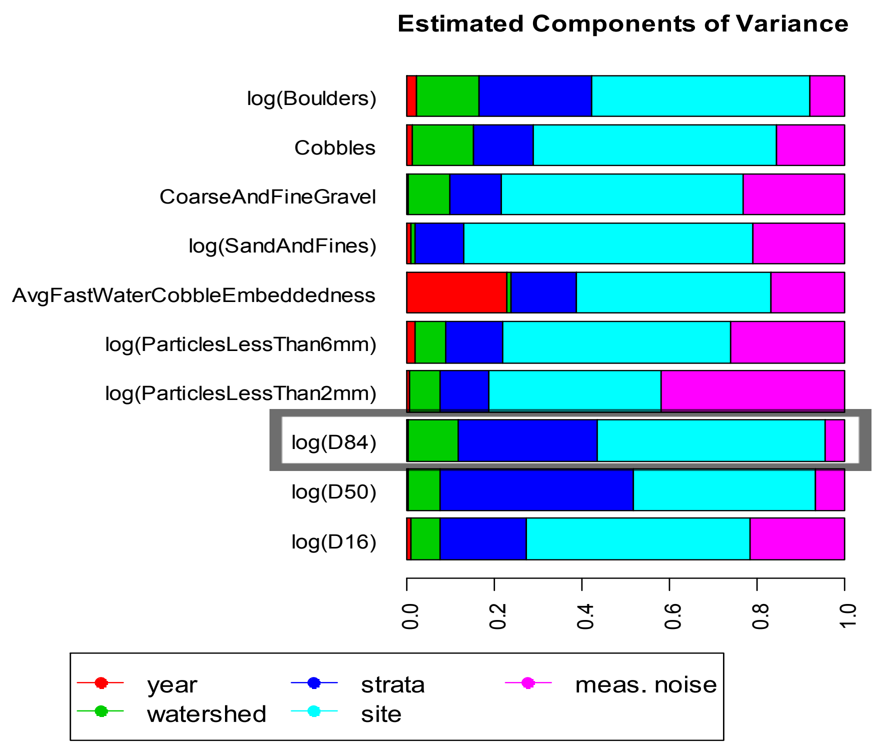


Figure 25. CHaMP 2012-2013 metrics reevaluation: Boulders, cobbles, gravel, etc. A reduction to 105 particles per sites was implemented with the 2013 habitat protocol, enabling more efficient measurements with little relative 'year' effect.

The iterative process for CHaMP metric variance decomposition and diagnostics that was implemented during each year of the pilot will be continued in 2014 and future years. The metric assessment process has proven useful for informing refinements to the CHaMP protocol and improving the quality of habitat data and metrics available for use by ISEMP, our collaborators, and others.

In February 2014, Council and BPA staff posed questions about the utility of CHaMP metrics as model inputs and for use in displays at different scales. Information designed to address questions from February, and previous BPA, Council, ISRP questions about the utility, capability, and quality of CHaMP's metrics is presented in the sections that follow. General information on the interoperability of CHaMP metrics with metrics of other programs is also presented. Specifics on 2013 CHaMP-PIBO integration efforts, and activities planned for 2014, is presented in Chapter VII under the heading "Coordination with Regional Programs."

CHaMP Metric Utility and Capability

The DEM-based CHaMP protocol generates metrics that are directly compatible with remote sensing information, other GIS/geodata, for example, PIBO cross-sections, and LiDAR data (Figure 26). Apart from providing capable metrics for estimating the status and trends of habitat conditions, a primary purpose of CHaMP is to feed models that link habitat to Chinook and steelhead abundance in the interior Columbia River Basin with standardized habitat data. Models being developed by ISEMP include purely empirical models such as Boosted Regression Trees, structural equation models, and first principles based models such as NREI and HSI models (see ISEMP 2014). In 2013 CHaMP-ISEMP continued its evaluations of CHaMP metric utility and capability.

The metric assessment process involves evaluating all metrics that are used as inputs to the hydraulic model (and other models). By assessing each metric individually analysts are able to evaluate the capability of individual inputs to a model, evaluate changes in CHaMP metric performance, and describe any changes in model confidence due to metric and model adjustments. A primary reason for this nested approach to CHaMP metric assessment is to limit the potential for error propagation in multi-step, multivariate fish-habitat relationship models outputs.

As an example, the CHaMP Metric D84 is used as an input to the hydraulic model, along with CHaMP discharge and bathymetry data, to generate velocity vector and water depth field results from a computational fluid dynamics hydraulic model. Hydraulic model results feed into higher level models linking habitat to carrying capacity or productivity, which are in turn used as inputs to the ISEMP watershed production model to estimate salmonid populations (Figure 27). The metric D84 should be considered capable only insofar as the measurement noise does not interfere with the ability of the entire modeling chain to produce adequately precise and accurate results.

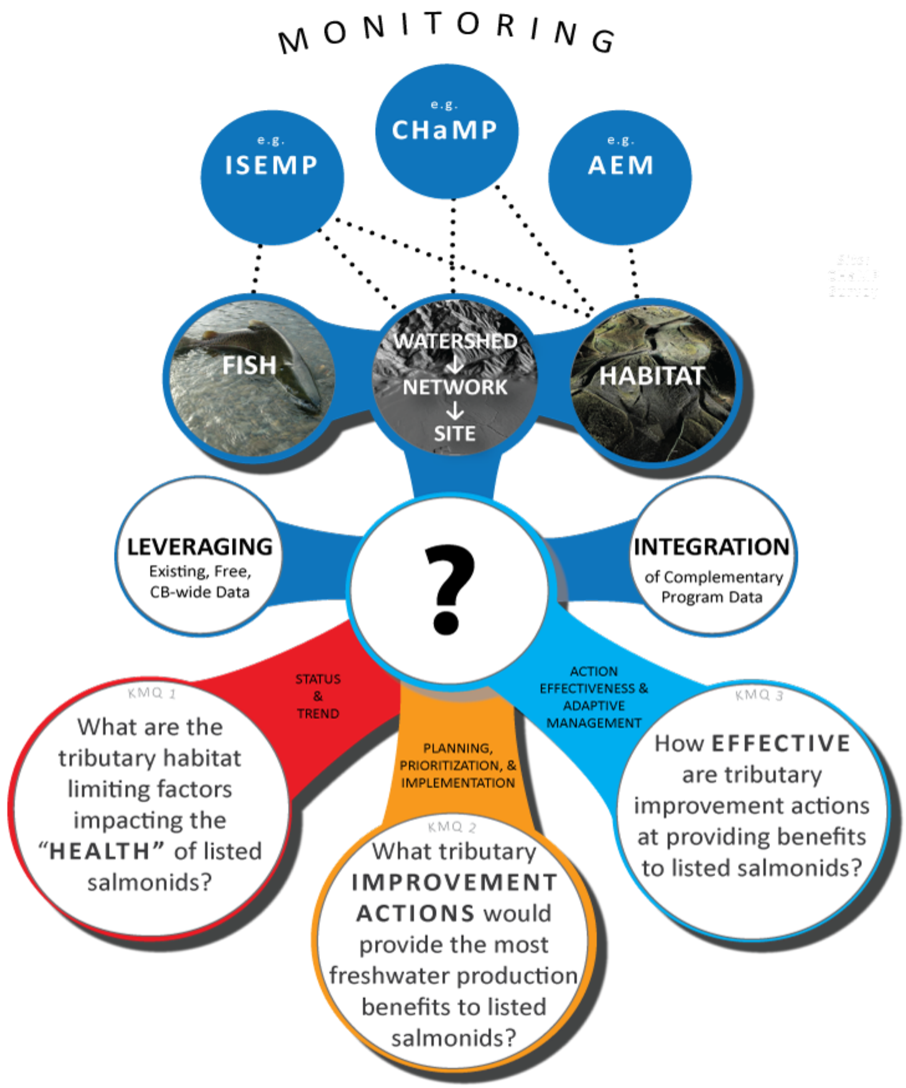


Figure 26. CHaMP leverages existing information in a variety of formats from other programs to capitalize on investments in monitoring and integrate other program data into this framework, where and when appropriate.

To assess this, ISEMP examined the sensitivity of hydraulic modeling results to changes in D84 and compared this sensitivity to actual measurement noise levels in D84. Figure 28 shows error in modeled depth (modeled depth – measured depth) at three locations of an individual CHaMP site, over a range of input values for D84. The linear fit exhibited in Figure 30, and confirmed across a suite of validation site datasets, suggests that error in hydraulic model predictions scales linearly with the natural log of D84. Because error scales with the natural log of D84 the hydraulic model is robust to small errors in the D84 metric.

Predicted depth and velocity vector fields vary linearly with the natural log of D84. The actual measurement error in D84 is relatively small on a log scale, as compared to site-site variation. It can therefore be concluded that current levels of measurement error in D84 will not interfere with the hydraulic model's ability to differentiate between sites or other spatial scales, nor do we expect the level of measurement error in D84 to negatively impact precision of capacity, productivity, or abundance estimates produced by higher level models such as NREI, HSI, or the life cycle models.

As higher-level models are further developed and calibrated, this sensitivity analysis can be extended into these higher-level models to ensure that CHaMP metrics are capable, the metrics are improved as needed, and only capable metrics are used.

Table 9 on the following page summarizes the relationship between key CHaMP metrics and the development of models and products designed to support management decision-making. In addition, a general crosswalk between CHaMP metrics/models and regional ecological concerns, is provided.

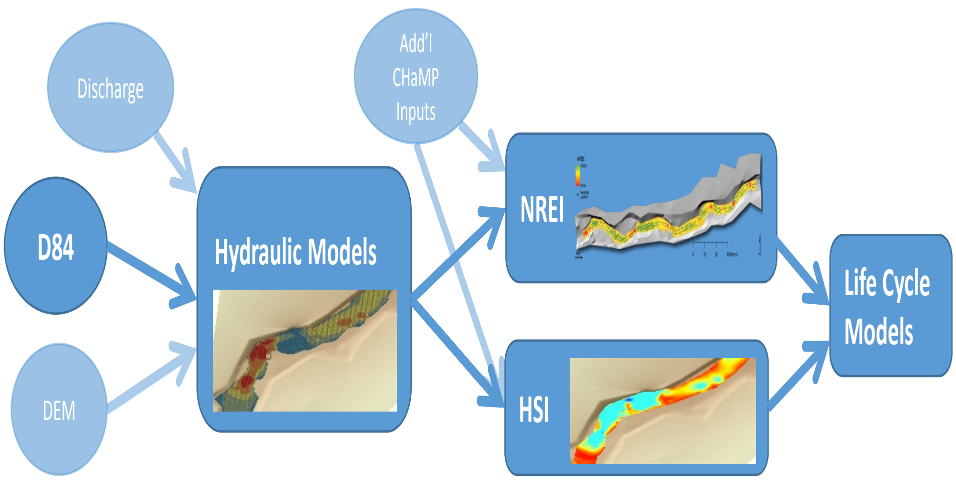


Figure 27. CHaMP metric data flow into ISEMP's hydraulic model and higher level habitat-abundance models.

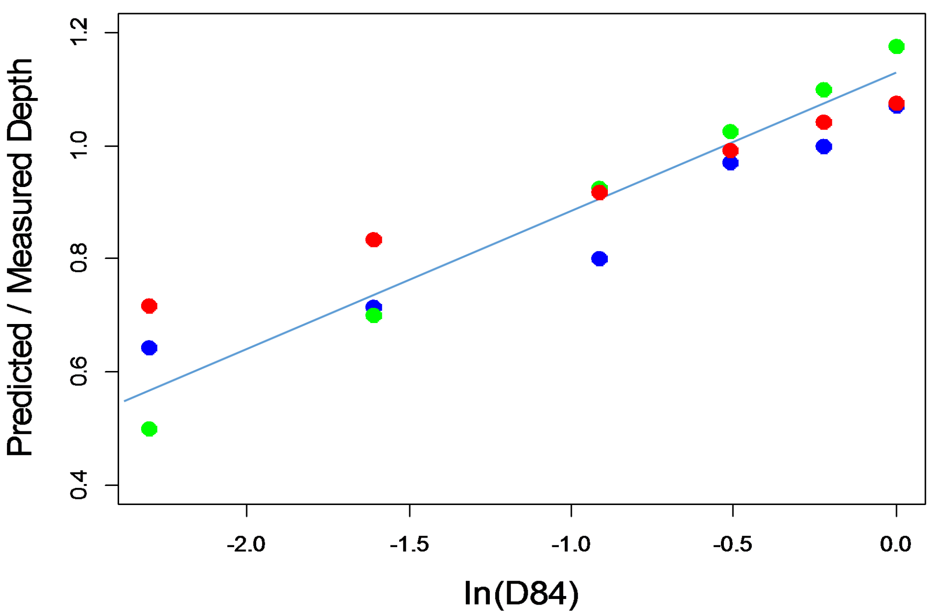


Figure 28. Relationship between hydraulic modeling error and D84.

- CHaMP's DEM based metrics have proven to be directly compatible with remote sensing, GIS, and other spatial/surveyed data such as PIBO cross-sections (see CHaMP 2013).
- Annual evaluation of CHaMP's metrics allows an ongoing assessment of changes in metric and model confidence as adjustments are made.
- Figure 27 depicts how improvements in metric precision limits the potential for error propagation in intermediate models (i.e., the hydraulic model) and higher level, multivariate fish-habitat relationship models like NREI and HSI that ISEMP is developing (ISEMP 2014).
- The CHaMP metric evaluation process includes an assessment of individual habitat metrics such as D84 to determine how well each metric is "performing" at a fundamental level, and its capability to support modeling efforts (Figure 28).

Table 9. Key CHaMP metrics, linkages between metrics and support of multivariate models and outputs, and relationship to ecological concerns for specific salmonid life stages

Indicator	Metrics	Units	Fish Response Category
Average Alkalinity	Site measurement of alkalinity	Milli-equivalent per liter	Survival
Average Conductivity	Site measurement of conductivity	Micro-Siemens per meter	Survival
Growth Potential	Derived from models relating drift biomass and temperature	Degree grams	Growth
Percent Below Summer Temperature Threshold	Threshold temperature metrics derived from year-round logger data and modeled along stream networks	Percent	Growth
Velocity Heterogeneity	Hydraulic Model output measuring velocity heterogeneity at a site	Index	Growth
Embeddedness of Fast water Cobble	Average of site embeddedness measurements	Percent	Survival
Pool Frequency	Site measurement of pool frequency	Count per 100 meters	Growth
Residual Pool Volume	Site measurement of residual pool volume	Cubic meter	Growth
Channel Complexity	Site measurements of depth, width, and thalweg sinuosity	Index	Growth
Habitat Suitability Index	Model derived values of velocity depth and substrate	Index	Growth
Total Drift Biomass	Site measurement of total drift biomass	Gram per cubic meter	Growth
LWD	Site measurement of LWD	Count per 100 meters	Growth
Fish Cover	Site measurement of fish cover	Percent cover	Survival
Channel Units	Site measurement of channel unit type and dimensions	Cubic meter	Growth
Channel complexity	Site measurements of channel units and side channel dimensions	Index	Growth
Particle Size	Site measurement of D50, D16, D84 substrate, occular substrate estimates	Millimeter	Survival
Fine Sediment	Site measurement of pool tail fines, ocular substrate estimates	Percent	Survival
Riparian Structure	Site measurement of riparian structure	Kilometer by type	Growth
Solar Input	Site measurement of solar input	Kilowatt/hour	Growth
Geomorphic Change Detection	Site measurement of geomorphic change between two sampling periods	Volume, Area, & Percent	Survival

Life Stage	Ecological Concern	Potential Restoration Action(s)
Parr to smolt	**Food** – Altered Primary Productivity & **Water Quality** - pH	Plantings, Beaver Introduction, Channel Modification, Side Channel
Parr to smolt	**Water Quality** - pH/Oxygen/Turbidity	Plantings, Beaver Introduction, Channel Modification, Side Channel
Parr to smolt	**Food -** Altered Prey Species Composition and Diversity & **Channel Structure and Form -** Instream Structural Complexity	Instream complexity, Fertilization, Planting
Parr to smolt	**Water Quality -** Temperature	Planting, Channel Modification, Beaver Introduction
Parr to smolt	**Water Quantity –** Increased Water Quantity/Decreased Water Quantity/Altered Flow Timing	Channel Form, Flood plain, wetland creation
Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Channel Modification
Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity,
Parr to smolt	**Channel Structure and Form** - Bed and Channel Form	Channel Modification
Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Riparian
Parr to smolt	**Food -** Altered Prey Species Composition and Diversity	Instream complexity, Fertilization, Planting
Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Riparian
Parr to smolt	**Habitat Quantity** - HQ-Competition	Instream Complexity,
Parr to smolt	**Peripheral and Transitional Habitats** - Side Channel and Wetland Conditions & **Habitat Quantity** - HQ-Competition	Channel Modification
Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Side Channel
Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity; Decreased Sediment Quantity	Sediment Reduction, Gravel Placement
Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Parr to smolt	**Riparian Condition** - Riparian Condition	Planting, Fencing,
Parr to smolt	**Water Quality –** Temperature, **Food** – Altered Primary Productivity	Planting, Channel Form
Eggs/Alevin	**Channel Structure and Form -** Bed and Channel Form	Channel Modification

Metrics Supporting Fish-Habitat Models

Assessment of the capability of CHaMP metrics to feed complex, multivariate fish-habitat relationship models must not be based solely on measurement noise or coefficients of variation, but rather on the impact CHaMP metric measurement noise has on the precision of higher level values in their prediction of carrying capacity, productivity, and/or other high level results of habitat-abundance models. A specific 2013 example that describes how CHaMP-ISEMP staff reevaluated and refined the capability of drift, a key metric used in fish-habitat relationship models and outputs, is presented below.

Drift versus benthic macroinvertebrates

The design of the CHaMP drift sampling protocol was largely based on work conducted by ISEMP describing the spatial and temporal variation present in invertebrate drift samples (Weber 2009). This work demonstrated that variation in drift abundances (density and biomass) among streams and stream reaches is greater than the sum of additional spatial and temporal sources of variation occurring within a sampling reach or throughout a season. This work also showed that while diel variation can be high, drift abundances remain relatively constant during daylight hours when habitat surveys are generally conducted, and the majority of salmonid foraging is likely to occur. This information suggested that drift could be characterized at a sampling reach with a reasonable level of precision given a modest amount of sampling effort. Further, drift samples collected using these methods have been successful in explaining variation in juvenile salmonid consumption, and can be incorporated into bioenergetics models that predict fish habitat growth potential (Weber et al. 2014).

Despite the potential to be a relevant and repeatable component of the CHaMP protocol, evaluation of signal-to-noise ratios from 2011 and 2012 repeat CHaMP surveys showed that metrics of drift abundance lacked sampling precision (see CHaMP 2013). To address this, in 2013 the CHaMP-ISEMP team performed a macroinvertebrate sampling study to reevaluate the utility and capability of CHaMP's drift macroinvertebrate metric to support the mechanistic NREI model (ISEMP 2014) and inform predictions of salmonid habitat carrying capacity and growth potential (Weber et al., 2014). Concurrent with drift study implementation, in 2013 CHaMP also supported ODFW and CRITFC drift sampling at sites in the Grande Ronde watersheds to enable their completion of a full 3-year panel using the CHaMP drift protocol.

The 2013 drift study involved drift collection at approximately 70 sites, with repeat sampling at about 15% of those sites. Variance (repeatability – field sampling precision) based on the number of nets deployed, net configuration, clogged nets and the discharge in which sampling occurred was also assessed. A pooled value from four nets was evaluated against one net, two nets or three sets of nets at each site. Samples were analyzed based on environmental groups, taxonomic groups, and whether separate or pooled nets comprised the sample. CHaMP 2013 drift study findings indicate that the deployment of two nets, as called for in the 2011 and 2012 versions of the CHaMP protocol, produces the best balance of effort/correlation. Benthic macroinvertebrate samples were also collected to help respond to BPA AEM staff questions regarding the utility and capability of drift versus benthic macroinvertebrate metrics.

Results show the deployment of two nets, as called for in the 2011 and 2012 versions of the CHaMP protocol, produces the best balance of effort/correlation. Samples taken earlier in the year during higher flows were highly variable and included both aquatic and terrestrial drift. The signal to noise ratio was great-

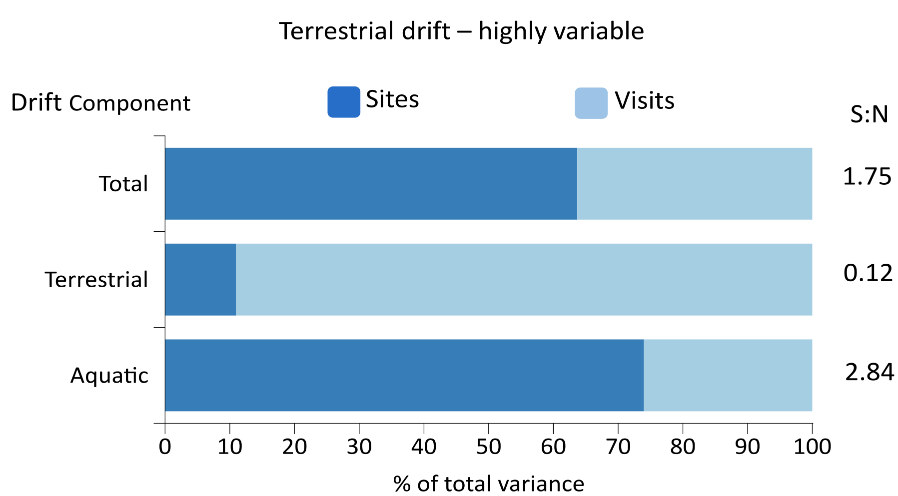


Figure 29. Signal-to-Noise ratios for terrestrial and aquatic drift components of CHaMP macroinvertebrate samples.

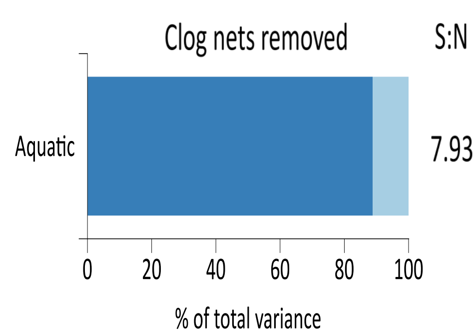


Figure 30. Signal-to-noise ratio for drift after samples with clogged nets were removed from analysis.

The Utility of CHaMP Drift Macroinvertebrate Data

- Unlike benthic macroinvertebrates, drift biomass is a direct indicator of food for rearing salmonids and can be directly related to juvenile habitat quality.
- The CHaMP drift sampling protocol was largely based on work conducted by ISEMP describing the spatial and temporal variation present in invertebrate drift samples (Weber 2009).
- CHaMP measures drift for use as an input to an energetics based relationship model (NREI) between habitat characteristics and juvenile salmonids because, by itself, drift is not a good indicator of habitat quality. The value of the CHaMP drift metric to describing fish-habitat relationships increases when it is used with other metrics.
- ISEMP-CHaMP work has demonstrated that drift biomass can ultimately be used to predict fish abundance and growth.

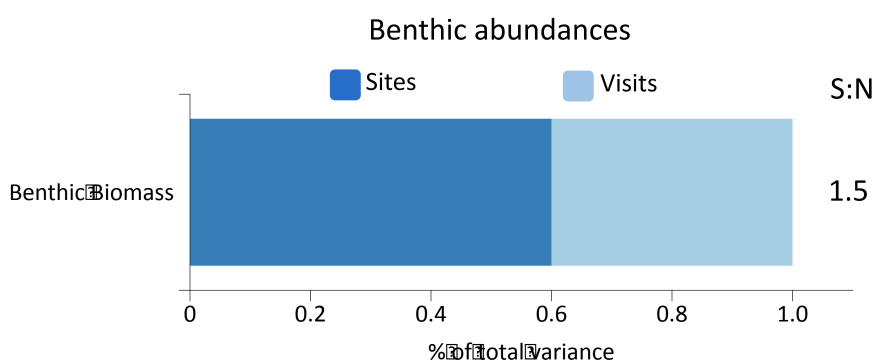


Figure 31. The ability to repeat benthic invertebrate biomass and relate this to drift produced a low signal-to-noise ratio (1.5)

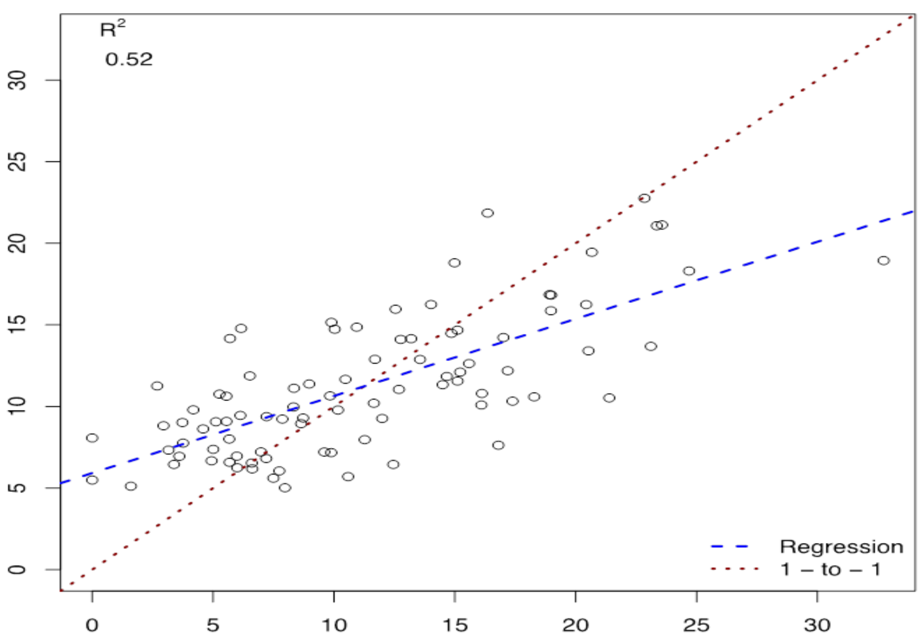


Figure 32. The relationship between observed drift biomass vs predicted drift biomass from benthic samples. Observed drift samples do not include terrestrial drifting invertebrates, which can represent over 50% of salmonid diets.

er for aquatic drift; however, it was still lower than desirable (Figure 29). When clogged nets from the study were removed from the analysis the aquatic drift signal-to-noise ratio increased greatly to 7.93 (Figure 30). This shows the importance of adjusting 2014 training to strongly emphasize proper sample timing and net deployment techniques to avoid high flows and the potential for clogging, and improve drift macroinvertebrate sample and metric quality.

Drift study results also show that the ability to repeat benthic invertebrate biomass and relate this to drift had a low S:N ratio (1.5; Figure 31) and in fact had a much lower ratio than drift samples not corrected (Figure 29) and corrected for clogging (Figure 30). Further, the relationship between benthic and drift (not including terrestrials) was found to be moderate (Figure 32), indicating the ability to collect benthic invertebrates and relate them to drift suffers from not only this moderate relationship, but also the inability to take consistent benthic samples (i.e., the S:N will be <<1.5 for estimating drift from benthic samples).

Specific questions about drift posed to CHaMP over the period 2011-2013 are presented in the next section. Underneath each, a summary answer is provided based on information from the 2013 study and other sources. For readers interested in more discussion, a detailed response follows each summary answer.

Detailed macroinvertebrate discussion

Q: What does the biomass or taxonomic diversity (or functional groupings) of drift macro-invertebrates indicate in terms of stream habitat quality and quantity for juvenile salmonids and is this the same thing as indicated by benthic macro-invertebrate biomass or diversity?

A: Drift macro-invertebrate biomass is a direct indicator of the food available to rearing salmonids and as such is a measure of habitat quality. Benthic macro-invertebrate diversity is typically used as a measure of water quality and is not directly related to habitat quality for juvenile salmonids.

Stream-rearing salmonids are drift and surface feeding fishes, that is, they capture food items out of the water column as the water moves past a holding or foraging location (Fausch 1984, Hughes and Dill 1990). Food items tend to be macro-invertebrates that are planktonic (e.g., copepods, some dipteran larvae), benthic forms detached from the bottom either volitionally for dispersal or due to disturbance, or terrestrial forms that have become entrained in the flow (Bannon and Ringler 1986, Nakano and Murakami 2001). Collectively the food items available for these fishes to feed on are referred to as "drift". The composition of drift is driven by a number of factors – season, extent and quality of adjacent and immediately upstream riparian vegetation, time of day, and to a lesser extent water quality. In general, drift is not an ecological community; rather, it is a collection of entrained particles that are planktonic in that they have weak to no control of their location in the water column relative to the bulk motion of the water. In contrast to drift, the benthic and infaunal community of macro-invertebrates live in and on the stream bed. These organisms have specialized feeding guilds (e.g., scrapers, shredders) and tend to be cryptic (stoneflies) or well-defended (caddis flies). The composition of the benthic macro-invertebrate community has been shown to be a strong function of water quality, e.g., temperature, pH, conductivity and substrate size, as would be expected since they form the second trophic level of the aquatic food web – the primary consumers. As such, benthic macro-invertebrate diversity is determined by the abundance, form and diversity of the stream primary production – algae and vascular plants – and in highly oligotrophic areas, by the volume and quality of allochthonous input from riparian vegetation (Wallace et al. 1997). Therefore, while the drift can share some species with the benthic macro-invertebrates, the abundance and composition of these communities can be independent (weak correlation of biomass) because their structure can be driven by fundamentally different bio-physical processes.

Drift biomass and composition is driven by both terrestrial and aquatic productivity and the mechanisms and opportunities for deposition of terrestrial organisms into streams. In fact, terrestrial invertebrates often account for 50–85% of trout diets during summer months (Dineen et al. 2007, Utz and Hartman 2007) and provide about 50% of their annual energy budget (Kawaguchi and Nakano, 2001; Nakano and Murakami, 2001; Sweka and Hartman, 2008). Benthic biomass and composition is driven by primary productivity, food web interactions, and the form of plant material available for forage. Since the determinants of drift and benthic macro-invertebrate biomass or composition are fundamentally independent, measures of drift and benthic macro-invertebrates assay very different aspects of stream condition. Benthic macro-invertebrate biomass is a direct indicator of net primary productivity (NPP) while drift biomass is a direct indicator of amount of deposition of terrestrial invertebrates into the stream, as well as the presence of species and life stages that have entered the drift. These two measures of "amount of bugs in the stream" sound analogous, but can indicate very different stream conditions – for example a reach with high benthic biomass due to the dominance of large case-making caddis fly larvae will not necessarily be a reach with a high drift biomass as these individuals do not enter the drift. Conversely, the biomass of particular taxa within the benthic macro-invertebrate community can be correlated with overall drift biomass, since behavior and life history forms of benthic macro-invertebrates can result in the generation of a large volume of drift – for example a reach with high Dipteran abundance will have high drift biomass and will support rearing juvenile salmonids.

Q: Why does CHaMP/ISEMP measure stream macro-invertebrates in the water column (drift) rather than on the stream bottom (benthic)?

A: Drift macro-invertebrates are measured as an input to an energetics based relationship between habitat characteristics and juvenile salmonids; benthic macro-invertebrates don't enter into the bioenergetics of juvenile salmonids and thus aren't measured to determine stream habitat quality for salmonids.

CHaMP/ISEMP is tasked with developing metrics and indicators of stream habitat quality and quantity to support spawning and rearing of ESA-listed anadromous salmonids in the interior Columbia River basin. High quality spawning habitat has been shown to be determined by a suite of physical processes that drive the formation of features necessary for redd construction and proximity to high quality juvenile rearing habitat (Falke et al. 2014). High quality juvenile rearing habitat has been shown to be driven by the availability of cover and energetically profitable habitat. Energetically profitable habitat is the combination of water temperature (metabolic rate, digestion/assimilation rate), flow velocity (cost of locomotion, flux of food particles), and food (size, quality, density of drift particles), and by its very nature implies heterogeneity of conditions as fish may not be able to optimize their energetic balance in one location due to trade-offs in cost of locomotion (low velocity flow) versus food delivery (high velocity flow) and metabolic costs (lower at lower temperature) versus growth rate (higher at higher temperature). Quantifying the biomass of drift, along with water temperature and a spatially explicit distribution of flow velocities at a site allows CHaMP/ISEMP to estimate each site's capacity to support rearing juvenile salmonids, as well as the growth potential of these fish. The relationship between site habitat characteristics and the fish response to these characteristics is developed by applying bioenergetics and NREI models to CHaMP/ISEMP habitat data.

Growth is perhaps the most proximate fish response to environmental changes and restoration. CHaMP/ISEMP evaluated the relationship between benthic and drifting invertebrates in describ-

ing consumption and growth rates of salmonids. The best predictor of fish consumption and growth rates was total drifting invertebrates (Weber et al. 2014). The model for this relationship is based on temperature and total drift biomass and translated to fish growth via the bioenergetics model (Weber et al. 2014). In addition, we have observed that higher growth rates often results in higher survival rates and thus growth can be used as measure in population life-cycle models currently under development in the Columbia River basin.

NREI models show great promise in identifying and quantifying the tradeoffs described above, help in improving our understanding of fish habitat relationships, and designing and evaluating effective restoration strategies (Fausch 1984, Guensch et al. 2001, Hayes et al. 2007, 2012, Hughes and Dill 1990, Hughes et al 2003, Hill and Grossman 1993, Imre et al. 2004, Jenkins and Keeley 2010, Kelly et al. 2005, Nislow et al. 1999, 2000, Rosenfeld 2003, Rosenfeld and Boss 2001, Rosenfeld and Ptolemy 2012, Rosenfeld et al. 2005, 2013). CHaMP/ISEMP tested a model developed by Hayes et al. (2007) to estimate the abundance of salmonids in stream reaches, with very encouraging predictive ability; however, the model itself proved to be unwieldy and difficult to implement (Wall 2014, Rosenfeld et al. 2012). Therefore a simpler model was developed and programed, and the approach was validated with estimates of abundance and growth of rearing salmonids at 30 CHaMP/ISEMP sites. With no model calibration, ISEMP has demonstrated that NREI models do a relatively good job at estimating fish abundance (see CHaMP 2013, ISEMP 2014). Results demonstrate the ability to synthesize the CHaMP/ISEMP metrics currently collected with hydraulic models from the DEM-based protocol to describe stream habitat quality and quantity. Indeed, the CHaMP protocol was developed to support these mechanistic models that directly relate fish biology to the metrics collected. With further calibration and the inclusion of other CHaMP/ISEMP metrics such as fish cover, improved results are expected.

Through the application of a mechanistic understanding of how fish use physical and biological habitat, site-level stream habitat metrics can be direct predictors of fish metrics, and as such, are measures of habitat quality and quantity that can be used in management decision support products. For example, estimates of capacity (maximum abundance) and productivity (maximum survival, a function of growth and abundance) are given by CHaMP/ISEMP habitat data (NREI output) and are direct input parameters of population-scale life-cycle models. It is important to note that the NREI modeling process mentioned above attempted to use only aquatic drifting invertebrates (i.e., terrestrial drift was not included), and the model suggested that these reaches could not support fish. Only when the terrestrial component was included in the model were fish were supported, as observed in these reaches. Therefore, benthic macroinvertebrates alone cannot be used as measures of food availability for rearing juvenile salmonids.

When developing the CHaMP protocol, developers of benthic macroinvertebrate indices and monitoring programs were consulted. These experts on benthic macro-invertebrate biology and monitoring were clear in their instructions - invertebrate drift was the most relevant to estimating fish responses, and that indices of biotic integrity (based on benthic macro-invertebrate taxonomic diversity) have not and will likely not be directly related to fish responses, nor be a reliable response to in-stream restoration projects, even from an invertebrate response. Based on CHaMP-ISEMP research, the rich literature on the relationship of invertebrate and fish interactions, and communication with leaders in the benthic invertebrate monitoring programs in the western US, it was concluded that drifting invertebrate biomass was the most relevant measure of fish food needed to describe a potential fish response to changes in stream habitat quality and quantity.

Q. Can stream macro-invertebrate metrics be generated in a repeatable fashion such that the data is useful for describing differences in biological and physical processes between sites and through time?

A: Yes, CHaMP/ISEMP, and others, have demonstrated methods for estimating the biomass of drift macro-invertebrates available as a prey resource for juvenile salmonids and demonstrated that these data can be used to predict fish abundance and growth.

All measurements are made with error and all metrics and indicators are estimates; the uncertainty associated with any metric or indicator (e.g., signal to noise ratio) is only one component of its utility. The other consideration for evaluating the metric or indicator utility is information content. Information content is the value or leverage a metric or indicator has in a decision making process. For example, a metric with a very high signal to noise ratio (S:N) that only explains a small fraction of the variation in an important decision criterion is not as information rich as a metric with a low S:N that explains a large fraction of the variation in the decision criterion.

Initial evaluations of the ability to describe invertebrate biomass were far more repeatable for drift than benthic communities (Weber et al. in review). Through repeated evaluations of drift samples collected in CHaMP/ISEMP it has been demonstrated that most of the variation between sampling events and crews can be addressed with sampling method training and post-hoc data quality assessments that identify clogged or fouled nets (Figure 29 and Figure 30). Crew training needs to address the proper setting of nets in cross-sections that can both be properly sampled with the drift nets and more importantly, are appropriate for determining the volumetric flow rate. Ideally, drift samples would only be collected in debris free nets, but certain sites, times of year or flow conditions can result in considerable volumes of plant material in the water column. Fouled nets still generate useful drift samples, but will not result in good esti-

mates of drift biomass available per unit time unless the flow rate is corrected to reflect the reduced flux.

In 2013 CHaMP-ISEMP also evaluated the ability to repeat benthic invertebrate biomass and relate this to drift. It was found that benthic invertebrate biomass had a low S:N (Figure 31), in fact had a lower and much lower S:N than drift samples not corrected and corrected for clogging, respectively. Further, the relationship between benthic and drift (not including terrestrials) was found to be moderate (Figure 32). Thus, the ability to collect benthic invertebrates and relate this to drift suffers from not only this moderate relationship, but also the ability to take consistent benthic samples (i.e. the S:N will be <<1.5 for estimating drift from benthic samples).

Q: Why do other monitoring programs (e.g., EMAP, PIBO) collect benthic macro-*invertebrates rather than drift as an indicator of "stream health"?*

A: Benthic macro-invertebrate sampling and the associated metrics and indicators developed to reduce the complexity of the taxonomic diversity data collected (e.g., Index of Biological Integrity and Observed to Expected ratios) have been shown to describe reach and watershed-scale water quality. CHaMP-ISEMP efforts and the work of others have been able to relate drift directly to estimates of fish abundance and growth; therefore CHaMP continues to support drift sampling in status and trends, limiting factors, or action effectiveness monitoring.

Benthic macro-invertebrate sampling, and the associated metrics and indicators developed to reduce the complexity of the taxonomic diversity data collected (e.g., Index of Biological Integrity and Observed to Expected ratios), have been shown to describe reach and watershed-scale water quality. However, as far as we are aware, this information has yet to have been directly related to fish abundance, growth, survival, or production - metrics that we believe BPA need to assess status and trends, limiting factors, or action effectiveness. It has clearly been assumed that if methods such as O/E, or RIVPACs suggest water quality or watershed health from an invertebrate perspective is in good condition, then conditions are also good from a fish's perspective. However, studies evaluating these indices across trophic levels show no concordance in conclusions as to what constitutes watershed health (Carlisle et al. 2008). In other words, conditions responsible for high community diversity are not the same for algal as for fish communities. CHaMP/ISEMP would be quite interested in the rationale and literature used to support the recommendation to monitor benthic macro-invertebrates to support habitat management programs for stream-rearing salmonids. While there is value in benthic macro-invertebrate information, it is unclear to CHaMP and ISEMP staff how it could be used to inform fish habitat status or response to restoration.

Clean Water Act reporting and compliance requirements have driven the design of many large-scale aquatic monitoring programs over the past several decades. As a result, methods available for survey and response design are dominated by the products developed by the US Environmental Protection Agency (EPA) for the Environmental Monitoring and Assessment Program (EMAP); in particular, the GRTS survey design tools and the field sampling protocols for transect-based wadeable stream surveys. The EPA continues to support both the survey design and sampling protocols and have made all of the supporting documentation available online. As such, it is relatively straightforward to adopt these existing methods and forego the time and expense of testing and refining new approaches. However, in adopting the EPA methods, users need to be aware that the EMAP objectives are also implicitly being adopted; that is, data to support watershed-scale, CWA focused assessments. CHaMP/ISEMP chose to take advantage of much of the technical development done by the EPA biologists and statisticians by adopting the GRTS survey design and many of the field sampling metrics; however, since the CHaMP/ISEMP objectives were fundamentally different from those of EMAP, a re-working of the EMAP response design was undertaken such that the transect framework was replaced by a full DEM and all biological metrics (fish, amphibian, benthic macroinvertebrates) were dropped and replaced with a fish food (drift macro-invertebrates) metric.

Automatically-derived habitat metrics

At present, the CHaMP protocol uses a two-tier hierarchical channel unit classification based on Hawkins et al (1993) and Bisson et al (2006). This classification system delineates channel units, not geomorphic units, and as such lacks important process inferences that may limit our ability to quantify fish-habitat relationships. The current CHaMP channel unit classification system also requires crew subjectivity. Advantages of modeling geomorphic units from topography include:

- Greater objectivity due to rule-based unit generation;
- Flexibility in the rule set (e.g. thresholds) which, if necessary, can be changed in the future. If the rule set is changed through time, the new geomorphic unit model can be re-run on previous years' topographic data without resulting in un-useable legacy datasets;
- The option to leverage other topographic datasets (e.g., LiDAR) that provide important out-of-channel context;
- Geomorphic unit membership is represented as a probability which preserves real-world ambiguity in unit boundaries;
- The ability to cross-walk with other programs that have different unit definitions; and
- A classification scheme tied to geomorphic processes.

With respect to CHaMP products in particular, geomorphic units can be coupled with repeat topographic surveys and associated DoDs to help inform trends monitoring, effectiveness monitoring and restoration design. For example, placing DoDs in the context of geomorphic units provides insight into site-

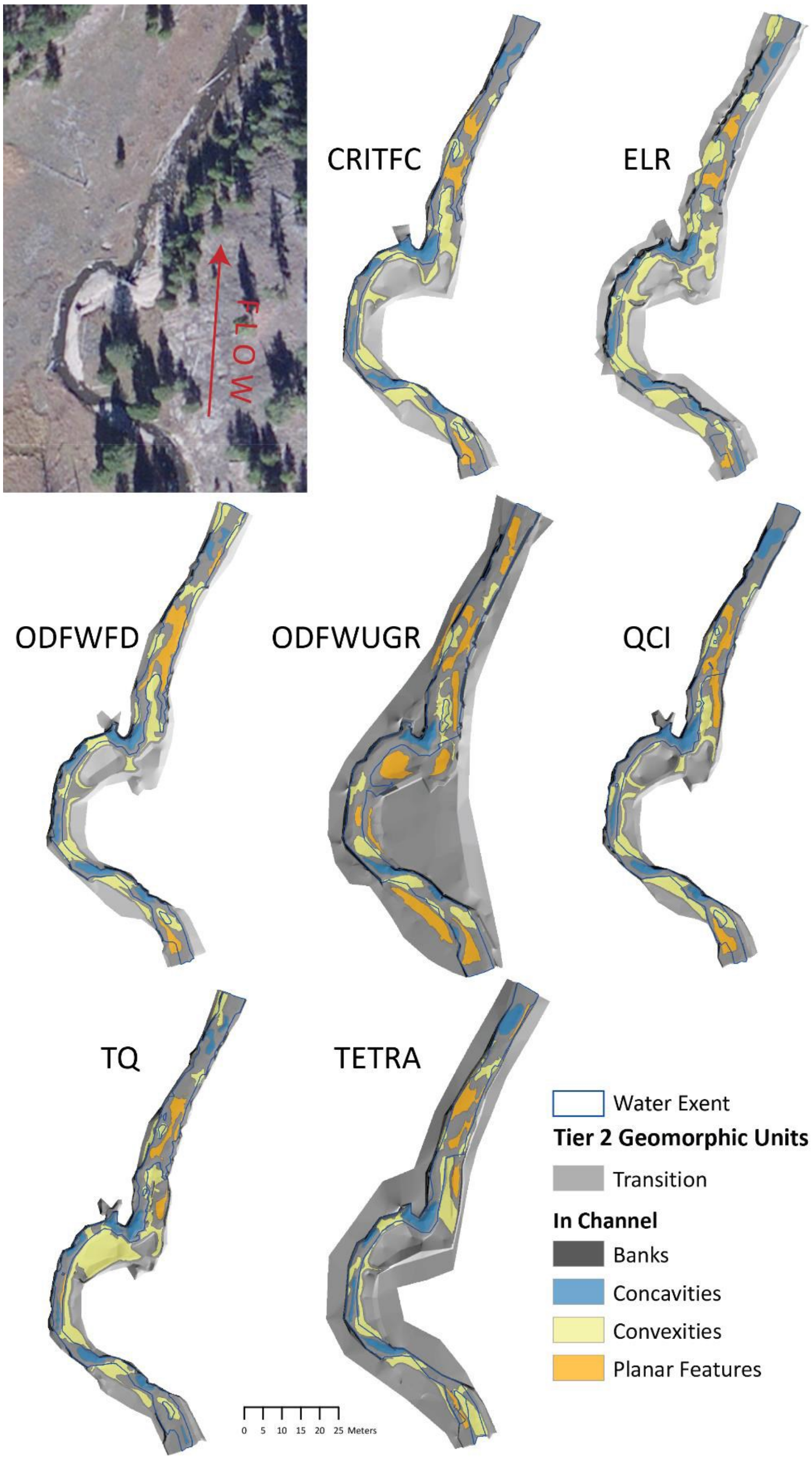


Figure 33. Bear Valley Creek (site CBW05583-028079) tier 2 manual classification by crews vs. tier 2 semi-automated topographic derivation (thresholded at a 68% probability). Aerial photo is shown for site context. Some manual editing was required in to produce this example. (S. Bangen, USU)

level behavior and turnover of habitat (e.g., riffle deposition). The final output geomorphic unit maps can then be utilized in ISEMP fish-habitat relationship models (i.e., hydraulic model, NREI, and for estimates of carrying capacity; see ISEMP 2014). Chapter III presents more information on the application of geomorphic context using RiverStyles.

Because CHaMP and ISEMP are using multiple approaches to describe fish-habitat relationships, in 2013 CHaMP continued development of a Geomorphic Unit Tool (GUT). The intent of this effort is to be able to automatically classify habitat units, that is, generate process-based hierarchical geomorphic classification units directly from topographic data (e.g., CHaMP DEMs, water depth rasters), such that derived habitat units explain fish densities as well as or better than field-classified habitat units.

An automated approach will help address potential concerns associated with crew subjectively in the field and potentially effect crew time cost-savings in the field as well. Addressing potential concerns about crew subjectivity (i.e., how consistently CHaMP is able to classify habitat units across crews) is important because in order to detect trends in habitat through time CHaMP must distinguish signal (e.g., changes in grain size) from noise (e.g. measurement error; see Ward et al. 2012, CHaMP (2013) and Chapter VI, Metrics Assessment, for more information on signal to noise ratios.)

Results from 2013 CHaMP GUT development and testing (Figure 33) show:

- Modeled units are generally spatially coherent. Some manual editing may be needed for high resolution results.
- For crew field-classified versus modeled units, a high level of agreement in the percentage of cells classified as tier 2 in-channel geomorphic units exists, indicating modeled units constituted the same relative area.
- In cases where modeled and field-classified units were discrepant, most misclassified cells were modeled as transition zones. In short, the high

percentage of modeled transition zones that did not match the manual crew classification is likely a result of the geomorphic unit probability threshold value used.

- Development of higher geomorphic unit probability thresholds will result in less polygon overlap and larger transition zones. These zones are biologically important and may be where higher fish utilization would be expected (e.g., transition zones between riffles and pool tails would be associated with relatively high spawning activity).
- With the exception of transition zones, where discrepancies existed between the modeled and manually mapped geomorphic units there were typically only one or two other types of units classified. For example, manually classified planar features were modeled as planar features, convexities, and transitions.
- Use of hybrid datasets, e.g. LiDAR + CHaMP topo data, results in greater out-of-channel context because LiDAR captures subtle out-of-channel micro-topography not possible with CHaMP surveys, given crew time.
- The 2013 application of the GUT used 2011 field season crew variability data and the quality of topography collected by CHaMP crews. This has vastly improved since 2011. Thus, there will likely be less variability in modeled geomorphic units as data from 2012, 2013 and onward are piloted with the GUT and evaluated.

In 2014 CHaMP will continue to pilot and evaluate the utility and capability of auto-derived metrics for use in collaborators' fish-habitat relationship models, and whether the use of auto-generated metrics could effect potential cost-savings in the field and reduce crew subjectivity. Specific next steps may include:

- Develop a rule set for classification of tier four geomorphic units for which derivation will not be fully automated because auxiliary (i.e. non-topographic) metrics, are required.
- Build a user toolbar within ArcGIS with an option for users to be able to manually delineate tier four units that require auxiliary evidence.
- Test the GUT across all CHaMP sites – Once the user interface is built it will be tested across all CHaMP sites.

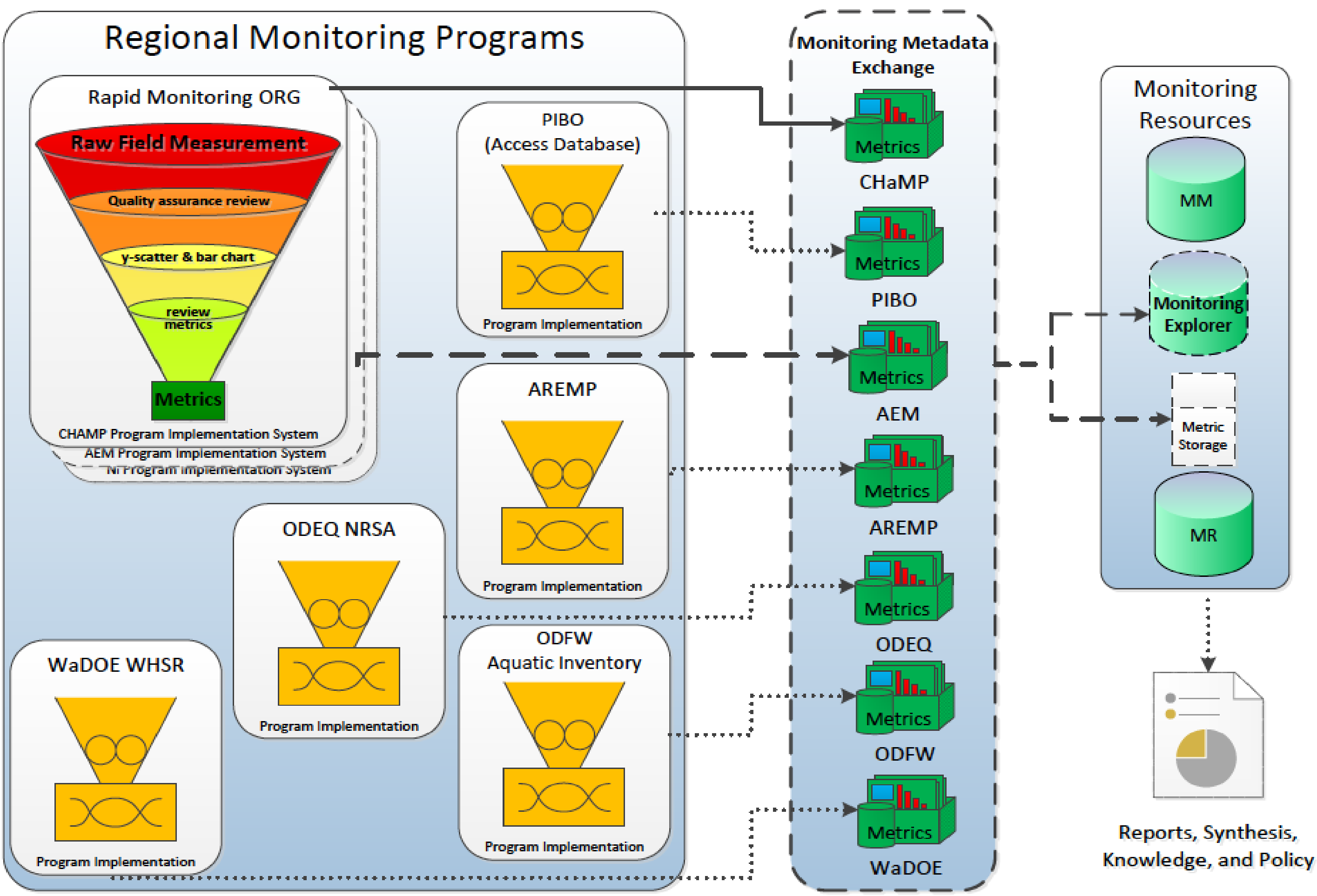


Figure 34. Potential framework for leveraging CHaMP metric information with information from other programs, using existing PNAMP infrastructure and a "Monitoring Metadata Exchange". (Dashed and dotted lines are conceptual ideas for 2014 and future years.)

This process will inevitably flag issues within the automated architecture design that will need to be addressed. Due to the sheer diversity of CHaMP sites sampled we anticipate several rounds of testing and rule-set adjustments.

- Validate against CHaMP repeat sites - A greater degree of variability in geomorphic unit derivation was observed among topographic datasets collected by different crews than was hypothesized. To test the assumption that topographic survey data has improved since 2011 and therefore geomorphic units will be modeled more consistently, CHaMP will assess the variability in geomorphic unit derivation among crews at a subset of 2012 and 2013 repeat sites.

Metric Interoperability

There are many facets to consider when discussing program metric interoperability. For example, metrics from two or more programs would need to share the same calculation and output format to be stored in and served from common database.

In 2013 CHaMP continued to support evaluations of CHaMP-PIBO program metric interoperability. Information on this effort is presented in Chapter VII. In 2013 CHaMP development team members also explored options to leverage existing metadata storage and point display frameworks created through PNAMP as a mechanism by which information from multiple programs could be shared with users. Figure 34 depicts how a Monitoring Metadata Exchange could serve information about different programs' data through a common interface. Dashed and dotted lines in represent conceptual next steps for multi-program metric integration work.

With respect to CHaMP's metric inclusion rules, important components of an inter-program evaluation include:

- Information content – is the metric specifically related to salmonid productivity including survival and growth?
- Data form – Does the metric provide robust statistical information and quality data (i.e., can it detect heterogeneity, is it repeatable)?
- Feasibility – Can the metrics be generated by field tools and software currently available, and can field work be performed by 3 person crew/day at 80% of sites sampled?

Metric interoperability evaluations should consider whether cross-walks can be developed to make metrics from separate programs comparable and how to quantify errors or bias induced from program-program metric differences. Ultimately, if metrics are not interoperable significant work may be required to make them interchangeable, or the end result may not greatly improve elucidation of fish-habitat relationships. Accordingly, a comprehensive approach to program metric integration needs to include discussion of what modifications to sample frame(s), weights, etc. may be required to fully integrate the study designs from one or multiple programs. This step is necessary if interoperability is meant to include the ability to leverage data from multiple programs in the elucidation of fish-habitat relationships (Figure 35).

Lastly, it is important that evaluations of program interoperability consider whether other programs will be able to support change and facilitate integration.

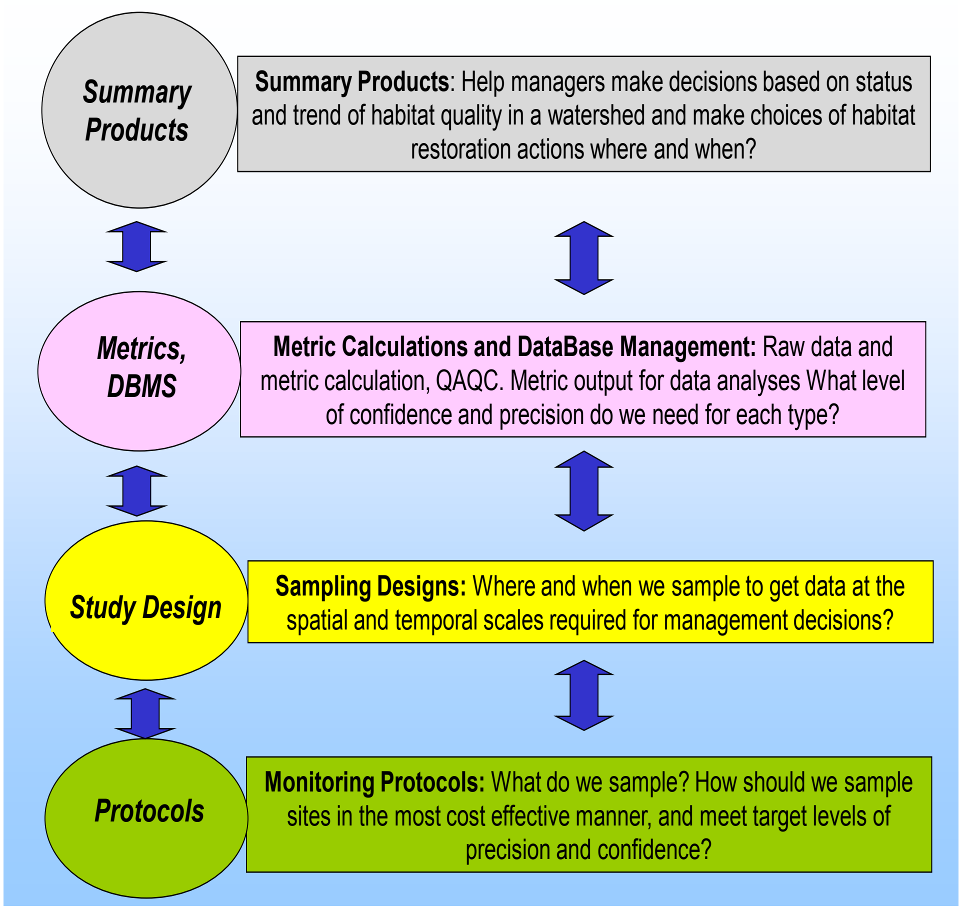


Figure 36. An evaluation of metric interoperability should be multi-faceted and consider how to incorporate different sampling designs, and the quality of different metrics.

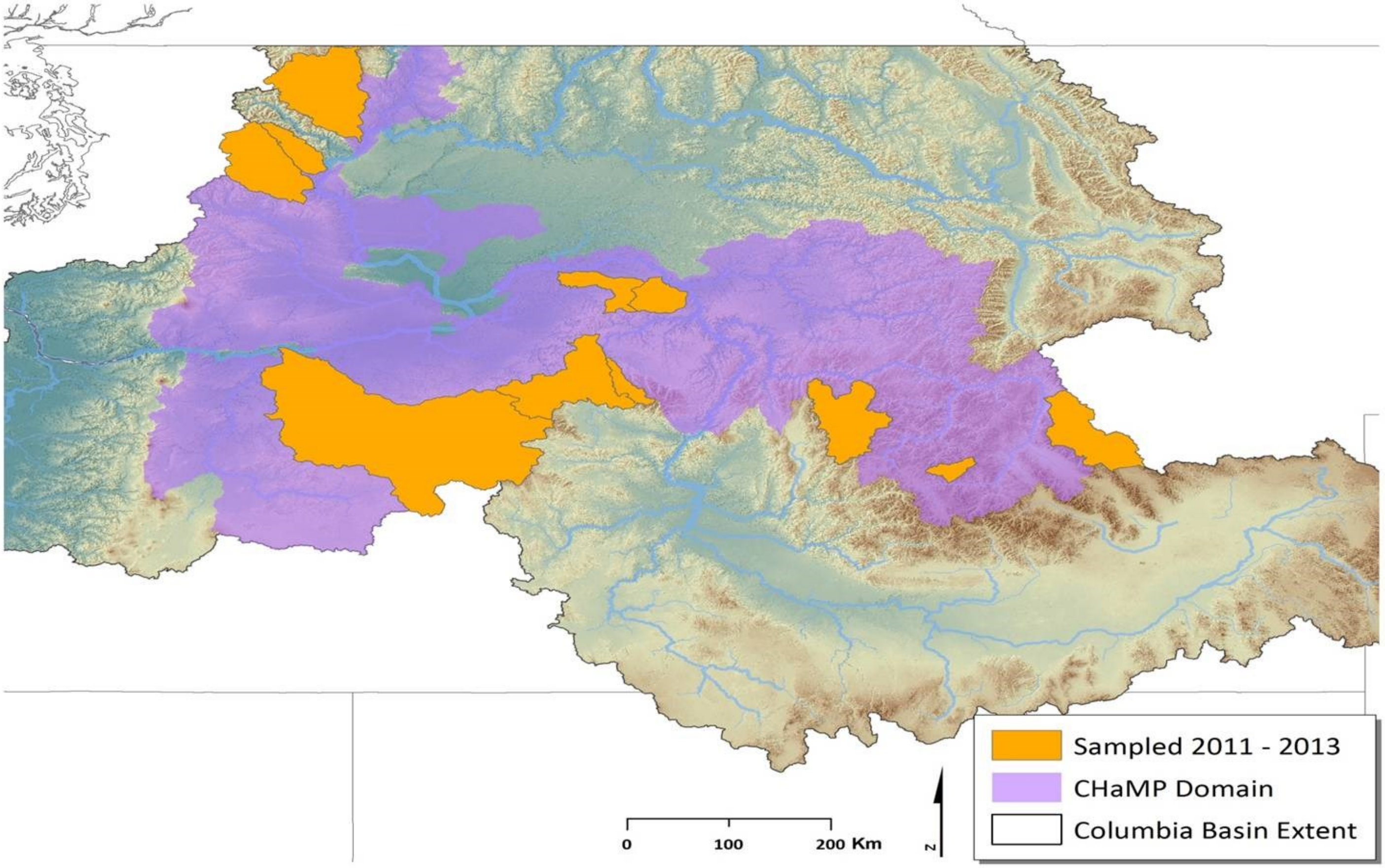


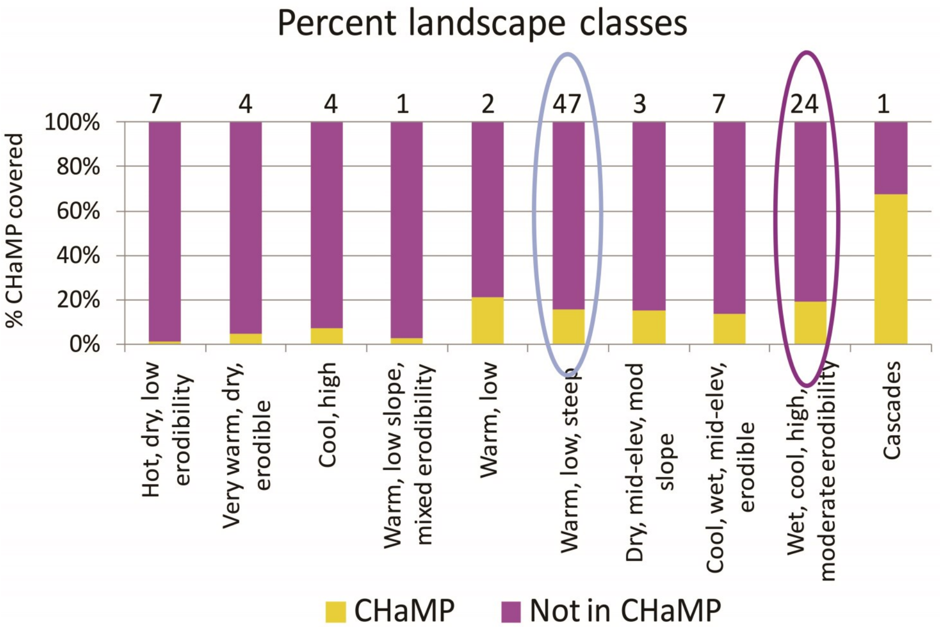
Figure 36. Map displaying the spatial extent of Chinook and anadromous steelhead TRT populations in the Columbia (purple and orange), and the extent of watersheds that CHaMP monitored during 2011 – 2013.

Extrapolating CHaMP Metrics and Indicators to Unsampled TRT Populations

CHaMP's nine watersheds cover a fraction of the domain of listed Chinook and steelhead in the interior Columbia basin (Figure 36, next page). Therefore, a key question of interest to managers and restoration practitioners is to what extent CHaMP results might be extended/ extrapolated to domains not covered by CHaMP? If relationships between CHaMP habitat metrics and other continuous attributes for which we have data across the entire interior Columbia basin can be developed, these relationships can be used to estimate spatially-explicit habitat distributions in unsampled areas, as well as to increase precision of estimates in sampled areas, across any spatial scale of interest.

Insight into CHaMP's relevance to domains not sampled can be gained by classifying the full domain and then comparing the extent of CHaMP's coverage in each of the resultant classes. Whittier et al.'s (2011) use of GIS data to classify USGS accounting units in the Pacific Northwest at the 'sixth field' scale (sixth field HUC) can be used to illustrate one way in which CHaMP's results might be extrapolated into unsampled areas. To develop the natural feature classification, Whittier et al (2011) applied principal components analysis (PCA) and clustering techniques to scale data for seven climatic, land form, geology, and stream form variables. The stream extent (stream km) of those classes that fell within the Chinook/ anadromous steelhead domain was summarized as the proportion of the domain in each of the classes (Figure 37).

Two natural classes ("Warm, low, steep" and "Wet, cool, high, moderate erodibility") accounted for 71 % of the relevant domain. The proportion of each natural class covered by the sampled CHaMP watershed stream networks ranged from near 0% ("Hot, dry, low erodibility" class) to a high proportion (75% in the natural class "Cascades"). Although the CHaMP watersheds were not statistically selected from the population of potential 'CHaMP' watersheds in the TRT domain, it might be argued that metric data from the sampled CHaMP watersheds that cover 15% or higher proportion of TRT classes could be extrapolated to the unsampled watersheds. This proposition could be tested by comparing metric scores in a random set of locations in each of the unsampled natural classes with CHaMP's metric scores. Other classifications for potential evalua-



Although the CHaMP watersheds were not statistically selected from the population of potential 'CHaMP' watersheds in the TRT domain, two natural classes ("Warm, low, steep" and "Wet, cool, high, moderate erodibility") accounted for 71 % of the relevant domain.

Metric data from the sampled CHaMP watersheds that cover, say, 15% or higher proportion of TRT classes could be extrapolated to the unsampled watersheds. This proposition could be tested by comparing metric scores in a random set of locations in each of the unsampled natural classes with CHaMP's metric scores.

Figure 37. The extent of several of Whittier et al.'s (2011) natural classes in the Chinook/anadromous steelhead Columbia domain (TRT domain). The bar graphs are scaled to 100%. The per cent of the TRT domain covered by each class is across the top. The yellow portion of the bar indicates the percent of each of the natural classes that is covered by CHaMP's monitoring. For example, the natural class "Warm, low, steep" accounts for about 47% of the TRT domain. Of that, CHaMP watersheds cover slightly more than 15%. The extents are determined by the stream network km occupied by TRT populations.

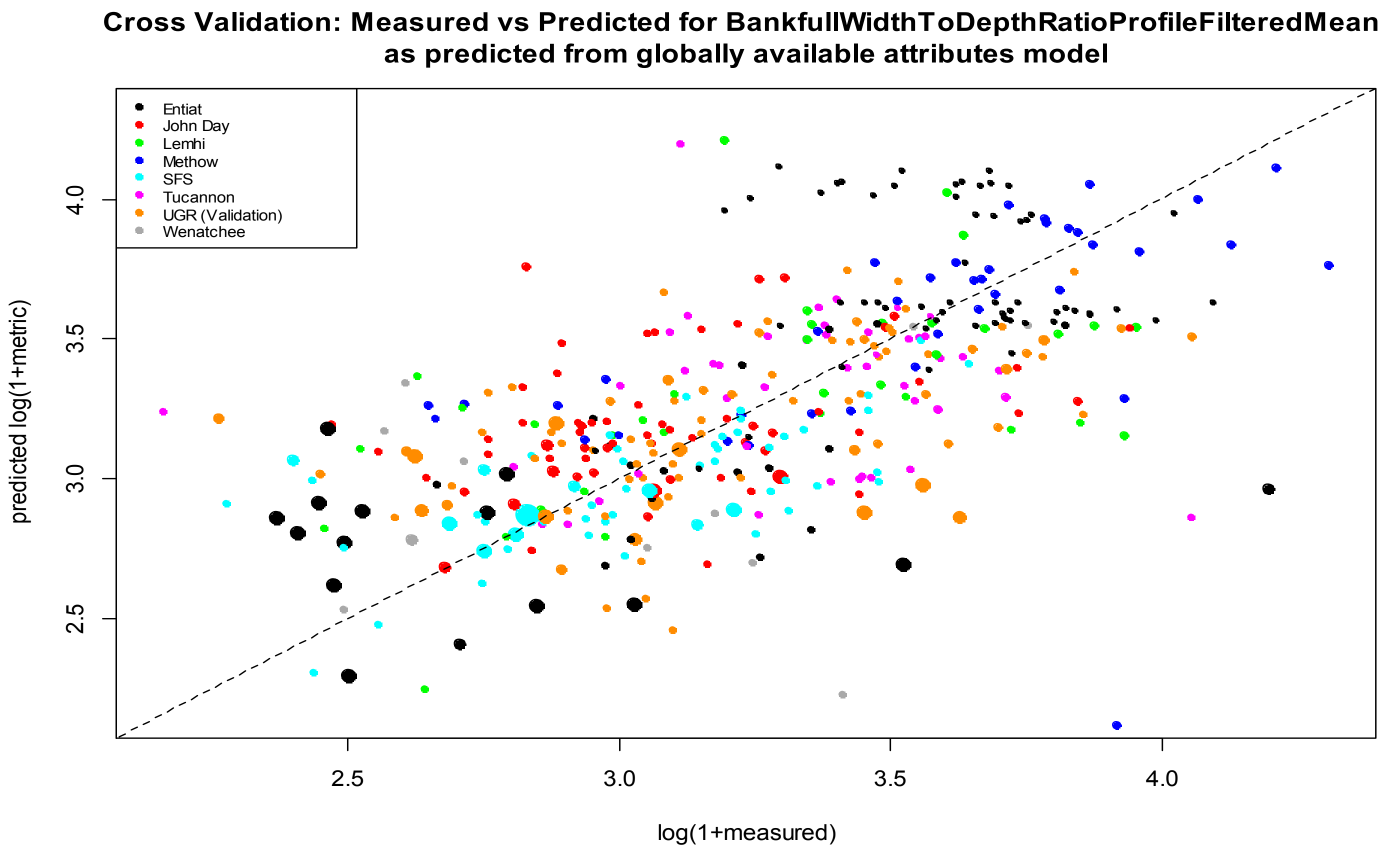


Figure 38. Cross validation results for regression of geo-spatial attributes and Bankfull Width-to-Depth Profile Filtered Mean. The x-axis shows the natural log of the CHaMP metric and the y-axis shows the predicted value as estimated in leave one out cross validation. Dot color indicates watershed and dot size is scaled to the sample design weight of the measured site

tion include: a geomorphic classification (at the level of CHaMP's valley class stratification, or at a finer geomorphic resolution (e.g., RiverStyles); Omernik's ecoregion classification and others.

ISEMP performed a linear regression of CHaMP metrics on globally available geo-spatial attributes and Whittier (2011) classes, while properly accounting for non-uniform sample design weights (R package svyglm). In many cases, strong linear relationships were found between these metrics and the geospatial attributes. Prediction error was assessed through leave one out cross validation, and thus provides the best estimate of the predictive ability of the above relationship at non-sampled sites for which the sampled sites are a representative sample (Figure 38).

In addition to assessing the slope and prediction error, analysis of residuals was performed to ensure predictions are not biased by watershed (Figure 39). Figures 38 and 39 show that there is a strong relationship between globally available geo-spatial attributes and bank-full width to depth profile filtered mean, and the residual errors do not vary by watershed. This suggests that this relationship explains nearly all watershed-watershed differences, and that predictions made for other interior Columbia Basin watersheds using the regression model are likely to have site-level prediction errors consistent with the errors calculated for the initial regression.

Thus, regression on these globally available geospatial attributes provides a powerful tool for extrapolating CHaMP metric estimates into un-sampled regions. This analysis has been done for a suite of key CHaMP metrics, and thus far has been successful in providing similar relationships on which fish-habitat relationships are being modeled. Further work is ongoing to expand and improve these relationships.

When developing relationships between habitat and juvenile salmonid survival, habitat metrics must be estimated at the same spatial scale at which survival is assessed for a given life stage

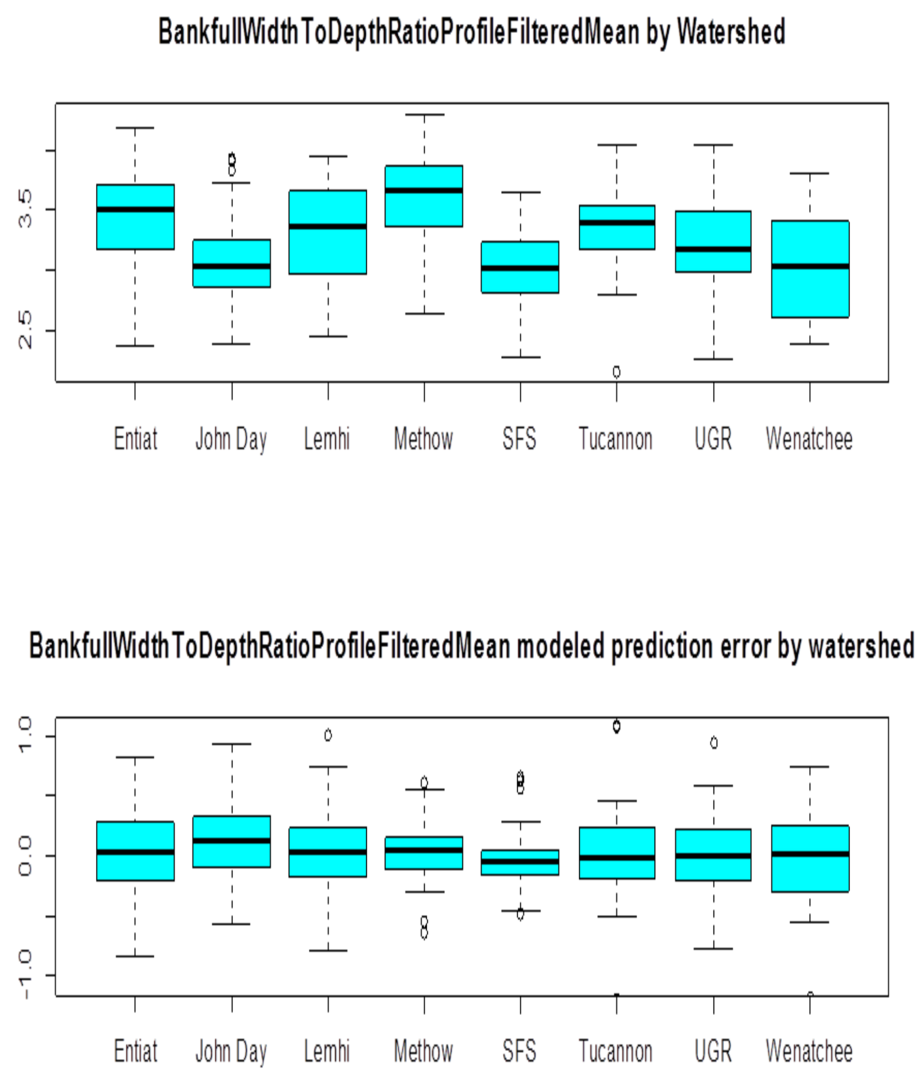


Figure 39. Bank-full width to depth ratio profile filtered mean, by watershed; and cross validation residual from predicated bank-full width to depth ratio profile filtered mean, by watershed.

Table 10. Reduction in uncertainty in D84 for upper Murderer's Creek from augmenting sampled data with modeled data.

Estimate	N	Estimate	LCB	UCB	Reduction in 95% C.I. Width
GRTS Analysis (spsurvey)	12	3.999	3.520	4.478	70%
GRTS Analysis and Modeled Values	50	3.860	3.760	4.052	

and for a specific salmonid population. The spatial domain for some populations may contain only a few sample CHaMP sites, and precision of mean CHaMP metrics at those scales may therefore be problematically low. To address this, estimates made from sampled CHaMP sites can be supplemented with estimates made for all sites in the spatial domain of interest, using the relationships between metrics and geospatial attributes developed using data from the entire CHaMP domain, thereby improving spatially explicit estimates within sampled domains.

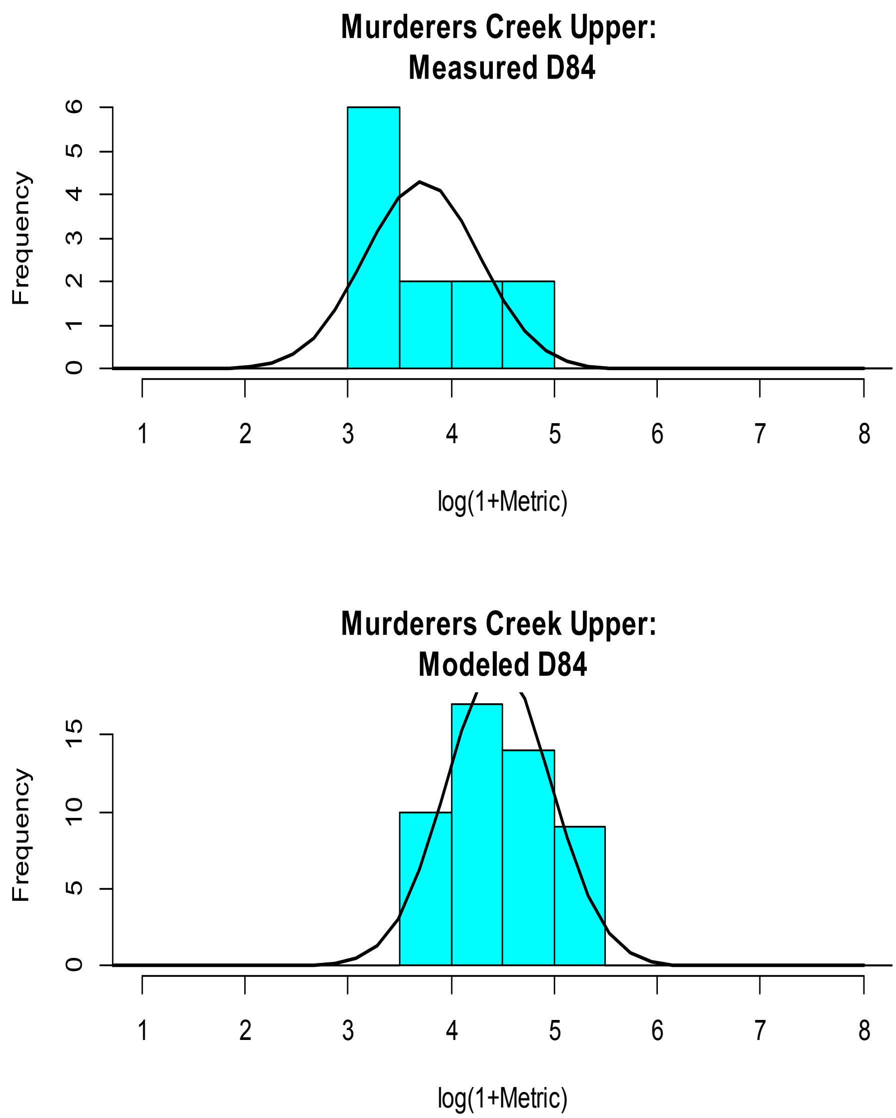


Figure 40. Measured D84 (top) and modeled D84 (bottom) in upper Murderer's Creek.

In Figure 40:

- Estimates from sampled CHaMP sites can be supplemented with estimates made for all sites in a domain to improve spatially explicit estimates within sampled CHaMP domains.
- For example, 12 sampled CHaMP sites from a GRTS based design are present in the upper Murderer's Creek spatial domain for the parr-smolt O. mykiss life stage. Because there are only 12 sites, resulting estimates for CHaMP metrics have fairly wide confidence intervals (Upper graph).
- A total of 50 sites exist where CHaMP metrics can be predicted based on geo-spatial attributes within this domain. These modeled values, along with careful accounting for the estimated distribution of model prediction error, can be used to augment CHaMP predictions (Lower graph).
- In the case of the resulting point estimate for D84, the mean differed little from the original estimate and the uncertainty of the estimate, as indicated by the width of the confidence bounds, was reduced by approximately 70% (Table 10).
- Given that assumptions about estimates can be validated on a case-by-case basis, augmenting sampled data in this manner can be used to greatly improve the precision of estimates at fine spatial scales.

For example, a spatial domain for an approximately closed *O. mykiss* population over the parr-smolt life stages has been defined in upper Murderer's Creek within the John Day watershed. Only 12 CHaMP sites from a GRTS based design are present in this spatial domain and, consequently, resulting estimates for CHaMP metrics have fairly wide confidence intervals. However, a total of 50 sites exist where CHaMP metrics can be predicted based on geo-spatial attributes exist within this domain. These modeled values, along with careful accounting for the estimated distribution of model prediction error, can be used to augment the CHaMP predictions (Figure 40).

The 12 sampled CHaMP sites were used as an informed prior in an empirical Bayesian analysis of modeled D84 at all 50 sites. The distribution of prediction error was included in the model and the resulting point estimate for mean D84 differed little from the original estimate. The uncertainty of the estimate, as indicated by the width of the confidence bounds, was reduced by approximately 70% (Table 10).

While the improvement in precision is significant, all such estimates must be made with care as several assumptions are made in the process and must be validated on a case-by-case basis to ensure appropriate use of the augmentation process. These assumption include spatial independence of models (as discussed above), as well as insignificant spatial autocorrelation of residuals, normality of residuals, and constant variance of residuals (validations performed but not reported for this example). Given that these assumptions can be validated on a case-by-case basis, augmenting sampled data in this manner can be used to greatly improve precision of estimates at fine spatial scales.

CHAPTER VII: 2013 IMPLEMENTATION REVIEW

Introduction

This chapter presents information on overall project coordination as well as how individual CHaMP elements were implemented in 2013. Discussion in the sections that follow builds on content in the 2011 and 2012 CHaMP lessons learned reports and is designed to focus on the significant changes and challenges associated with 2013 implementation. A summary perspective based on the three years of project is also provided along with recommendations for 2014 implementation. Please refer to the Ward et al. (2012) and CHaMP (2013) for specific information about field implementation in each previous project year.

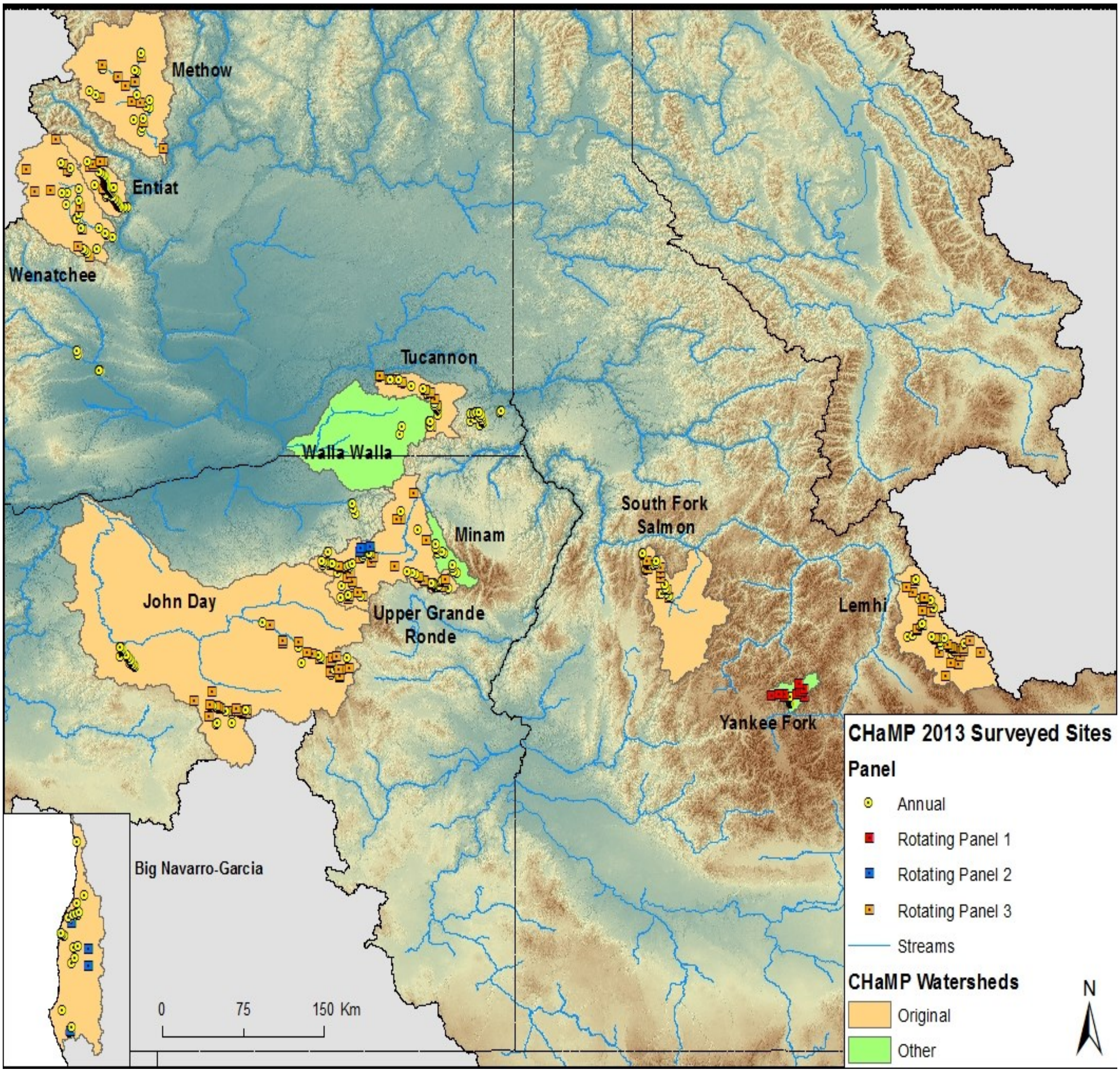


Figure 41. Sites and watersheds surveyed using the CHaMP 2013 protocol.

Program-wide Coordination

Coordination among all aspects of the project improved again from 2012-2013, as it had from 2011-2012. Due to lessons learned from the two previous years of implementation and adaptive project management, the number of recommended adjustments to the 2013 protocol and other program elements stayed about the same or decreased from 2012. As mentioned previously, coordination between the CHaMP and ISEMP projects increased in 2013 due to advances in ISEMP's fish-habitat relationship modeling and synthesis product development efforts, which are supported in many ways by CHaMP habitat data collection, metrics, and custom tool development. In December 2013 the CHaMP-ISEMP team held discussions to outline its FY 2014 contracting strategy, with input from BPA policy and decision makers. Concerted time and effort was invested to ensure that project implementation tasks in 2014 would continue to support CHaMP-ISEMP collaboration to help address KMQs. As a result, although use of prior year budgets and contracts facilitated contract development, contracting for FY 14 took additional time overall. The end result, however, was the identification of strategic CHaMP tasks and deliverables designed to further the most promising approaches and products outlined in the analytical framework of the CHaMP 2012 report (CHaMP 2013).

Coordination with Managers (NPCC, BPA, NOAA)

As in previous years, coordination with managers in 2013 occurred through phone calls, emails and meetings. In an effort to rotate the location of the post-season workshop to areas around the interior Columbia River Basin and potentially draw more crew participation, the 2013 the post-season workshop was held in early December in Boise, ID. In a shift from 2011 and 2012, the goal of the 2013 post-season workshop was not to present preliminary data from 2013 in support of fish-habitat relationship product discussions with managers. This is because lessons learned from 2011 and 2012 showed that, even with improved QA tools and crews needing less time for end-of-field-season data QA, attempting to wrap up QA on an entire year's worth of CHaMP data and immediately produce preliminary analyses results proved highly challenging. Therefore, the CHaMP team worked with BPA and other managers to shift sharing of CHaMP-ISEMP analyses and synthesis products to late February 2014. Information that was shared and discussed with managers and policy and decision-makers during the February 2014 ISEMP -CHaMP Analyses & Synthesis Workshop forms the basis for Chapters II-IV of this report.

Coordination with Regional Programs

The role of CHaMP project collaborators grew again in 2013, particularly in terms of expanding the number of watersheds in which the CHaMP protocol was implemented and providing analytical support. As examples, ODFW leveraged its resources to begin CHaMP data collection in the Minam watershed, the Shoshone-Bannock tribes began CHaMP protocol implementation in the Yankee Fork watershed; and CRITFC contributed to the 2013 study to help evaluate the utility of drift macroinvertebrate sampling. CHaMP collaborators also continued to advance the use of CHaMP metrics in the development of tools and synthesis products, such as HabRate and CRITFC's life cycle model, to help answer BPA's KMQs. Also in 2013 the USBR leveraged CHaMP data collected in the Methow to assist with parameterization of its LCM (see ISEMP 2014).

Discussion with regional collaborators and crew members about 2013 implementation occurred at the CHaMP 2013 post-season workshop. Team CHaMP-ISEMP information sharing and product update sessions were held with regional collaborators on a second internal day of the workshop, and a combined CHaMP-ISEMP project work planning session was held on a third day. These added collaboration sessions in December resulted in the FY14 contracting strategy, discussed previously, and facilitated alignment of CHaMP-ISEMP deliverable development and reporting goals with other regional management and decision-making processes that were ongoing or planned for 2014.

CHaMP-PIBO

Throughout the 2013 implementation period BPA policy staff expressed considerable interest in furthering the identification of potential efficiencies that could be gained through CHaMP-PIBO program integration. Collaboration with BPA and PIBO staff involved in-the-room meetings as well as phone discussions to address BPA policy and management staff questions that included:

- Can sampling sites and data from the two programs be used interchangeably?
- Can sites and data from one program be substituted for sites/data of the other program, that is, can the number of sites sampled by either or both programs be reduced without adverse effects to the study design(s) or a decrease in the quality or utility of the metrics that CHaMP and ISEMP are generating to help answer fish-habitat relationship questions?
- Can metrics and datasets from the two programs be used and displayed together in a meaningful way?

In November 2013 BioAnalysts (T. Hillman memo, 9/19/2013) produced a paper for BPA titled "Options for Converging PIBO and CHaMP" to assist with identification of program components that could be converged to potentially effect time and cost savings without jeopardizing the goals and objectives of each program's study design. The optimal approach to Hillman's proposed options are, roughly in the order:

1. Data sharing / management tasks
2. Spatial Overlap and Sampling Design alignment
3. Metric and Indicator alignment.

The overarching rationale for approaching the proposed tasks in the order suggested above is to minimize risk to both programs and the loss of ongoing

value while maintaining the programs' benefits and flexibility. The goal of this approach is to recommend changes and actions that balance project-specific logistics with progress towards regional approaches to collecting, analyzing, reporting and sharing aquatic habitat monitor data. Accomplishing a joint/merged data management task would be a large step forward towards the goal of a region-wide stream habitat monitoring effort (see Metric Interoperability). A single data management portal would make multiple programs' stream monitoring data immediately available through a single query interface, thereby removing initial concerns surrounding lack of coordination. Secondly, several immediate steps can be taken to address the question of spatial redundancy between these two monitoring programs. Ultimately, more extensive evaluation will be necessary to fully align survey designs, but initial steps in this direction can be implemented with little loss of information. Aligning metrics and indicators is an ongoing effort, underway within each program and as a task from the Federal Caucus.

With respect to program metrics, BioAnalysts recommended that the CHaMP-PIBO work group examine at a minimum (1) the relationships between habitat metrics and fish performance (e.g., survival, productivity, biomass, and/or abundance) and (2) the relationships between common metrics (T. Hillman 2013). Step 1 is ongoing via ISEMP's work to examine the relationship between CHaMP-ISEMP habitat metrics and fish performance (e.g., using boosted regression tree models, structural equation models, etc.; see ISEMP 2014) and development of some correlations between PIBO metrics and juvenile survival (C. Paulsen).

In 2013 the CHaMP-ISEMP team continued to examine relationships between common CHaMP-PIBO metrics (refer to CHaMP (2013) for background and preliminary CHaMP-PIBO information on common metrics). Numerous metrics from two programs were evaluated at the end of FY13 and grouped according to "interoperability" (e.g., are the metrics calculated exactly the same way? Is the metric unique to only one program?) to help develop workflow for CY14 related to metric and indicator alignment (Task 3).

In order to answer questions about potential efficiencies that could be gained by the programs agreeing to share sites, alter their study design and/or sample size, etc.. BioAnalysts and CHaMP-ISEMP staff determined that additional statistical analyses and management-level discussions would be required in 2014 and beyond to evaluate the risks and benefits of changes to the number of sample sites, site distribution, and frequency of sampling. The multiple considerations that need to be a part of metric integration and interoperability discussions are presented in Chapter VI, Metric Assessment.

For 2014 CHaMP-PIBO work will continue to focus on evaluating the core set of habitat metrics common to both programs, options for combined use, and discussing options to manage and serve these data. Additional discussions between CHaMP-ISEMP, BPA and the CHaMP-PIBO work group will be required in 2014 to determine what if any of the options presented by BioAnalysts relating to changes in program sampling and study design should be pursued. (see Chapter VI).

Discussion about shared data management will continue in 2014 as well. Additional work will be required to develop cross-walk models to address the consistent difference in the relationship between some program metrics.

Please refer to Chapter VIII, "Can data integration across regional monitoring programs (MMX) be accomplished?" for a table summarizing "Same" and "Similar" CHaMP-PIBO metrics.

CHaMP-AEM

The BPA's Action Effectiveness Monitoring (AEM) program was rolled out in 2013. The AEM protocol is largely built from the CHaMP protocol and relies on total stations and CHaMP custom GIS and QA tools. Consequently, BPA and AEM project staff requested that CHaMP support the attendance of AEM crews at training in 2013. In addition, CHaMP was asked to provision AEM crews with CHaMP project equipment to the extent possible, provide study design development assistance, technical assistance throughout the field season, and post-season QA support. Multiple pre-season discussions were held with BPA staff to identify mechanisms to accommodate additional non-project participant needs in 2013. The CHaMP coordination team developed an interim "Governance Document" to outline expectations about CHaMP collaboration and participation in 2013, and costs that would have to be bore by new entities for participation. Ultimately, the CHaMP project was able to define support mechanisms and implementation costs for AEM crews from Tetra Tech, the CTUIR, Shoshone-Bannock Tribes, and the CTWSR, as well as the new ODFW Minam watershed.

Although CHaMP project support for the new AEM effort in 2013 was successful, the late nature of the request for CHaMP to help guide development and implementation of another regional monitoring program consumed valuable team time during the critical period leading up to training and field season implementation. Examples of the challenges the CHaMP team addressed included: a compressed timeline for the development of the Governance Document and associated AEM contracts for CHaMP program support, the need to review CHaMP study objectives and sampling design in detail with the AEM development team to address questions about why a CHaMP site should not be moved or eliminated when an AEM site would lie in proximity to it, and how the AEM protocol and methods should be aligned with the CHaMP protocol so that the CHaMP data management workflow and tools could be leveraged by the AEM program.

Recommendations to improve CHaMP-AEM coordination in 2014 include earlier AEM-CHaMP staff communication regarding expectations surrounding CHaMP support of the AEM

project. Repeating the hurried approach to integrating the training and field season support for two large regional monitoring programs is not favorable. AEM program development and implementation schedules would benefit from better alignment with the schedule established by the CHaMP-ISEMP development team, as AEM is designed to leverage CHaMP methods and tools, so that AEM program efforts can capitalize on the existing cycle of pre-season planning, implementation and metric studies, lessons learned analyses, and subsequent protocol modifications. Additional dialogue will be required in 2014 regarding how to better coordinate monitoring objectives and study design development between the two programs, as these are important aspects of metric and program interoperability (see Chapter VI).

Habitat Sampling and Protocol Summary

- ***Are the methods implemented by CHaMP exportable to other projects and programs?***

In 2013, CHaMP field implementation involved 23 crews and 124 associated hitches, totaling 513 visits (429 unique sites in 2013. Over the 2011-2013 pilot period, 1,394 site visits were conducted.

Sampling was implemented in new watersheds in 2013, as in 2012, which resulted in another year of incremental growth beyond core CHaMP project watersheds during the pilot period. This growth was driven by implementation of BPA's AEM project. The map at the beginning of this chapter depicts the watersheds and types of sites that were sampled in 2013 using the CHaMP protocol.

The CHaMP protocol has been revised annually since its inception to incorporate the knowledge gained from each season of field implementation during the 2011-2013 pilot period. During this time, the habitat protocol is best viewed as a living document that was subject to change as CHaMP added, subtracted, or modified portions of its sampling methods. To ensure stability and standardization of the CHaMP protocol during the field season, any changes to methods are adopted and trained prior to the beginning of the field season and adhered to until the next year's protocol modifications are complete. Decisions about whether to modify a method are based on many considerations, such as, "What does the proposed change mean in terms of data collection time and analysis cost? Would the change result in higher quality data and metric outputs? Since 2011, CHaMP has documented all sampling method changes in detail using a protocol change log.

As mentioned previously in Chapter VI, CHaMP metrics are also evaluated annually after every field season for precision (root mean square error; coefficient of variation, and signal to noise ratio), comparability between crews, and measurement accuracy. Therefore, because protocol changes can affect metric calculations, CHaMP must also consider questions such as, "Can a metric "cross-walk" be created to allow data collected under one method in one year to be combined with data collected using an alternate method in subsequent year(s)?.

Many of the protocol changes that were implemented for the 2013 sampling seasons were designed to increase measurement accuracy and precision, and decrease costs for both the field implementation and metric generation processes. Examples of such protocol adjustments include:

- Modifying methods to produce higher resolution metrics used for assessing fish habitat condition.
- Dropping select measurements or metrics that were determined to be highly variable and not repeatable.
- Adopting different approaches to increase accuracy, precision, and comparability between monitoring efforts.

A summary of protocol method changes and rationale is presented in Table 11. The total efficiency gained through these protocol improvements is hard to evaluate due to the crew workflow and data capture challenges and time expenditures associated with topographic survey equipment (i.e., total stations; see Equipment).

<u>Key protocol improvements for 2013</u>

- **Undercuts**

The use and importance of undercut banks by and for salmonids for fish cover and thermal refuge has been well documented in the literature; however, they have also proven to be problematic to capture and quantify in the field because of the various shapes and sizes of undercuts, and their seemingly random distribution within a site.

CHaMP made changes to its undercut methodology based on findings from variance decomposition analyses conducted on annual sites sampled in 2011 and 2012. Data from 2011 indicated that undercut measurements were not very repeatable and, although better in 2012, the method still needed improvement. Therefore, CHaMP enhanced its undercut methodology to leverage survey techniques together with the auxiliary data collected in an attempt to save time and money during the survey, increase accuracy, and improve metrics to support a richer range of analyses.

Specific enhancements to the undercuts portion of the protocol included:

- Improvements to the language for undercut qualification
- Addition of figures for clarification
- Collection of higher resolution locational and GPS data at the channel unit scale
- Standardization of width and length measurements.

Improvements to the methodology did in fact increase metric data quality and repeatability at a site, as evidenced by metric calculations with higher signal-to-noise ratios and R values. Undercut changes also created efficiencies in data acquisition and cost savings, and improved metric content.

Substrate

Significant changes implemented in 2013 reduced the number of substrate particles from 210 to 110, which saved approximately an hour per site.

Table 11. Examples of CHaMP Protocol changes made from 2012-2013 and rationale. (adapted from Peitz et al. 2002)

Previous Version Number	New Version Number	Revision Date	Method	Changes made	Reason
1.2	1.3	2013	Channel Segment Numbers	Uniquely identified non-qualifying side channels, detached them from channel unit they flowed in to.	Associating non-qualifying side channels with the channel unit that they flowed into was not consistent among crews and the data utility was unknown. Unique record will allow additional side channel metric calculations.
1.2	1.3	2013	Fish Cover	Included boulders and undercuts in estimation of Total NO fish cover.	Including boulders and undercuts will provide a better estimate of total no fish cover and allow interpretation of those elements that may overlap.
1.2	1.3	2013	Ocular Substrate Composition	Changed Bedrock size class from >4000mm to n/a	Bedrock will be classified based on its characteristic, not its sizes.
1.2	1.3	2013	Large Woody Debris	Removed "Jam" classification	Difficult to assess in the field based on rules of touching pieces. Utility of data not known.
1.2	1.3	2013	Undercut Banks	Required three width measurements at predefined locations along undercut length.	Average width measurements were inconsistent among crew members. Having defined locations where measures are taken eliminates field judgment calls.
1.2	1.3	2013	Particle Size Distribution	Reduced number of counts to 110 pebbles (11 pebbles at 10 cross-sections)	To increase the efficiency of data collection.
1.2	1.3	2013	Drift	Reduced collection of drift samples to a subset of CHaMP sites	To increase efficiencies and improve data capture techniques

- **Macroinvertebrates**

As discussed in the metrics section, drift sample collection at all CHaMP 2013 sites was replaced with a study to examine the large amount of variability being displayed by the CHaMP macroinvertebrate drift metric.

__Protocol recommendations for 2014__

Preliminary results from 10 percent repeat visits performed at 50 2013 sites suggest that the CHaMP protocol needs to better quantify large wood volume and better capture a subset of side channel metrics, both of which are critical components of salmonid habitat.

CHaMP data indicate that the 2013 size categories used to assign length and width to large wood pieces for quantification purposes are too large to allow

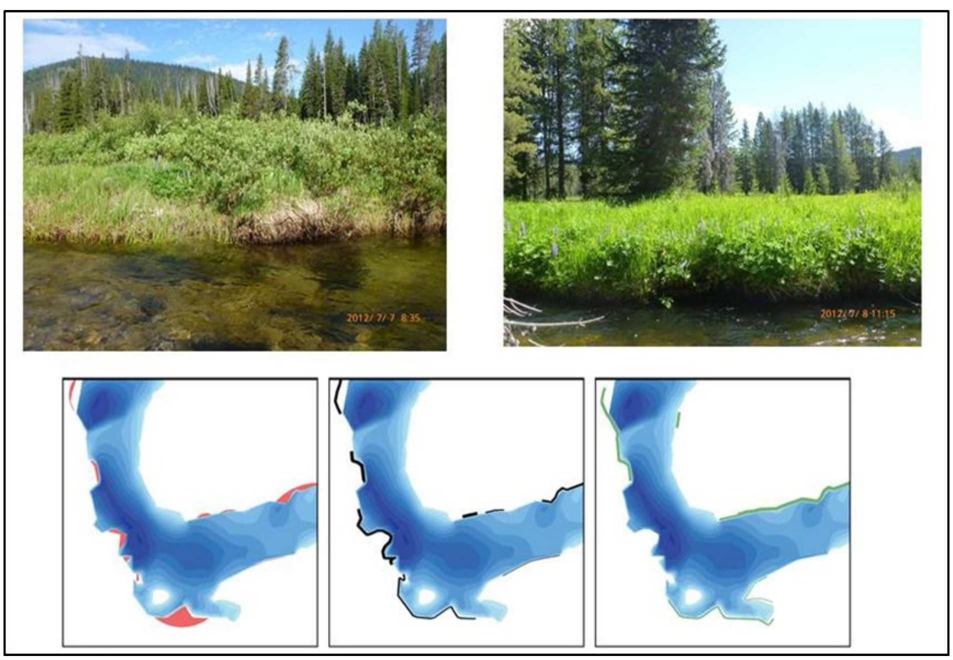


Figure 42. Spatially explicit undercut locations area and length at CHaMP sites.

meaningful calculation of large wood volume and more precise data are needed. In 2014 changes will be made to the large wood method to improve length and diameter data for each piece of wood collected in order to more accurately calculate the large wood volume metric. Proposed changes to the large wood method should result in minimal addition to data storage (data base modification), data summarization, QA/QC, and training in 2014.

Preseason Planning

Training

The "CHaMP Camp" 2013 pre-field season training was held in from June 2 to June 12 in Cove, Oregon at the Ascension Camp & Conference Center. As in 2011 and 2012, the 2013 training was started in the first week of June to accommodate all crews that need to start their field season by June 15 and those agencies that do not start hiring field staff until June 1. Because this time period has worked well for all three years of project implementation, training will most likely targeted at this period for 2014 and subsequent CHaMP project years.

Approximately 83 participants were trained at stream-side field locations, outside on campus, and in classroom and computer lab settings. Of the 83 trainees, 13 were CHaMP field crew supervisors and leaders that also acted as lead trainers or helper trainers. The training remained structured like the training in 2012 to maximize training time, minimize outside distractions, and build on the previous year's framework. The cost of instruction, facilities, meals, vehicles, and equipment for almost all participants was covered by the CHaMP project. Returning to the same venue and using many of the same trainers again made logistics, pre-planning for the event, and training execution much simpler and more efficient. Overall, training schedule and module development, logistics, staffing and coordination have improved over each of the past three years of the pilot project.

In 2013, the number of different entities that participated in training grew to include collaborators from BPA's Action Effectiveness Monitoring (AEM) program. New crews associated with the AEM program in 2013 that attended CHaMP Camp include the CTUIR, CTWSR, and SBT. These crews were provided standardized training on the full CHaMP protocol, primarily by staff from CHaMP. CHaMP coordination staff devoted a significant amount of time from February-April to discussions with BPA management staff, COTRs, and interested AEM project collaborators in order to identify and develop policy and administrative mechanisms that would allow new non-project AEM participants to attend CHaMP training and collaborate in 2013 field implementation.

All attendees were requested to complete the full training regardless of prior training(s) and entities were strongly encouraged to send a minimum of three crew members to the training for the full 10-day period. CHaMP coordination prior to and during training facilitated observation and limited participation by drop-ins participants. The importance of training a full crew in the CHaMP protocol was emphasized during discussions with potential AEM collaborators because each year of training promotes standardization, teaches new concepts, reinforces methods that have not changed thereby minimizing protocol drift, and allow returners to learn more advanced methods and serve as helpers within training groups and their crews.

The 2013 training placed added emphasis on the importance of data standardization, method repeatability, and overall data quality. To improve training on topographic surveying techniques and data post-processing, which were identified as areas for improvement in 2012, information-intensive material was broken up into introductory and advanced modules. This allowed trainers to better tailor module content to the experience level of each training group. In addition more trainers, including professional surveying staff from Utah State University, were added to help crews through the survey and GIS-intensive portions of the curriculum. To help ensure that all trainers taught the 2013 CHaMP protocol in a consistent manner and to promote success and standardization among the technicians, all lead trainers were required to provide a proposed training outline for their module. Senior CHaMP crew and trainer experience was leveraged to hone module mechanics and recommended work flow, site setup, and time allocation. In 2013 the use of trainer outlines, which allowed CHaMP protocol development and training team leads to provide feedback and recommendations on each trainer's proposed approach and key concepts prior to training, was introduced. Based on post-training feedback, this approach improved teaching consistency and protocol messaging and will be replicated as CHaMP move towards the 2014 field season.

An exit survey was used to solicit overall feedback to improve the training event for 2014. The 2013 survey included additional questions designed to capture comparative and retrospective input from two-year (2012 and 2013) and three-year (2011, 2012, 2013) CHaMP Camp trainees and trainers. Feedback received from this important subset of exit survey respondents was highly favorable and suggests that many of the lessons learned that were incorporated in 2013 training were successful at achieving goals for improvement(s). Feedback on the changes to training that the CHaMP team implemented from 2012 to 2013 and over the three year pilot period are summarized in Table 8.

Training recommendations for 2014

- Continue to emphasize the need for repeat participation by veteran crews and attendance at all 10-days of CHaMP training to promote standardization and ongoing improvement.
- Explore the feasibility of involving more crew supervisors from other collaborating entities as lead trainers or helper trainers to reinforce and expand their skills.

- Assess the potential for additional in-basin training after camp prior to season start, and/or advanced training modules and options for multi-year returners.
- Modify the 2013 Governance Document framework as needed to facilitate participation by new entities and/or CHaMP implementation in new watersheds again in 2014.
- Explore how to better align AEM project development with existing CHaMP workflow to identify 2014 AEM training/support needs.

Table 12. Summary of comments from two and three-year returning trainees on changes to the CHaMP field season training from 2012-2013 and over the full 2011-2013 pilot period.

Comments on training change from 2012 to 2013	Comments on training change over three years (2011-2013)
The 2013 training better emphasized workflow, standardization, repeatability and referring to the protocol	CHaMP has become more standardized as it gains experience, and has improved greatly since 2011.
More trainers were available to help	Significant improvements have been made to workflow, GIS processing tools, AUX data capture application and methods.
The overall training ran smoother in 2013 and the handouts/tutorials/ tools were better	Everything has improved each year since 2011: the protocol is tighter, the organization is better, the trainers are more consistent.
Topics were taught in a more clear and consistent manner by and among trainers	Massive improvements in module information content, trainer consistency, and the smoothness of CHaMP's custom tools and applications.
Workflow and mock surveys on the last three days improved from 2012.	

Equipment

During each season of the 2011-2013 pilot CHaMP explored better and more efficient practices for use of existing instrumentation, and evaluated other pieces of equipment and/or models that could better support the CHaMP field sampling effort. Ultimately, the goal is to increase the variety of tools that can be used for data standardized data collection and output formats. Specific equipment changes are presented next.

As in 2011 and 2012, the success of season implementation in 2013 hinged on the quality and integrity of the equipment necessary to complete sampling at a site in a reasonable time frame (goal: 80% of sites in 1 day with 3 crew). Specific equipment challenges and changes made for 2013 are described in the sections that follow.

Total Stations

A large part of the CHaMP protocol involves the collection of topographic data. Therefore, survey equipment and workflow used to collect data points must be as accurate and efficient as possible.

In 2013 topographic data capture at most CHaMP sites occurred as it had in 2011 and 2012, by use of a total station. At the start of the CHaMP pilot, selection criteria for topographic survey equipment were based largely on instrument portability and extended battery life. Lessons learned from 2011 and 2012 indicate that purchase of the most compact and rugged total station on the market came at a cost to instrument performance and crew sampling efficiency.

Unfortunately, CHaMP crews struggled again in 2013 with the Nikon Nivo 5C Total Stations. Reoccurring issues that were reported by crews and documented in detail by CHaMP include:

- Frequent software freeze-up,
- Slow or incapable EDM (Electronic Distance Measurement),
- Unexplained vertical errors,
- Heat and solar sensitivity,
- Frequent loss of calibration.

Prior to the start of the 2013 field season, the CHaMP team worked with BPA staff to develop a plan to replace, at a nominal fee, all 23 Nikon Nivo 5C total stations that were purchased by the project in 2011 with a newer version of the same model. The decision to do this was made after the 2012 season in an attempt to fix or lessen the total station challenges that CHaMP documented in its 2012 report (CHaMP 2013), thereby improving the workflow and efficiency of 2013 crews. The newer Nikon version boasted a "more powerful Electronic Distance Measurement (EDM)". Surveyor's umbrellas were also purchased and added to each kit, which did seem to minimize the occurrence of heat and solar related issues for some crews. Nonetheless, most problems that were encountered in 2012 persisted in 2013 while others arose.

In early 2014, after repeated attempts to troubleshoot and fix issues with company representatives that visited CHaMP staff in the field, CHaMP began to investigate alternative total stations from other manufacturers so that new, more reliable total stations could be procured in FY14 well ahead of the start of the 2014 field season. The goal was to ensure adequate time for additional machine testing, calibration and habitat protocol refinements before 2014 training. BPA engaged members of its technical staff in CHaMP's process of researching and documenting alternate Total Station models. This enabled members of the CHaMP development team to convey its lessons learned from field

testing various models over the 2011-2013 period to BPA staff, and share details of program implementation and equipment needs to help guide BPA in its authorization of new total stations for the project. The CHaMP team prepared a matrix presenting options, technical specifications, pricing, and trade-offs for BPA and recommended migration to the TopCon DS 205 in 2014.

A significant amount of discussion occurred between the CHaMP development team and BPA staff to reconcile CHaMP's Total Station purchase proposal (Topcon DS205) with the total station model that BPA staff initially requested that CHaMP purchase for the project (Topcon DS105). In February 2014, at the very end of the CHaMP FY13 contract period, BPA staff agreed the model proposed by CHaMP presented the best option to balance cost with solutions and improvements to the field data collection workflow.

An unexpected consequence of meeting BPAs requests for detailed total station model information exchange and discussions was that it pushed out the timeline for making critical equipment decisions, which in turn had a ripple effect and pushed out overall project contracting for CY14, as well as pre-field season target dates for equipment purchase and procurement.

Datalogger

Results from using the Allegro MX over the 2011-2013 period were mixed (see Ward et al. 2012, CHaMP 2013). In 2013 migration away from the Allegro MX data logger to a new open-source code CHaMP application that would run on an iPad mini or standard-sized tablet began in order to eliminate Allegro performance and breakage issues in 2014. Effort being expended by the AEM project to develop a tablet data logger application will benefit CHaMP in that the new AEM protocol application will also support the entire CHaMP protocol. This in turn will enable both the CHaMP and AEM projects to utilize the same data collection platform (tablets) and protocol applications in 2014. Other advantages anticipated with the shift to the iPad tablet data logger include eliminating the need for other pieces of auxiliary data capture equipment, such as the Garmin handheld GPS (although most crews still prefer to use while navigating to the site markers initially), Clinometer, and GPS Camera.

Solmetric Suneye

CHaMP used the Suneye again in 2013 for solar input data collection; however, lessons learned during the 2012 field season prompted CHaMP to purchase and provide waterproof bags for all of the Suneyes in an attempt to prevent failures of this expensive electronic piece of equipment due to contact with water. Unfortunately, even after the provision of a waterproof bag. the Suneye's extreme sensitivity to water caused a number of these devices to need repair or replacement in 2013.

Additional Prism Pole Assembly

By 2013, many crews had become much quicker at collecting topographic data. Therefore, CHaMP provided a second prism pole assembly so that, for a three person crew, the person collecting auxiliary data could join the topo team as a second rodman

Equipment recommendations for 2014

- Begin to transition from the Nikon Nivo 5C total station to the Topcon DS205 total station

The base model of the reflectorless Topcon DS205 is reasonably priced, comes equipped with ATR (Auto-Target Recognition), and is very easy to upgrade to an Auto-Tracking instrument, or even a "poor-man's" robot. ATR should not only improve the accuracy of CHaMP surveys since it 'automatically' finds the precise center of prism on every shot, but will also speed up the process of searching for the target while lessening general surveyor fatigue.

- Explore replacing the Allegro MX units with iPad Mini tablets.

CHaMP should leverage the tablet application being developed by Sitka for the AEM project to facilitate CHaMP's transition to tablet data loggers. Advantages of this switch will include the ability to replace some auxiliary data capture equipment with iPad functionality.

- Reinstall the optical plummets that were removed from the backsight tribrachs and replace the 'traverse style' riser/adapters with simple 'puck style' prism adapters.

This shift should address the issue of 2013 crew confusion between the level bubble on the tribrach itself and the one on the riser/adapter, when they were not calibrated together, and also fix challenges with the riser/adapter optical plummet constantly losing calibration.

EQUIPMENT

- The most significant CHaMP equipment issue in 2013 was again related to total station performance and reliability.
- A key lesson learned from the pilot is that purchase of a surveying instrument that was highly compact (for portability in the field) and more rugged came at the cost of equipment performance and likely negated gains in crew sampling efficiency in 2012 and 2013.
- Intensive comparisons and field testing were conducted in 2013 to document instrument challenges. CHaMP worked with BPA at the end of FY13 to identify a different make and model of total station to purchase in limited quantity for use by select 2014 CHaMP crews.
- Project contracting for CY14 was pushed out to accommodate discussions with BPA technical and project staff, who authorized CHaMP to purchase 13 new instruments in February 2014.
- After the 2014 field season CHaMP will evaluate the potential to complete replacement of the remaining total stations concurrent with continuing to leverage other topographic survey instruments.

Custom CHaMP Tools

CHaMP Topographic Toolbar

In 2013 crews continued to use the CHaMP Topographic Toolbar in ArcGIS to process topographic data collected using total stations during field visits to sites. The primary enhancement to the toolbar was an optional quality assurance check and summary of processed topographic data prior to publishing to champmonitoring.org. Although these checks were not mandatory, the behind the scenes structural update to the toolbar will make enhancements to these checks in 2014 feasible. The second toolbar improvement was the update of cross section layout and metric calculations to include wetted side channel widths. Other behind-the-scenes improvements included the development of validation procedures for RBT metrics and a new metric procedure to calculate residual pool depth for channel units located along the thalweg.

Topo Toolbar recommendations for 2014

- Improve quality assurance checks
- Finalize the layout and calculation of cross-sections within side channels.

River Bathymetry Toolkit

RBT development in 2013 focused on adding several minor new metric calculations while leveraging the increasingly stable platform developed in prior years. The new features included:

- Calculation of new thalweg pool depth and thalweg residual pool depth metrics for each channel unit. This was accomplished by intersecting the channel Thalweg with each channel unit polygon and then finding both the deepest location along the thalweg in the channel unit, and the depth at the location where the thalweg exits each channel unit.
- Increased flexibility for CHaMP analysts to use the RBT for purposes other than central champmonitoring.org RBT runs. Manual inputs for both the default raster cell size and the default cross section width were created so that analysts could configure the RBT for larger, wider channels that those typically surveyed within CHaMP.
- Improvements to the RBT feature that compares multiple surveys and then changes the extent of their DEM rasters to all share the same spatial extent (which is required for GCD) so that it could fix concurrency as well as orthogonality.
- Restriction of visits so they have a single wetted extent polygon.
- Addition of a new metric for the standard deviation of the water depth.
- Addition of another the cross section width to depth ratio metric calculation to use max depth in addition to average depth.
- Production of a 64 bit version of the RBT in addition to the regular 32 bit version so that the RBT could be run against the ArcGIS Server at CHaMP-Monitoring.org, the latest version of which is only available in 64 bit.

The CHaMP Topographic Toolbar that crews use to post-process their topographic survey data into GIS datasets that are fed into the RBT dramatically increases the consistency of the topographic data, thereby making the RBT more reliable and stable. In 2013, this combination of the toolbar and RBT worked well and allowed for rapid processing of surveys once uploaded.

RBT recommendations for 2014

- Build on the existing stable platform
- Continue to add validation checks
- Add a few minor metric enhancements. New metrics include a revised approach to bank angle (to produce a metric that is more comparable with transect-based protocols) and add site-specific FIS error modeling.

Data Management System

The CHaMP data management system is integrated within and accessed from the URL https://www.CHaMPmonitoring.org (CM.org). The CM.org site is the central hub for access to all CHaMP study designs, monitoring data, and metrics.

Enhancements to CHaMPMonitoring.org

In 2013, Sitka enhanced a number of CM.org features to improve quality assurance functionality, performance and usability. Specific updates included:

- Add ability to incorporate ad hoc sites into a survey design on an opportunistic basis
- Add TrueTemp QA tool for stream temperature data and automated anomaly detection (Figure 43, next page)
- Replace QA plots with a full feature chart control (Figure 44, next page)
- Add more flexibility for uploading topographic dataset(s)
- Allow topo files to be uploaded in "Needs Attention" state
- Display topo QA report
- Download topo files from watershed-scale
- Add engine to support generating Site.gdb
- Re-engineer the topographic survey / RBT orthogonality engine
- Allow file upload directly from CM.org and remove need for the Egnyte cloud file server
- Export Microsoft Access databases containing monitoring data nightly
- Improve performance for loading data to grids
- Provide ability to load CHaMP 2011 Solar Pathfinder data
- Provide additional help within the CM.org application

Data Logger Improvements

Changes to the data logger application for the 2013 field season were based on 2012 field collaborator and post-season workshop feedback (see Equipment for logger Hardware). Logger software improvements that were implemented in include:

- Create new record navigation controller for parent form
- Create parent channel unit form that includes all channel unit methods as subforms

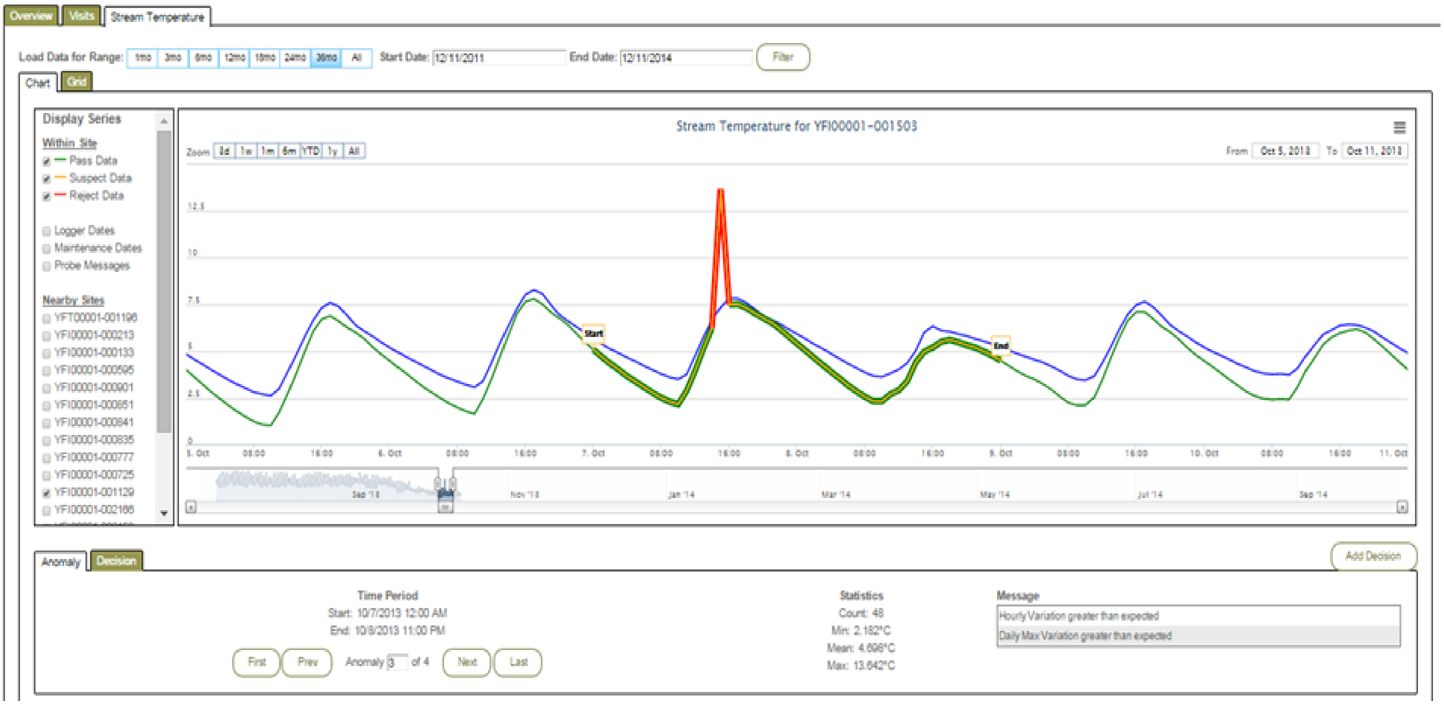


Figure 43. CHaMP 2013 stream temperature QA tool, incorporated into the CHaMP data management system. Suspect data are flagged and rejected (in red). Data from a nearby site were plotted for comparison.

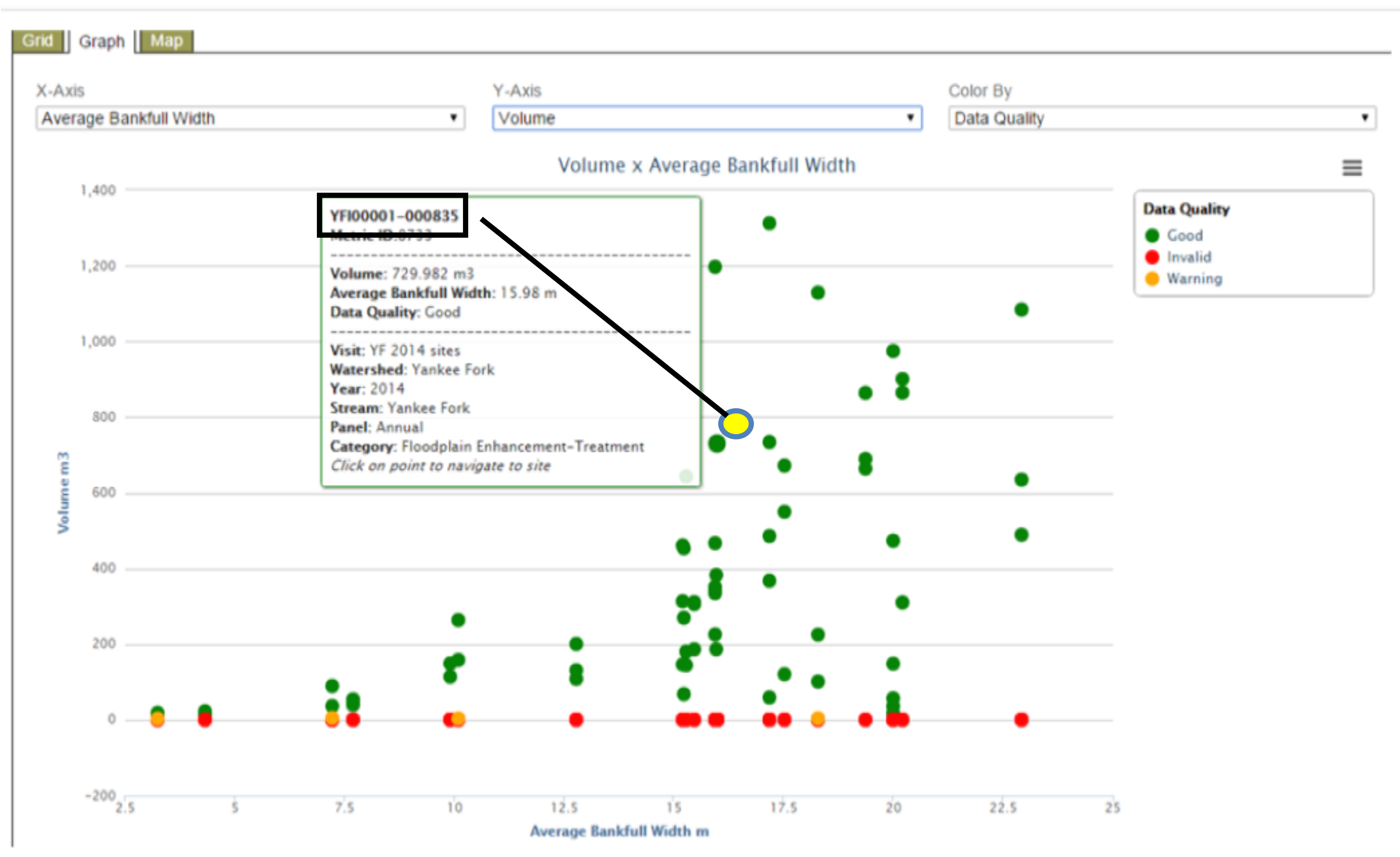


Figure 44. The new CHaMP 2013 measurement and metric QA tool component of CM.org, which allows the user to select the attributes represented on the x-axis and y-axis, select the attribute used to color the points, hover the mouse over a point to pop up site details, and zoom the graph on both the x- and y-axis.

- Move LWD, Pool Tail Fines, Pebbles, Undercut Banks forms to the Channel Unit form
- Create parent transect form that includes all transect methods as subforms
- Move Solar Input, Riparian, and Photos to the Transect form
- Create a new Channel Unit Layout form for entering Unit#, Tier1, Tier2, and Segment Number.
- When Unit# is clicked, jump to the detail form for that unit.
- Update the Discharge form to automatically build stations, calculate tape distance, calculate station width, and calculate discharge
- Automatically create 15 discharge stations
- Enhance functionality of validation summary report
- Add button to allow user to control when the validation summary is run
- Add the ability to jump from any form to validation summary form
- Create a validation icon for "not required, but missing"
- Support entering three depths for undercut banks and then display the average.

Laptop Data Broker Improvements

All 2013 crews were able to use the CHaMP laptop data broker to receive immediate feedback about the completeness and quality of their data. This in turn produced a significant decrease in the time between when 2013 auxiliary data were collected and when they were posted to CM.org, and a notably decreased the effort required to complete quality assurance review of the auxiliary data.

Specific Data Broker enhancements for the 2013 field season included:

- Send auxiliary xml file via ftp instead of as a web service call
- Add ability to indicate a method was not implemented
- Add ability to indicate a measurement was not implemented
- Automatically update broker software on the laptop
- Add data status grids for organization and crew
- Send Scouting files to crew laptop
- Allow user to indicate that air and stream temper files are not currently available
- Filter tree to only display data sets that are actionable
- Create channelunit.csv and benchmark.csv file on laptop

Data Broker recommendations for 2014:

- Increase file upload time-out for slow internet connection
- Set time-out parameter in configure file
- Add message for time-out
- Add button to reset photos for uploading after time-out
- Support raw files from any topo survey equipment
- Either remove all validation or get list of expected file extensions

Import Study Designs from Sample Designer

In 2013 Sample Designer enhancements were added to support the upload of site coordinates (latitude and longitude in decimal degrees) to a new block (combination of panel and category) within the study design during the active field season. This improvement was made to address collaborators' desire to be able to implement the CHaMP protocol "opportunistically" during the active field season at sites that were not initially included in the pre-field season sampling design. Much of the interest in being able to opportunistically include new sites was driven by the desire to be able to perform effectiveness monitoring at newly created restoration sites. Collaborators also identified the need for the data upload process to be completed with a much shorter turn-a-round time (days, not weeks as was the norm with the former manual upload process).

Sample Designer enhancements allowed the addition of *ad hoc* sites to a new block in a manner that avoided confounding the weight calculation for the status and trend blocks within the overall CHaMP study design. Creating the ability for a site to be added opportunistically also made it available for site evaluation, hitch planning, and download from CM.org to the Data Broker by all 2013 crews (AEM and CHaMP).

Overall data management system (CM.org) recommendations for 2014:

- Make Site map and site photo .pdfs available for download
- Improve documentation for metric calculations
- Continue to update metric calculations
- Add support for additional metric engines
- Handheld data logger
- Update Allegro for 2014 methods
- Pilot iPad application in one watershed/contractor
- Clean out non-measured text from xml file after user removes the non-measured toggle for the measurement or input group

CHAPTER VIII: IS THE CHAMP PILOT COMPLETE?

The implementation of CHaMP was initiated under a "pilot" designation following discussions with the ISAB/ISRP and their concerns regarding the development of a new region-scale habitat monitoring program based on response and survey designs that were considered not fully established. Thus, the initial footprint (Wenatchee, Entiat, Methow, John Day, Tucannon, Lemhi, Upper Grande Ronde, SF Salmon) was to be considered a trial run for the program before any additional watersheds were brought into the sampling design. That is, the "full" implementation of CHaMP, as suggested by the BiOP RME Working Group, was designed to represent the tributary habitat data needs of the BiOp RPA and the AMIP life cycle modeling task. The "pilot" implementation of CHaMP was assumed to be less than the full set of sites necessary, so that after sufficient confidence in the methodology was generated, a more complete sampling of the interior Columbia River basin would be undertaken. While the cautious approach to the launch of the program certainly was warranted – an enormous investment was being considered based on the development work done within ISEMP in the John Day River basin – the terms of the "pilot" designation weren't specified, nor were the evaluation criteria to indicate moving the projects designation to post-pilot, or production. In order to move the program's status to a general discussion, we have developed a set of evaluation criteria in the form of a series of questions that we feel adequately demonstrate that the CHaMP pilot has met its objectives.

Given three complete monitoring-evaluation cycles and the extensive QA/QC processes implemented by the CHaMP team on all aspects of the project (protocol, training, field data collection gear, data capture, data cleaning, data stream, data management, analysis methods), we feel that the project has matured to a sufficient degree that it meets the technical expectations of a robust, dependable stream habitat monitoring method. Furthermore, we feel that CHaMP implementation groups, collaborators, and the ISEMP analysis efforts have demonstrated the utility of the CHaMP data to resolve critical uncertainties for both tributary habitat and salmon population management efforts. As such, we consider the pilot implementation phase of the Columbia Habitat Monitoring Program to be complete, that the robustness and utility of the method has been adequately demonstrated, and that the Environment, Fish and Wildlife Program can confidently implement CHaMP to address key management question as called for in the FCRPS Biological Opinion and other programmatic directives.

To support the assertion that the CHaMP pilot phase is complete, we have constructed an evaluation rubric that consists of a series of questions. The questions and our responses are presented below. Developing additional evaluation criteria is certainly appropriate, and in future conversations with the ISAB/ISRP and other review entities, the content of this rubric could be modified.

Does CHaMP Generate Useful Descriptions of Stream Habitat Condition?

Yes, useful descriptions of stream habitat condition are generated by CHaMP. Status, and eventually trend, descriptions of physical and biological habitat in salmon-bearing streams of the interior Columbia River basin are generated by CHaMP. A broad suite of univariate metrics as well as a number of multivariate metrics result from the CHaMP response and survey design (Figure 45). These metrics can be used for design-based inference at the site-scale for habitat project construction and effectiveness assessment, for regional status/trend assessment at the watershed-scale, and for model-based inference at the process-domain-scale (Figure 46, next page).

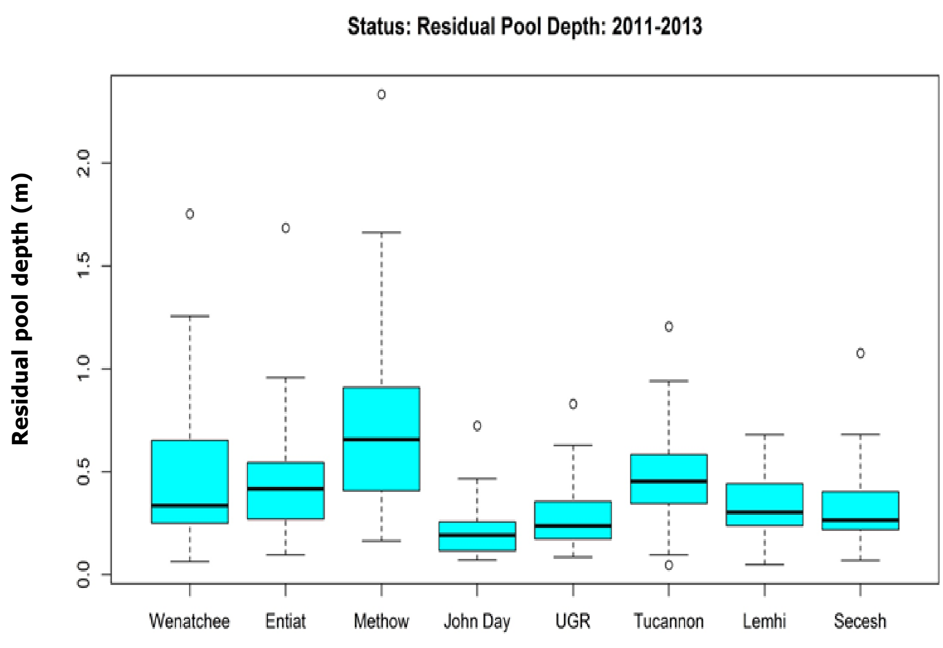


Figure 45. A single CHaMP metric, Residual Pool Depth, combined over the first three years of sampling (2011-2013) at annual sites in CHaMP "pilot" watersheds to show status.

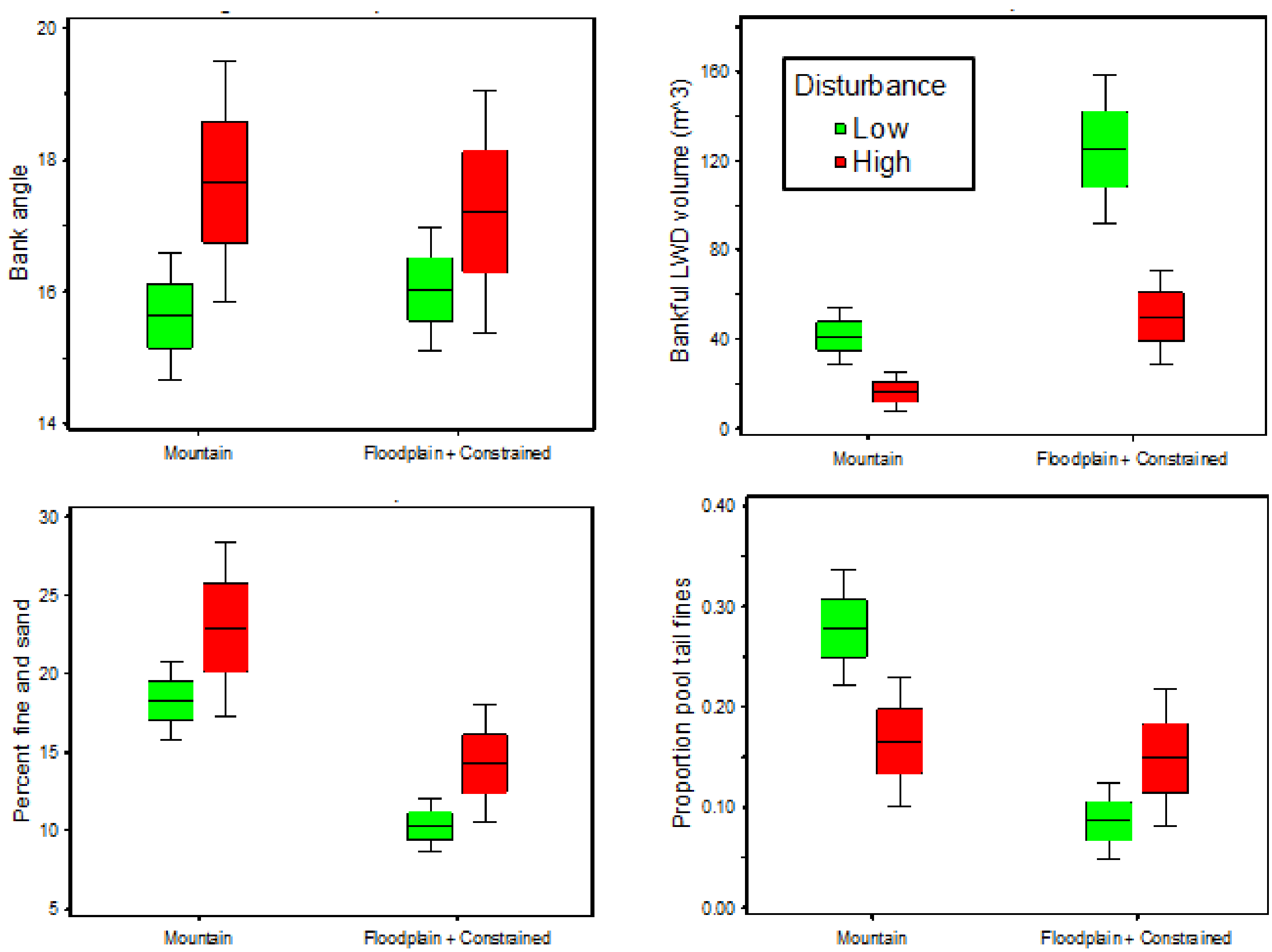


Figure 46. CHaMP survey and response design can be used to distinguish levels of human disturbance. Four CHaMP metrics from sampling locations in the Grande Ronde watershed summarized by the degree of human disturbance (low vs. high) and the valley type class.

Are CHaMP Methods Robust?

Yes, the CHaMP method set is highly robust. All methodological components of CHaMP – data collection, data capture, data QA/QC, data management and data reduction - have been fully tested during the development period and the pilot phase. The testing process during the pilot phase consisted of implementation of the program at ~350 sites per year by ~10 independent crews with a tight data delivery timeline of 60d post field season to have QA/QC'd measurements ready for automated metric generation. The metric generation software has been developed in parallel with the pilot field measurement data collection such that as the field methods were refined, the data reduction algorithms were updated to be backward compatible and to deal with all new use-case variants of input data. As such, each component of CHaMP has been tested through direct implementation and the expectation of being able to maintain production timelines. The process has not been easy on crews and CHaMP staff, as beta testing all aspects was done simultaneously with the release of final methods and metrics; however, the process dramatically accelerated the development cycle, resulting in a very robust product.

The field data capture methods have undergone rigorous refinement during the three years of the pilot phase to improve accuracy and precision of the data collection, as well as to improve implementation efficiency. The methods have been applied across as wide a range of environmental conditions as would be expected within the low-water sampling window of the interior Columbia River basin, as well as some additional, more coastal watersheds. The methods have been applied for the past three years, and while that is a short time-frame, flow conditions, snow melt timing and wild fire extent has varied over a wide range during these years, allowing validation that the methods are robust to the expected between year variation.

Each field season is bracketed with lessons learned and method training meetings. As a result, feedback on equip-

ment, data collection methods, training and work flow is collected from the field crews as the field season wraps up. This information is incorporated with feedback on the data QA/QC process, metric generation algorithms, and any input on the utility of metrics to form the update tasks for the coming implementation year. Each year, update tasks are executed to tighten training methods, data collection equipment function, and data collection methods. All updates are field tested for further refinement and where appropriate, the field methods documentation and training modules are modified. During the field season, feedback on implementation is solicited through regular meetings with crew supervisors. Similarly, as the QA/QC season progresses, regular communication is maintained between crew supervisors and the project data management team. Each year is capped with an analysis meeting, where that year's data is first available for use, any analyses making use of previous year's data are presented to and by the overall CHaMP community, and a summary report that captures programmatic changes and data applications that have been developed during the previous year. Through these multiple layers of feedback, the project has been able to catch and correct methodological errors and inefficiencies in a rapid, transparent manner, resulting in a robust data collection, reduction, and management program.

Can CHaMP Methods be Exported to Other Projects and Programs?

Yes, all components of the CHaMP method set are exportable to other projects. In fact, many of the methods that make up CHaMP were developed by other programs, and thus have already demonstrated their exportability, while other aspects developed specifically for CHaMP have already been exported to other projects. The CHaMP survey design is based on the Generalized Random Tessellation Stratified (GRTS) algorithm, a method already well established in the environmental monitoring community. Many of the methods from the response design were also adopted from other regional programs. For example, almost all of the non-DEM based metric methods were adopted directly from the Oregon Department of Fish and Wildlife Aquatic Habitat Inventories project and the US Forest Service PACFISH-INFISH Biological Opinion Effectiveness Monitoring project (PIBO). The DEM-based metric methods build off of well-established surveying methods applied to fluvial systems; however, CHaMP has extended these methods dramatically with the GIS post-processing accomplished by the River Bathymetry Toolkit (RBT). The RBT methods have been exported to work on other forms of topographic data (e.g., topographic and bathymetric LiDAR based surfaces). For the most part, the entire CHaMP response design has been adopted by the Action Effectiveness Monitoring (AEM – 2010-001-00) project in the Columbia River basin, while other entities (California Department of Fish and Wildlife, TetraTech Inc.) are implementing CHaMP, or major components of CHaMP in other watersheds (coastal California, Puget Sound) to also monitor the impacts of stream habitat restoration.

Can Data Integration Across Regional Monitoring Programs (MMX) be accomplished?

Yes, stream habitat data can be integrated over multiple regional monitoring programs. Through the PNAMP ISTM project, a metric by metric comparison of seven regional monitoring programs was undertaken, and a table of potential metric exchange was constructed. All programs had an equivalent degree of overlap in terms of number of metrics that could potentially be shared. While the ISTM project did point out that it would be possible, developing the workflow or the actual crosswalks between metrics was not done as part of the project. However, CHaMP and PIBO did go through the process of generating an interoperable dataset – that is, a set of metric data that was monitoring program independent. The effort is not complete, but as a first pass, it was possible to crosswalk 24 metrics, with an additional 26 identified that could be transformed with a little more effort (Table 13 and 14, respectively). To generate this data set, some met-

Table 13. CHaMP-PIBO metrics identified as the same or requiring a linear transformation only (22), or similar (need to be constructed from measurements (2).

Directly Exchangeable (10)—Same Metrics (No cross-walk necessary)*	*Requires Crosswalk (12)—Same Metrics (Regression correction necessary)*
Conductivity	Pool Percent
Temperature	Pool Frequency
Site Length	Substrate: D16
Gradient	Substrate: D50
Site Sinuosity	Substrate: D84
Bankfull Width	Average Thalweg Depth
Wetted Width	Wetted Width to Depth Ratio
Pool Tail Fines <2 mm	Residual Pool Depth
Pool Tail Fines < 6mm	Bankfull Width CV
Bankfull Large Wood Frequency	Bankfull Width to Depth Ratio CV
Similar Metrics (2)—CHaMP can generate (algorithm-based crosswalk)	Bankfull Width to Depth
Percent Undercut Banks	Bankfull Large Wood Volume
Bank Angle	

*quantitative criteria for regression parameter and r2 have not yet been set.

rics needed to be transformed (12, linear transforms only), some needed to be constructed from measurements (2), while others (10) mapped directly from one program to the other. Currently, a data management system is being built to house and serve the metrics, as well as generate an initial set of indicators constructed from the interoperable dataset.

The CHaMP-PIBO data integration effort is an important first step in generating a regional approach to the management, distribution and reduction of stream habitat monitoring data. There is no reason to expect that the CHaMP-PIBO experience was unique; crosswalks between other metric sets could be developed just as easily and also housed / served in the integrated data management system. This does not go all the way to the development of a data exchange template (MMX) for regional stream habitat data, but the crosswalk algorithms are a necessary component of an exchange format for relevant metrics and necessary for determining the extent to which the integration is possible.

PIBO and CHaMP are moving beyond the MMX template idea to try cross-program analyses where each program's data is incorporated by the other program to increase coverage and sample size. To date, these analyses are not mature enough to report on, but the ability to support regional decision making with data from multiple regional monitoring programs is being developed.

Do the CHaMP Response and Survey Design Support Habitat Management Decision-making Across the Interior CRB?

Yes, the metrics generated by CHaMP can be used to support habitat management decision-making across the entire interior Columbia River basin. The CHaMP survey design was not initially established for the entire interior Columbia River basin (ICRB), rather inference domains were specified as target watersheds within the ICRB. However, we have found that the current population

Table 14. CHaMP-PIBO metrics for which transformations could be developed.

Macroinvertebrates	Fast-Turbulent Percent
Understory No Cover	Fast-Turbulent Volume
Canopy No Cover	Fast-NonTurbulent Area
Percent Ground Cover	Fast-NonTurbulent Frequency
Percent No Ground Cover	Fast-NonTurbulent Percent
Coarse and Fine Gravel	Fast-NonTurbulent Volume
Boulders	Total Undercut Area
Cobbles	Pool Volume
Sand and Fines	Pool Area
Site Wetted Area	Wetted Large Wood Frequency
Site Bankfull Area	Wetted Large Wood Volume
Fast-Turbulent Area	Wetted Volume
Fast-Turbulent Frequency	Bank Stability

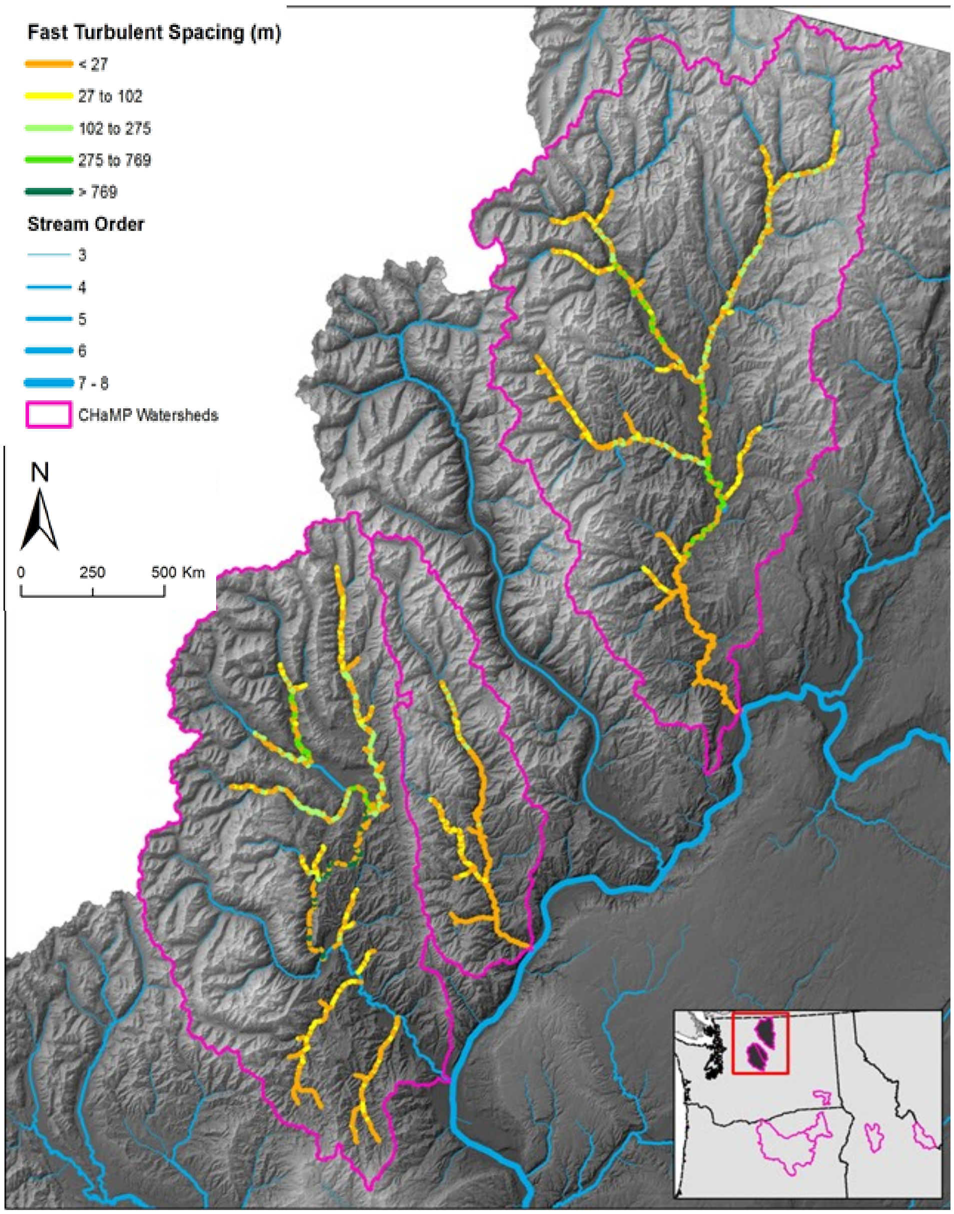


Figure 47. Extrapolation of a single CHaMP metric to the stream network. Fast Turbulent Spacing, a metric derived from the DEM at each CHaMP location is extrapolated to the stream network within the CHaMP sampling frame in the Wenatchee, Entiat and Methow River basins.

of CHaMP sites within the ICRB captures most of the subwatershed level variation that is present and, as such, can be used to support decision-making work across the entire region. At issue is how we imaging that variation in stream habitat condition is distributed within the ICRB. What controls the between site variation in stream habitat condition? Does reach-level variation in stream habitat vary smoothly across the entire ICRB (simple function of distance), or is habitat condition sufficiently dependent on watershed such that watersheds contain unique combinations of site level attributes (function of watershed), or is habitat condition determined by physical processes such that these process domains contain unique combinations of site level attributes independent of watershed (function of process domain)? In reality, all three – distance, watershed, process domain – and perhaps other, controlling factors play a role, but it appears that process domain is the primary driver of models to estimate stream habitat condition in un-sampled reaches.

Extrapolating from a set of sampling locations where we know an enormous amount about the condition stream habitat to sites where we only have imprecise knowledge of their condition is a classic estimation problem. In this case, based on the premise that physical processes are primary determinants of stream habitat condition, commonly available spatial data (e.g., GIS layers of elevation, gradient, geology, precipitation, human disturbance, valley form, stream order) can be used as predictor variables for site-level habitat attributes. Fitting these data to the CHaMP metrics allows the estimation of metric values at non-sampled sites based on their process domain state (Fig. 47). These relationships can be used to make site level predictions of habitat state, and can be used to improve sub-watershed scale habitat condition predictions as priors in a Bayesian estimation process. In either case, the power of the method comes from the robust, regionally relevant information inherent in the CHaMP metric data set.

Are More CHaMP Sites Necessary (i.e., is post-pilot expansion needed to represent the ICRB in terms of fish-habitat relationships)?

The need for additional sampling locations beyond the current population of CHaMP sites depends on the management question being addressed. Originally, the CHaMP survey design was built around a selected set of target watersheds with a statistical sample to be developed within each watershed. The target watersheds were chosen to represent the range of conditions thought to be necessary to address the needs the FCRPS BiOp RPAs. To cover the range of conditions, target watersheds were chosen to represent MPGs, but consideration was also given to the perceived level of habitat degradation (as indicated by an estimated decrement in freshwater survival of juvenile salmonids) and the existence of on-going fish population monitoring work. As a result, a non-random population of watersheds was developed, each to receive a statistical survey design-based set of habitat sampling sites. In the end, slightly less than one half of the selected watershed were included in the sample survey design process. Thus, the question remains, are more sampling locations, in particular, more sampling locations in watersheds originally targeted, but ultimately not sampled, required to meet CHaMP's initial objective? If the objective is to sample all of the watersheds in the initial definition of CHaMP, then yes, a near doubling of the number of sampling locations would be necessary to satisfy this management need. However, we have learned a number of things through the implementation of the CHaMP "pilot" that likely makes the initial design inefficient. For example, the suite of sites in the CHaMP "pilot" sample covers the range of ecological conditions present in the salmon-bearing part of the ICRB. Figure 48 shows the population of HUC6s in the steelhead and spring/summer Chinook ESUs of the ICRB, scored by their Omernik Ecoregion designation of all HUC6s, compared to the overlap of CHaMP sampling (presence of a sample within the HUC6). CHaMP "pilot" sampling covers the core range of ecological settings of salmon bearing streams in the ICRB.

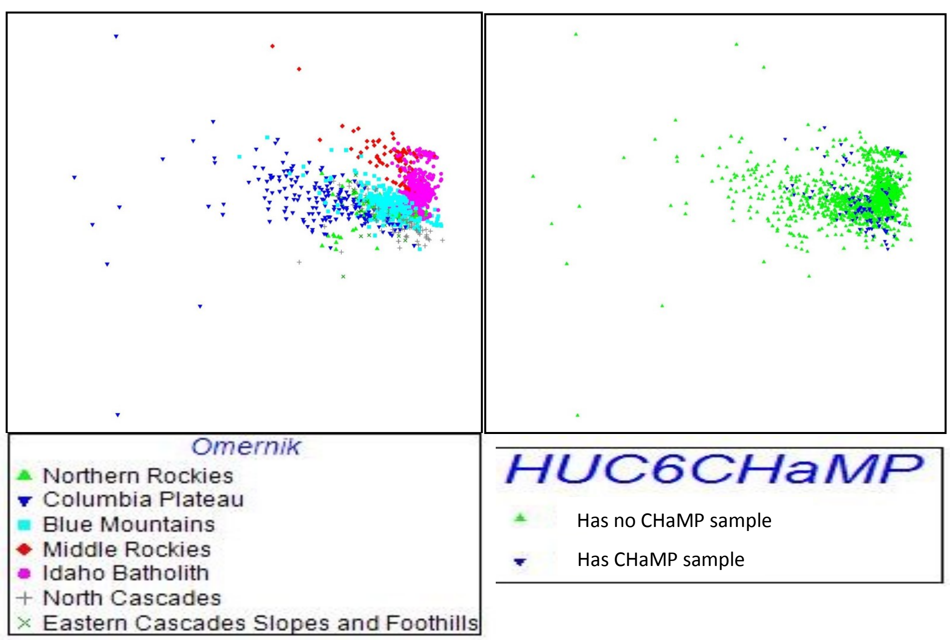


Figure 48. NMDS plots of CHaMP sample coverage of ecological conditions in the ICRB. Panel (a), left, shows all HUC6s in the steelhead and spring/summer Chinook ESUs of the ICRB, scored by their Omernik Ecoregion designation. Panel (b), right, shows the same population of HUC6 watersheds scored by the presence of a CHaMP sample location.

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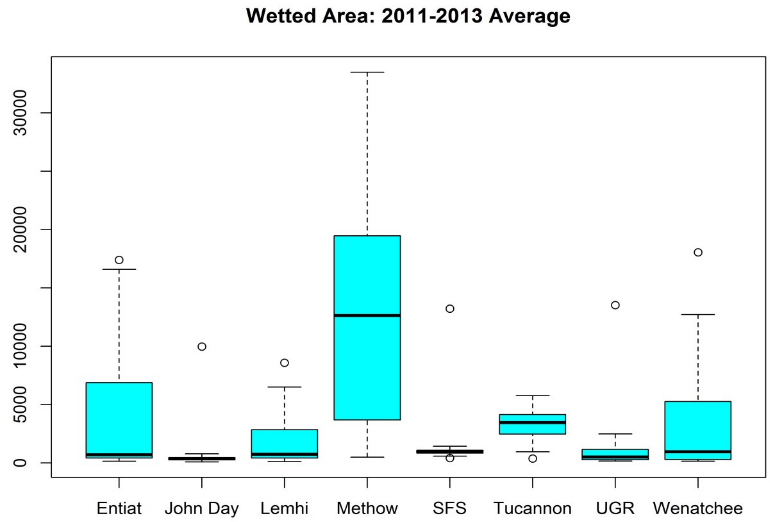
APPENDIX A—CHAMP METRICS (2011-2013), DATA SETS, PRODUCTS

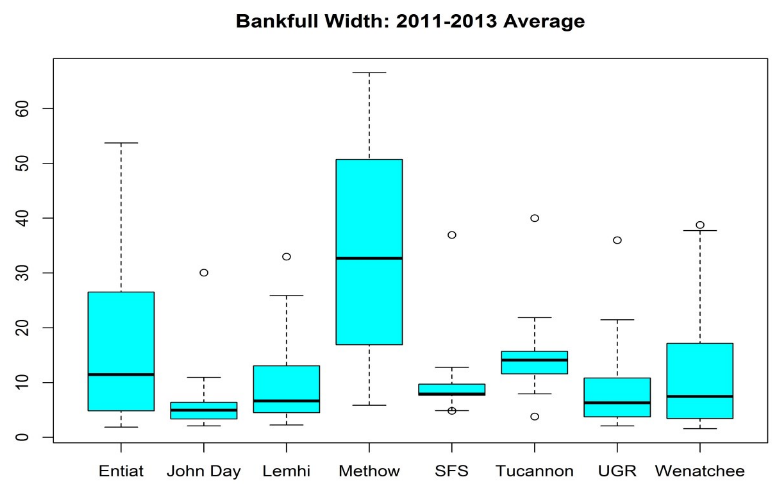
Summary status plots of key metrics in CHaMP watersheds from the 2011-2013 dataset are presented herein.

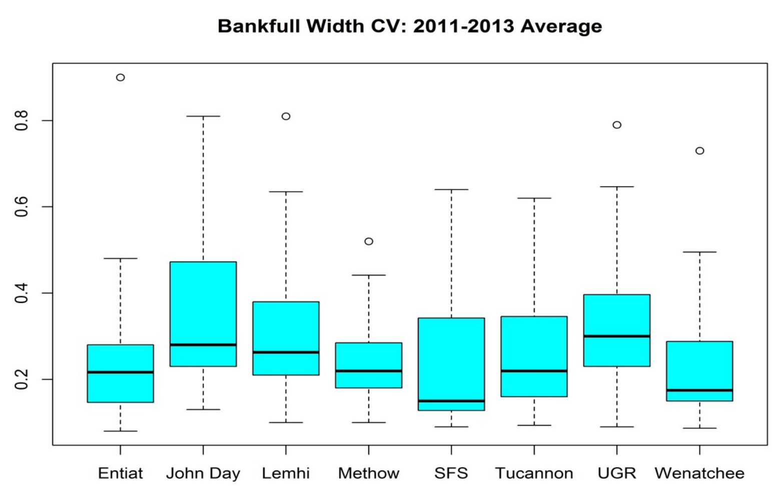
The CHaMP data management system (CHaMPMonitoring.org) provides access to myriad products developed by CHaMP-ISEMP staff to support CHaMP implementation.

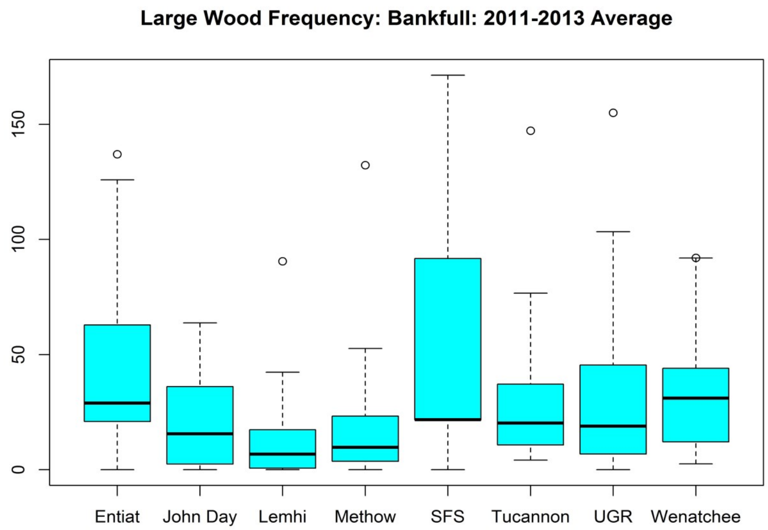
The PNAMP Monitoring Resources website provides access to other online information related to CHaMP.

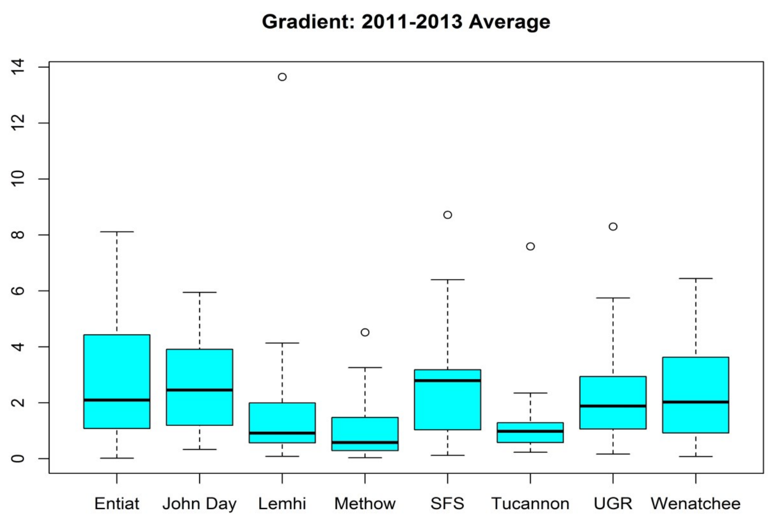
- For all previous versions and the current version of the CHaMP protocol, go to https://www.monitoringmethods.org/Protocol/Index and type "CHaMP" in the 'Protocol Name' field at the top.
- Information about other project associated with CHaMP may be found at https://www.monitoringresources.org/Resources/Program/Detail/18.
- Samples designs may be accessed by going to https://www.monitoringresources.org/Designer/Design/Index and typing "CHaMP" in the 'Monitoring Project' field

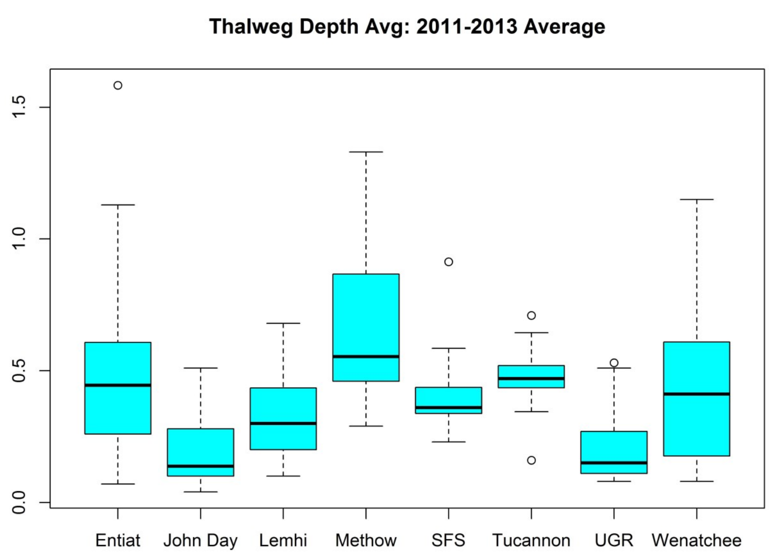


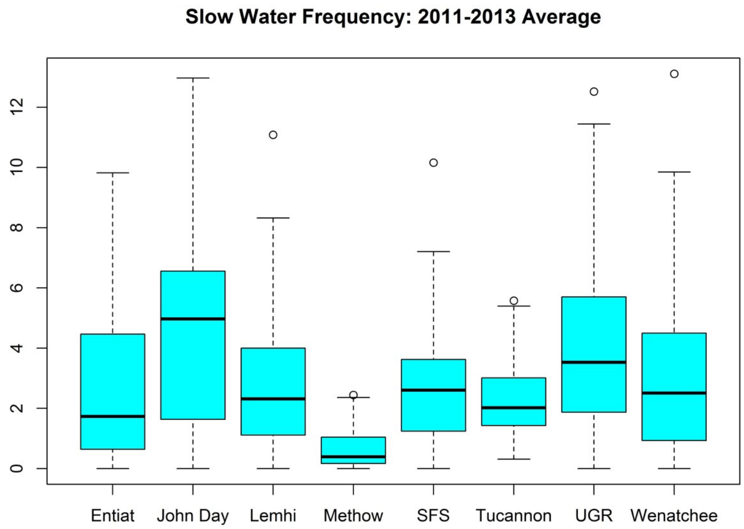


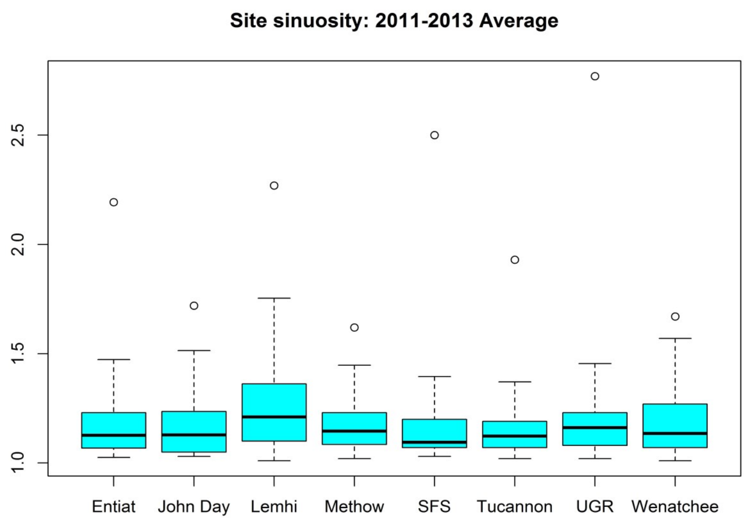


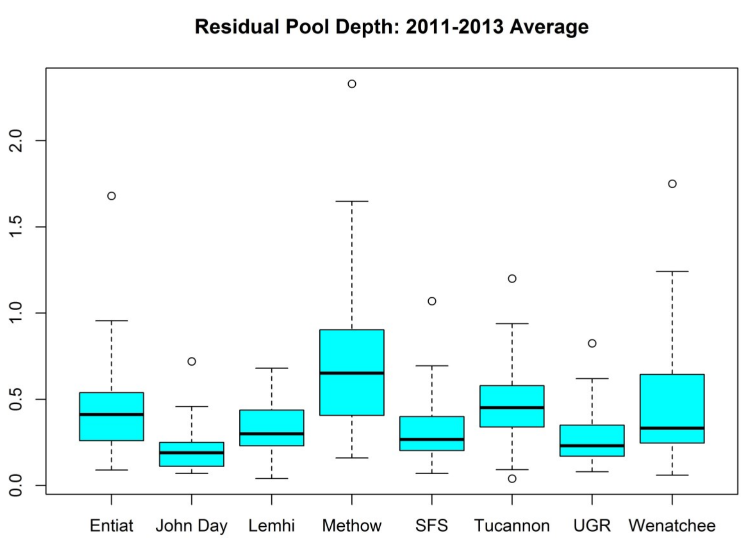

Large Wood Frequency: Bankfull: 2011-2013 Average
0
50
100
150
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee

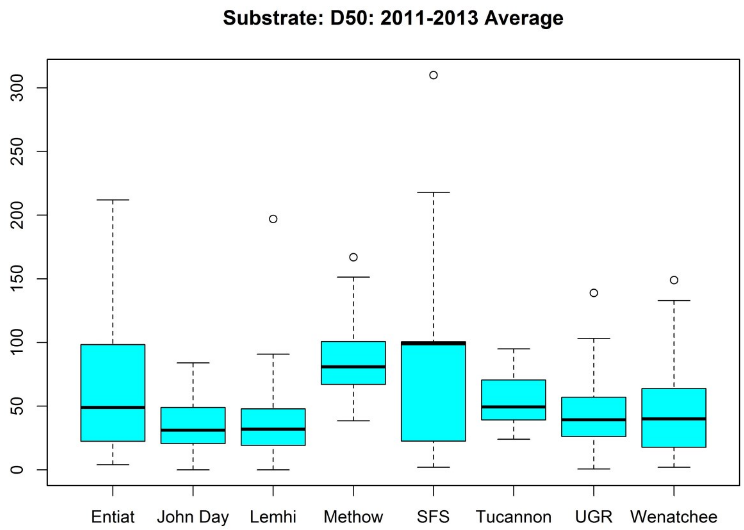

Gradient: 2011-2013 Average
0
2
4
6
8
10
12
14
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee

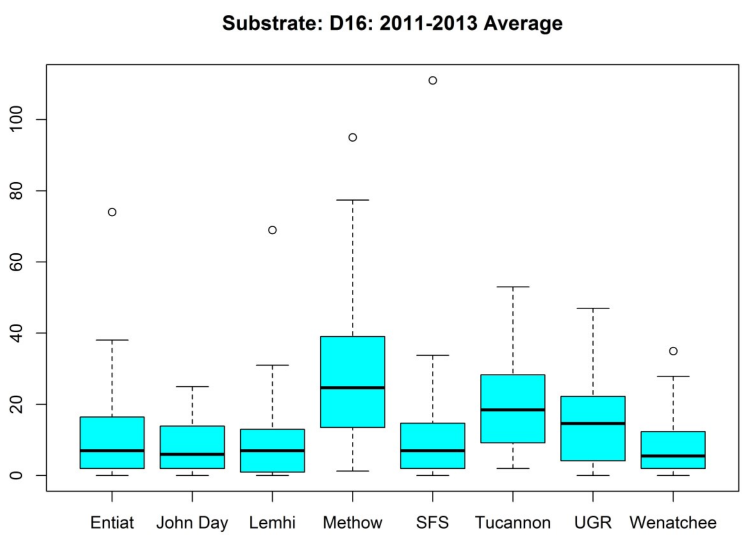

Thalweg Depth Avg: 2011-2013 Average
0.0
0.5
1.0
1.5
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee

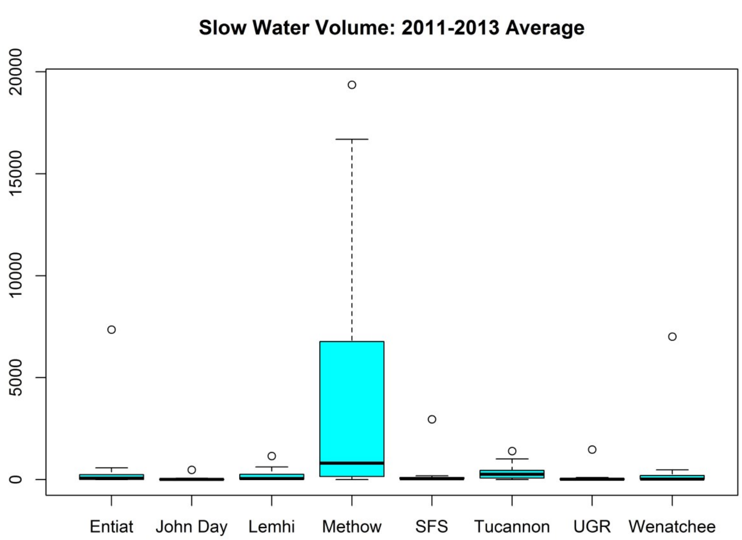

Slow Water Frequency: 2011-2013 Average
0
2
4
6
8
10
12
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Site sinuosity: 2011-2013 Average
1.0
1.5
2.0
2.5
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Residual Pool Depth: 2011-2013 Average
0.0
0.5
1.0
1.5
2.0
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Substrate: D50: 2011-2013 Average
0
50
100
150
200
250
300
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Substrate: D16: 2011-2013 Average
0
20
40
60
80
100
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Slow Water Volume: 2011-2013 Average
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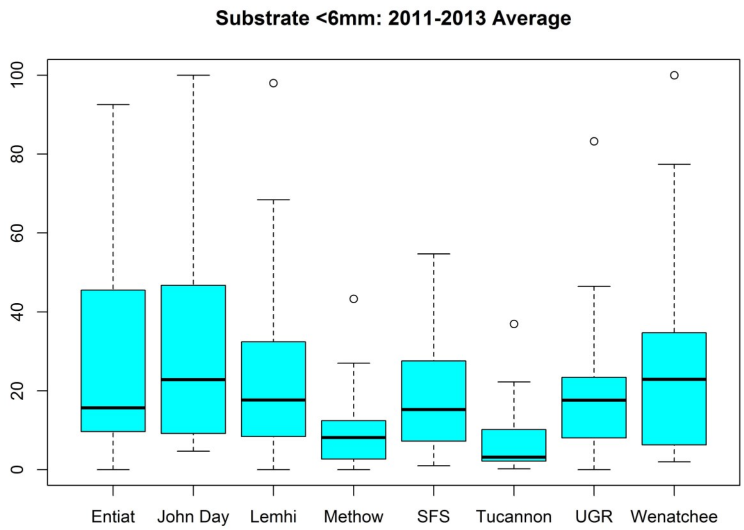
5000
10000
15000
20000
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Substrate <6mm: 2011-2013 Average
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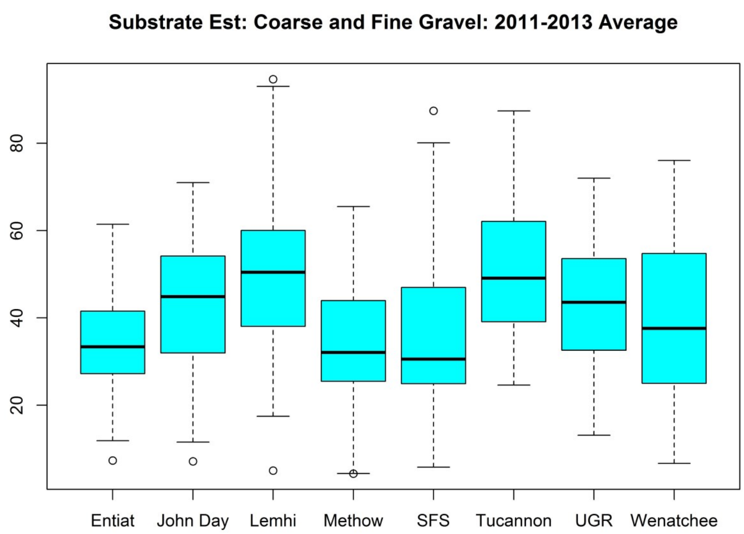
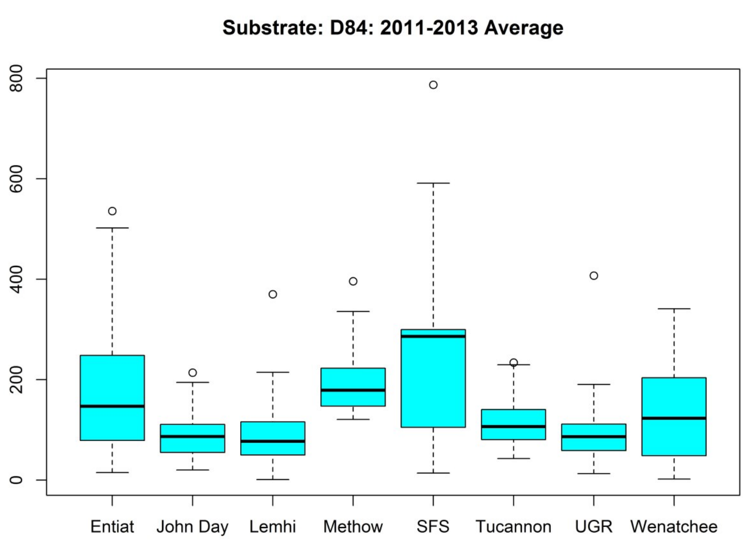
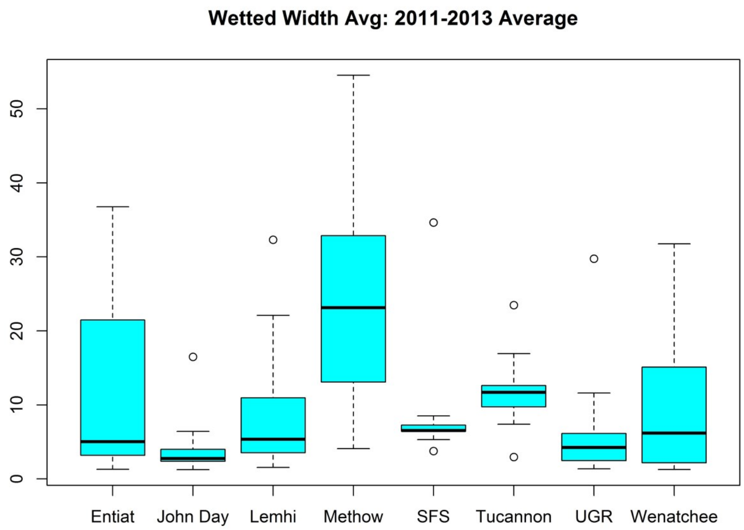
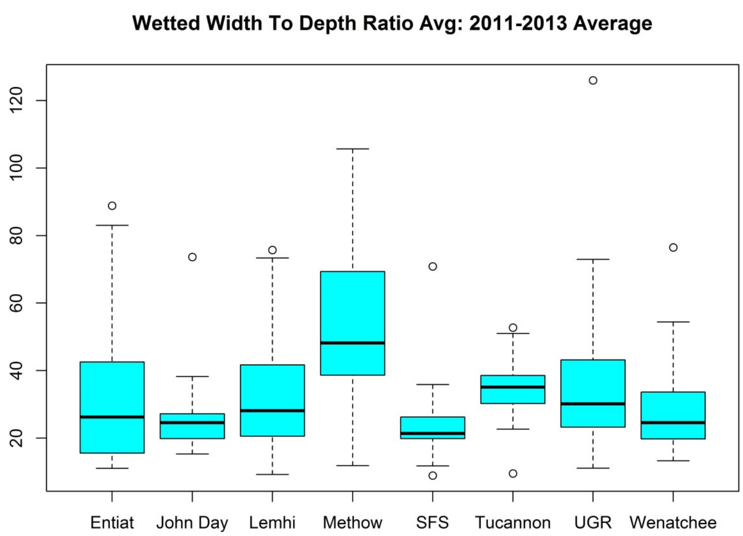
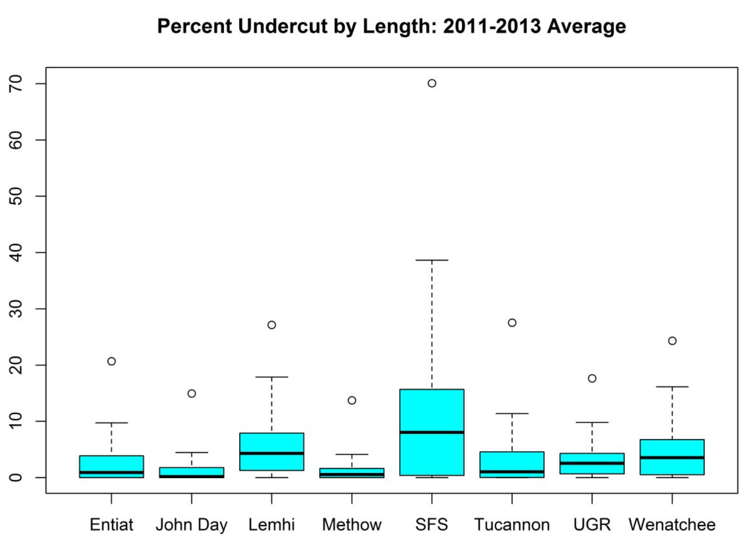
40
60
80
100
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Substrate Est: Coarse and Fine Gravel: 2011-2013 Average
20
40
60
80
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Substrate: D84: 2011-2013 Average
0
200
400
600
800
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Wetted Width Avg: 2011-2013 Average
0
10
20
30
40
50
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Wetted Width To Depth Ratio Avg: 2011-2013 Average
20
40
60
80
100
120
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee


Percent Undercut by Length: 2011-2013 Average
0
10
20
30
40
50
60
70
Entiat
John Day
Lemhi
Methow
SFS
Tucannon
UGR
Wenatchee

APPENDIX B—PUBLICATIONS

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