



Upper Columbia Basin Network Integrated Water Quality Monitoring Protocol

Narrative Version 1.9

Natural Resource Report NPS/UCBN/NRR—2016/1231





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Photograph of NPS Biologist conducting a cross-section survey at Big Hole National Battlefield.
Photograph courtesy of the National Park Service

ON THE COVER

Photograph of the John Day River at John Day Fossil Beds National Monument.
Photograph courtesy of the National Park Service

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Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #
1.0 Draft	January 2009	UCBN	Revision following peer review	-	1.0
1.0	January 2016	UCBN	Macroinvertebrate sampling techniques/site selection is now covered in the stream channel characteristics monitoring protocol. Minor revisions to state water quality thresholds. Revisions to the data management section due to updated water quality database and changes to Aquarius Time-Series Software. No changes were made to objectives or water quality techniques. In 2008, the timing of water quality sampling was shifted from May-October to June-November. This change is documented in this version.	Additional details and revisions needed following 7 years of implementation. Integration of macroinvertebrate sampling with stream channel characteristics protocol due to collaboration with USFS-PIBO program.	1.9

1. “Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, ...etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
2. Notify the UCBN Data Manager of any changes to the Protocol Narrative or SOP so that the new version number can be incorporated in the Metadata of the project database.
3. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOP.

Note: Standard operating procedures (SOPs) are published and bound in a separate document.

Contents

	Page
Change History	iii
Figures.....	vii
Tables.....	ix
Appendices.....	xi
Executive Summary	xiii
Acknowledgments.....	xv
List of Acronyms and Abbreviations	xv
Background and Objectives	1
Rationale for Monitoring Water Quality in the Upper Columbia Basin	1
Integration with other Monitoring Protocols.....	4
Overview of UCBN Water Resources.....	6
Status of UCBN Waterbodies (303d and State Beneficial Uses)	14
Objectives	22
Sampling Design.....	25
Sampling Design Rationale	25
Selection of UCBN Waterbodies for Monitoring.....	26
Target Population	26
Macroinvertebrate Measurements, Sampling Design, and Frequency	30
Selection of Water Quality Monitoring Station.....	30
Water Quality Measurements, Sampling Design, and Frequency.....	30
Power Analysis for Continuous Water Quality Data	34
Strengths and Limitations of the Sampling Design.....	34
Field and Laboratory Methods.....	37
Field Season Preparations for Water Quality Sampling.....	37
Locating and Establishing Water Quality Monitoring Stations.....	37
Continuous Water Quality Data Collection.....	38
After the Field Season	38
Data Management, Analysis, and Reporting	41

Contents (continued)

	Page
Overview of Data Management Work Flow	41
Database(s) Overview	42
Quality Assurance and Quality Control Overview.....	43
Metadata Procedures	44
Sensitive Information	44
Data Certification and Delivery Overview	45
Continuous Water Quality Data Analysis	45
Status of Core Water Quality Parameters.....	48
Trend in Core Water Quality Parameters	50
Data Analysis of Macroinvertebrate Data	51
Annual Macroinvertebrate Status Summary	51
Macroinvertebrate Trend Analysis.....	53
Reporting.....	53
Data Archival Procedures.....	54
Protocol Testing and Revision.....	54
Personnel Requirements and Training	57
Personnel Requirements	57
Roles and Responsibilities.....	58
Training	58
Quality Assurance and Quality Control	59
Operational Requirements	61
Annual Workload and Schedule.....	61
Water Quality Equipment Needs.....	63
Capital expenses:.....	63
Expendable supplies:.....	63
Budget	64
Literature Cited	65
Glossary of Terms.....	71

Figures

	Page
Figure 1. Conceptual model of the hydrologic, biotic, and geomorphic components and processes of UCBN lotic systems.	3
Figure 2. High priority vital signs organized according to the spatial extent and temporal rate of predicted or anticipated change in UCBN ecosystems(Garrett et al. 2007).	5
Figure 3. Upper Columbia Basin Network parks and Bailey’s Ecoregion Provinces.....	6
Figure 4. Stream network in Big Hole National Battlefield and associated HUCs illustrating the large watershed area and total stream length outside of the park in comparison to area and stream length within the park.....	10
Figure 5. City of Rocks (CIRO) stream network and HUCs.	11
Figure 6. Overview of the relationships among data sources, measurable objectives, and the overall assessment of water resources in UCBN parks.....	26
Figure 7. Core water quality field season tasks (June-November).	40
Figure 8. Generalized data management annual work flow for water quality monitoring, cross section data and calibration and maintenance metadata collection.	42
Figure 9. Water quality monitoring station and instrumentation database user interface Access front-end.	42
Figure 10. Aquarius Springboard interface, used to transfer raw tabular .csv continuous water quality data to the Aquarius.	43
Figure 11. Water Quality Monitoring Station and Instrumentation Database queries to be used for quality review.....	44
Figure 12. Lapwai Creek, water quality monitoring results box-plot 2008-2014.....	49
Figure 13. Daily maximum and mean water temperature in Lapwai Creek, NEPE, 2014.	50
Figure 14. Conceptual model for determining stream status used in the analysis of macroinvertebrates data to infer water quality.....	52
Figure 15. Hypothetical examples of macroinvertebrate data analysis using a multimetric approach.....	53
Figure 16. Staff structure for UCBN I&M program (modified from Garrett et al. 2007).	57

Tables

	Page
Table 1. NPS Units in the UCBN.....	7
Table 2. Percentage of UCBN park area in each land cover type as determined with the National Land Cover Dataset and the National Park Service digital park unit layer (NPS boundary).....	9
Table 3. Summary of water resources in UCBN parks.	12
Table 4. List of threats to UCBN water resources.	14
Table 5. 303(d) status of UCBN water resources.....	16
Table 6. Summary of sampling stations and sampling from the 1997 Baseline Water Quality Data Inventory and Analysis reports.....	17
Table 7. UCBN Waterbodies, encompassing HUCs, and designated state beneficial uses (2008).....	20
Table 8. Selected wadeable streams and stream length within the boundaries of each park as identified using NAIP imagery.....	27
Table 9. Prioritization and identification of potential UCBN water quality monitoring sites.	28
Table 10. Rotating panel design for water quality monitoring in selected UCBN streams. Sampling year and macroinvertebrate index period indicated for each stream.	33
Table 11. Regulatory thresholds for UCBN streams. Thresholds are set by state DEQs and consequently differ considerably among parks.....	46
Table 12. Summary of descriptive statistics for core water quality parameters for a spring and late summer sampling period at Lapwai Creek, 2007 (NEPE).	48
Table 13. Lapwai Creek Water Chemistry Summary 2014. Vital sign summary table for water chemistry in Lapwai Creek, June-November, 2014.....	49
Table 14. Data grade/rating for specific conductance each deployment period June-November 2014 in Lapwai Creek, NEPE.	50
Table 15. Means table, where μ is the mean and subscripts represent year and month, respectively	51
Table 16. Roles and responsibilities for implementing the water resource monitoring program in the UCBN.....	58
Table 17. Annual implementation schedule for water quality monitoring.....	62
Table 18. The detailed 2016 annual budget for integrated water quality monitoring in the UCBN.	64

Appendices

	Page
Appendix A. Index of Standard Operating Procedures	75

Executive Summary

The mission of the National Park Service is “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring networks.

The Upper Columbia Basin Network (UCBN) consists of nine widely separated NPS units located in western Montana, Idaho, eastern Washington, and central Oregon. One unit of the Nez Perce National Historical Park (NEPE), Bear Paw Battlefield, is actually located outside the Network boundary in eastern Montana. This unit and one other park, Big Hole National Battlefield (BIHO), lie outside the Columbia River Basin, although administratively speaking they are part of the Network. UCBN parks vary in size from 30 ha (74 ac) to more than 188,197 ha (465,046 ac), and all but two are less than 6,000 ha (14,826 ac). These park units operate with limited budgets and few staff, and are not able to provide personnel and funds for many of the natural resource concerns they face. The resources available at the network level greatly increase their capacity to meet increasingly complex resource management issues. While the parks have been identified as having significant natural resources, the majority were actually established to protect cultural and paleontological resources. The upper Columbia Basin holds a rich and fascinating cultural history, and several UCBN parks provide the nationally significant service of chronicling the pre-contact and contact cultures of the Nez Perce and Cayuse people, early pioneer and mission culture, and the tragic conflicts that arose between them. Two parks also protect and interpret globally significant fossil localities. Most also have some level of natural resource protection language included in enabling legislation or other guidance documents.

Parks of the Upper Columbia Basin Network include: Big Hole National Battlefield (BIHO), City of Rocks National Reserve (CIRO), Craters of the Moon National Monument and Preserve (CRMO), Hagerman Fossil Beds National Monument (HAFO), John Day Fossil Beds National Monument (JODA), Lake Roosevelt National Recreation Area (LARO), Minidoka Internment National Monument (MIIN), Nez Perce National Historical Park (NEPE), and Whitman Mission National Historic Site (WHMI).

The Upper Columbia Basin Network (UCBN) has identified 14 priority park vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent has been to come up with a balanced and integrated “package” of vital signs that meets the needs of current park management, but will also be able to accommodate unanticipated environmental conditions in the future. Water quality is a particularly high priority vital sign for six of the nine UCBN parks. The UCBN contains more than 34 rivers, streams, ponds and reservoirs located in nine park units spread over four large western states. Unlike many National Parks that are large and often encompass entire watersheds, most UCBN parks and water bodies are

small and embedded in large watersheds with diverse land use. Water quality in most UCBN water bodies has not been directly assessed within park units for regulatory compliance, though most streams are listed as impaired by states for at least one parameter.

This protocol details the why, where, how, and when of the UCBN's water quality monitoring program. As recommended by Oakley et al. (2003), it consists of a protocol narrative and a set of standard operating procedures (SOPs), which detail the steps required to collect, manage, and disseminate the data representing the status and trend of water quality parameters in the Network. This monitoring protocol combines two approaches: 1) collection of water chemistry data for "core parameters" from UCBN stream sites using continuous water quality monitors, and 2) macroinvertebrate biomonitoring using the United States Forest Service (USFS)- PACFISH/INFISH Biological Opinion (PIBO) sampling protocols. These data in combination with other vital signs monitoring, will provide a context for the interpretation of status and trends in water resources within the network.

The protocol is a "living" document in the sense that it is continually updated as new information acquired through monitoring and evaluation leads to a refinement of program objectives and methodologies. Changes to the protocol are carefully documented in a revision history log. The intent of the protocol is to ensure that a seamless and scientifically credible story about water quality conditions over time can be told to park visitors and managers alike. The next few years of monitoring results are eagerly awaited, as outstanding questions related to site variability, inter-annual variability, and the current water quality of park water bodies can finally be described. From there, the focus will shift toward trend analysis, in which biologically meaningful declines or increases will be detected, and appropriate management strategies can be developed.

Acknowledgments

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List of Acronyms and Abbreviations

BIHO Big Hole National Battlefield

CIRO City of Rocks National Reserve

CRMO Craters of the Moon National Monument and Preserve

DEQ Department of Environmental Quality

EPT Ephemeroptera, Plecoptera, Trichoptera aquatic macroinvertebrate index

EPA United States Environmental Protection Agency

GPRA Government Performance Results Act

GRTS Generalized Random Tessellation Stratified

HAFO Hagerman Fossil Beds National Monument

JODA John Day Fossil Beds National Monument

LARO Lake Roosevelt National Recreation Area

LULC Land use – land cover

MIIN Minidoka Internment National Monument

NAWQA National Ambient Water Quality Assessment (USGS)

NEPE Nez Perce National Historical Park

NOAA National Oceanographic and Atmospheric Administration

NWIS National Water Information System (USGS)

List of Acronyms and Abbreviations (continued)

ONRW Outstanding Natural Resource Waters

PIBO PACFISH/INFISH Biological Opinion (USFS)

QA/QC Quality Assurance/Quality Control

SOP Standard Operating Procedure

STORET data STOrage and RETrieval (EPA)

T&E Threatened and Endangered

TMDL Total Maximum Daily Load

UCBN Upper Columbia Basin Network

USGCRP United States Global Change Research Program

USFS United States Forest Service

USGS United States Geological Survey

WHMI Whitman Mission National Historic Site

WQX Water Quality eXchange (EPA)

WRD Water Resources Division of NPS.

Background and Objectives

Rationale for Monitoring Water Quality in the Upper Columbia Basin

Water resources have been identified as a high priority vital sign in the Upper Columbia Basin Network (UCBN). Water resources and habitats are used by many riparian, migratory, and terrestrial organisms in the Network, and water resources have intrinsic value as places of natural beauty and recreation (Garrett et al. 2007). The Water Resources Division (WRD) of the NPS provides a separate source of funding each fiscal year to the UCBN to accomplish water quality monitoring. Freshwater habitats are diverse and productive ecosystems, providing habitat for aquatic plant, invertebrate, and vertebrate species including many fishes and birds. Rivers and streams are intimately connected to riparian zones, providing habitat for many specialist species. Additionally, most upland animals rely on aquatic habitats to one degree or another.

Water resources in the semi-arid west have been strongly affected by human activity, and many UCBN streams and rivers are listed by states as impaired for one or more parameters. Most UCBN water bodies and many aquatic resources such as migratory fish are strongly influenced by activities in the larger watersheds outside park boundaries. Understanding the current status of freshwater ecosystems will help guide management and restoration efforts, and provide insight into ecosystem change in a landscape with changing climate and dynamic human influences.

During the UCBN vital signs selection process in 2005, water quality was identified as a high priority vital sign (Garrett et al. 2007). When asked what aspects of water quality were important to monitor, resource managers identified the sampling of macroinvertebrate communities within UCBN water bodies as the top water quality monitoring priority. Secondary priorities included baseline sampling of water chemistry parameters, characterization of channel morphology, and information on water quantity. The Network chose to develop an integrated water quality monitoring protocol that combines macroinvertebrate and water chemistry monitoring into one protocol. The decision to have an integrated protocol promotes efficient analysis and interpretation of results not possible if these vital signs were considered independently. Channel morphology and riparian vegetation monitoring have been addressed in separate protocols approved for implementation in 2011 (Starkey et al. 2011a and 2011b). Water quantity data, compiled from existing USGS gages adjacent to park sites, will be addressed in a separate SOP that will be developed in the future and added to this protocol.

Aquatic macroinvertebrate communities have strong effects on freshwater ecosystem processes and represent an important trophic linkage between primary producers and fishes. Measures of macroinvertebrate community composition and structure have been frequently used as water quality indicators because these communities integrate the effects of point and non-point source pollutants over spatial-temporal scales and can be used to answer many management questions. Also, macroinvertebrates are more cost-effective to sample than other biota or many water chemistry parameters. The condition of each sampled water body will be assessed using well developed indices of invertebrate community structure that indicate water quality in respect to reference or unimpaired water bodies within a region (Karr and Chu 1999, Hawkins et al. 2000, Hawkins 2006). For instance, the species richness of indicator taxa (e.g., mayflies, stoneflies, and caddisflies) and measures of

species evenness are two of several parameters frequently used as indices of water quality. Monitoring will also provide inventories of these communities for UCBN park water bodies, which currently lack species lists for most of the aquatic biota.

Water chemistry and temperature have strong effects on aquatic biota. Consequently, direct and indirect human alteration of stream water quality is associated with altered biotic communities and ecosystem processes. Because of the direct relationship between water chemistry and biota, water chemistry is typically a central component of any water quality monitoring program. More recently, monitoring of stream water temperatures has increased in the Pacific Northwest, because of concerns over cold-water fish habitat (primarily salmonid fishes), the recognized influence of land- and water-use on stream temperature regime, and the need for baseline temperature information to monitor the effects of climate change. NPS WRD has identified a suite of four “core water quality parameters”—temperature, conductivity, pH, and dissolved oxygen—that are critical to understanding baseline conditions in aquatic habitats. The UCBN added turbidity as a parameter to measure because turbidity is listed as a source of impairment in several UCBN park streams.

Figure 1 is a conceptual model that illustrates the primary rationale for monitoring water quality in UCBN parks. This model emphasizes the “open” and three-dimensional nature of aquatic ecosystems which are influenced from upland and riparian inputs and watershed-scale drivers. The largest-scale drivers are global or regional drivers acting on entire watersheds such as precipitation, climate regime (e.g., Pacific Decadal Oscillation, El Niño Southern Oscillation (Beebe and Manga 2004)), underlying geology and topography, and large-scale disturbances including volcanism (Quinn et al. 1991) and large-scale fires (Rieman et al. 2003). Global and landscape stressors include human-induced climate change, non-local pollution sources (e.g., atmospheric nitrogen deposition), alterations to hydrologic regimes through damming and irrigation withdrawals, and broad-scale cultural policies affecting water quality and fisheries policy (NRC 1996; Rahel 1997; Poff et al. 2003; Postel and Richter 2003).

Within individual drainage basins, upland land cover/land use, and cultural landscapes strongly affect aquatic ecosystems and communities by influencing hydrology, physical habitat, and nutrient, sediment, and toxicant inputs (Thompson and Lee 2000; Kershner et al. 2004; Allan 2004). Many effects of upland habitat alteration and degradation are mediated (and “buffered”) by riparian areas and wetlands because these areas strongly affect the magnitude and timing of inputs to surface water habitats (Naiman and Bilby 1998; McKinstry et al. 2004). For instance, riparian condition strongly affects aquatic physical habitat characteristics including light availability, temperature, channel form, sediment regimes, and substrate composition (Naiman and Bilby 1998; McKinstry et al. 2004).

The local distribution and abundance of aquatic organisms within each habitat type are determined primarily by spatial heterogeneity in physical and chemical properties among microhabitats (current speed of water, temperature, nutrients, dissolved oxygen) (Allan 1995; Dodson 2005), while global and watershed drivers indirectly affect local communities by determining the characteristics of physical habitats and influencing regional species pools. In turn, biota can alter the physical and chemical environment through metabolic activities (nutrient uptake, excretion, respiration), redd-building behaviors by salmonids that alter sediment composition and transport (Gottesfeld 2004), the

“ecosystem engineering” activities of beaver damming (Jones et al. 1997), or stream macroinvertebrates (Zanatell and Peckarsky 1996). Introduced species and manipulation of fish populations represent stressors acting at the local scale. Predator-prey and competitive interactions with introduced species, including warm water fishes, bullfrogs and non-native salmonids, have strong local effects on communities (Levin et al. 2002; Kolar and Lodge 2002; Adams et al. 2003). Figure 1 highlights the challenge of managing aquatic resources due to influences from multiple spatial scales, and the need for regional cooperation in such management efforts.

Well-articulated desired future condition statements have not yet been developed for water quality in UCBN parks. However, the mission statements for the NPS as a whole and for the individual parks clearly state the intent “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). Water quality is an important resources with nationally recognized merit. It is assumed that desired future conditions for all UCBN parks will include clean streams, rivers, and lakes free of human health concerns that provide visitors with recreational and scenic experiences. Monitoring macroinvertebrate assemblage composition and structure, and core water quality parameters will directly measure the water characteristics most important to park mission, visitor experience, and desired future conditions.

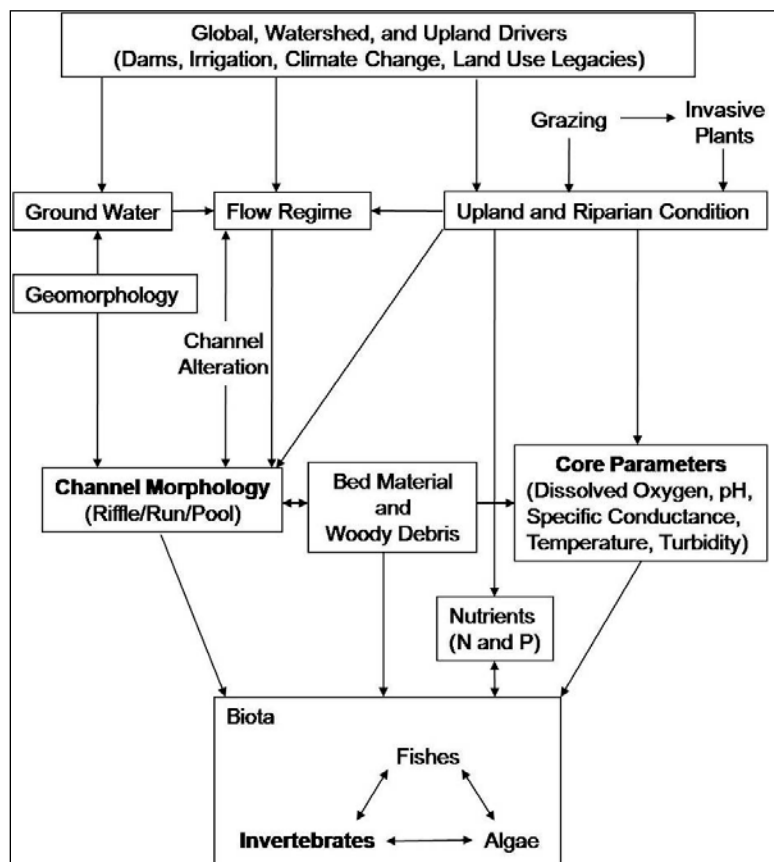


Figure 1. Conceptual model of the hydrologic, biotic, and geomorphic components and processes of UCBN lotic systems.

Integration with other Monitoring Protocols

A successful ecological monitoring program must be able to separate real change from inherent ecological variability. Temporal and spatial scale and the accompanying ecological organizational hierarchy act as lenses through which variability can become more or less focused. Patterns of variability may be apparent at one scale but not at another and meaningful detection of ecosystem change is dependent upon measurement at appropriate scales (Noss 1990; Morgan et al. 1994). Likewise, drivers, stressors, and effects may be operating at different scales simultaneously within a nested hierarchy (O'Neill et al. 1986; Wu and David 2002). The NPS I&M program, following suggestions by O'Neill et al. (1986), Noss (1990) and others (e.g., King 1993; Woodley et al. 1993), has identified integration of spatial, temporal, and ecological hierarchies as a key ingredient to network monitoring efforts (NPS 2003). Integration involves the inclusion of hierarchical levels above and below the level of interest into conceptual models and monitoring designs.

Following an approach presented by Woodley et al. (1993) and adapted by several other NPS I&M networks (e.g., Liebfried et al. 2004; Mau-Crimmins et al. 2004), the UCBN has organized vital signs (Figure 2) into three categories: threat-specific, focal resource, and ecosystem status. Selecting vital signs from each of these categories helps ensure a balanced and integrated program that can address the status and trends of ecological phenomena across a range of temporal and spatial scales, and for which effects are both known and unknown.

The UCBN will be using established federal sampling protocols and index periods as suggested by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) (Hayslip 2007) in an effort to ensure UCBN data can be easily integrated with existing regional monitoring efforts. In addition, programs and agencies listed in Appendix D (Integrated Water Quality Monitoring SOPs) will be consulted for guidance as the UCBN integrated water quality monitoring program continues to develop.

Sampling of benthic macroinvertebrates occurs during implementation of the UCBN stream channel characteristics protocol (Archer et al. 2012, Heitke et al. 2008, Starkey et al. 2011a, and Starkey et al. 2016). For this reason, sample design and field techniques have been removed from version 1.9 of the integrated water quality protocol and are outlined in Starkey et al. 2016. Analysis and interpretation of macroinvertebrate data is integral to understanding water quality, as such these topics are discussed below and in associated water quality SOPs.

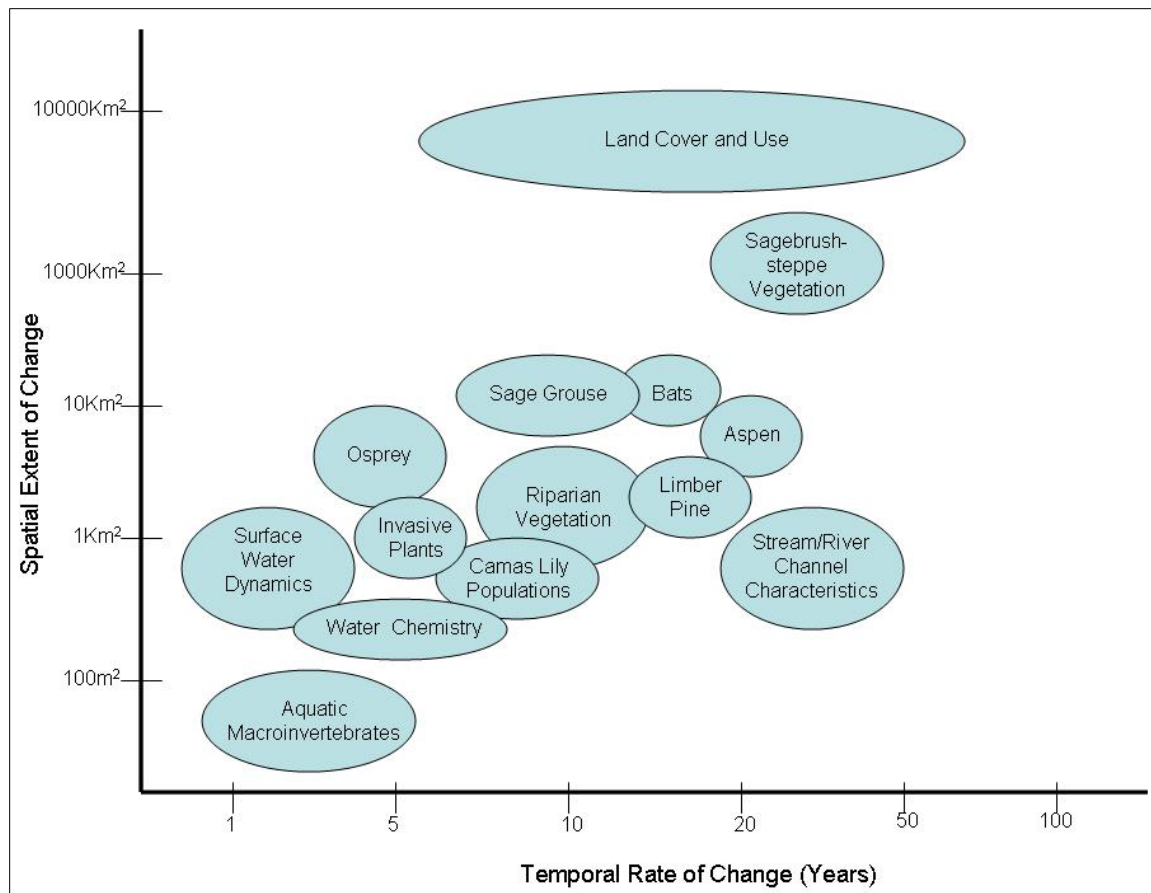


Figure 2. High priority vital signs organized according to the spatial extent and temporal rate of predicted or anticipated change in UCBN ecosystems (Garrett et al. 2007).

Overview of UCBN Water Resources

The lands contained in the UCBN are highly diverse. The UCBN is made up of nine widely separated NPS units located in western Montana, Idaho, eastern Washington, and central Oregon (Figure 3). Parks within the network vary in size from 30 hectares to more than 190,000 hectares, and all but two parks are less than 6,000 hectares (Table 1). UCBN park units include a total of over 245,000 hectares of land area, and units are spread over an area spanning 850 kilometers from east to west, 765 kilometers from north to south, and covering 2506 meters of vertical relief. The park units fall in four different ecoregions (Bailey 1995; 1998). Note that one of the units of the Nez Perce National Historical Park (NEPE), Bear Paw Battlefield, is actually located outside of the network boundary in eastern Montana. Neither Bear Paw Battlefield nor Minidoka Internment National Monument (MIIN) contain surface water resources and will not be considered in this protocol. Most network parks lie within the upper Columbia Basin, though Big Hole National Battlefield (BIHO) lies in the upper portion of the Missouri River Basin. While all of the units have been identified as having significant natural resources, the majority of parks were established primarily to protect cultural and paleontological resources (Table 1).

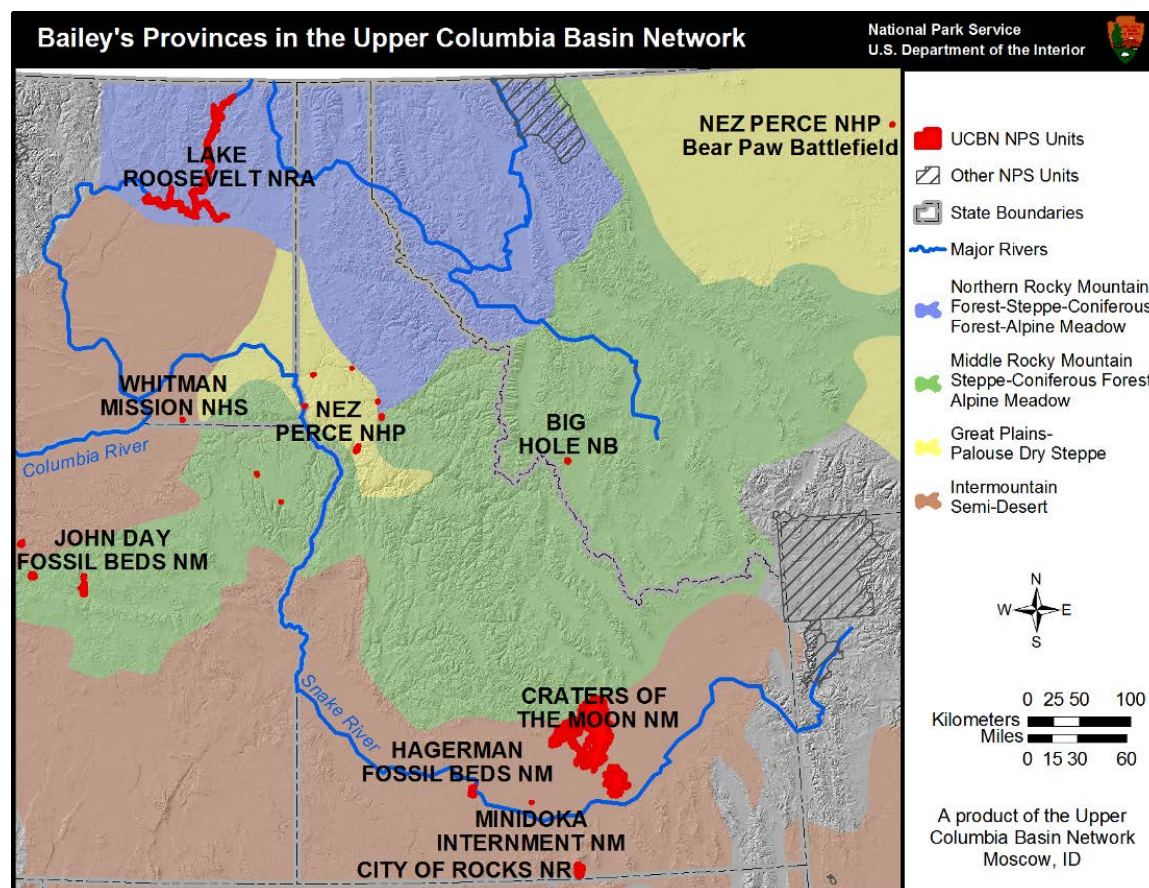


Figure 3. Upper Columbia Basin Network parks and Bailey's Ecoregion Provinces.

Table 1. NPS Units in the UCBN.

Park	Park Code	State	Acres	Hectares	Originally Established For		
					Cultural Resources	Natural Resources	Recreation
Big Hole National Battlefield	BIHO	MT	655	265	X	-	-
City Of Rocks National Reserve	CIRO	ID	14,107	5,708	X	X	-
Craters of the Moon National Monument and Preserve	CRMO	ID	469,711	190,081	X	X	-
Hagerman Fossil Beds National Monument	HAFO	ID	4,351	1,760	X	-	-
John Day Fossil Beds National Monument	JODA	OR	14,056	5,688	X	X	-
Lake Roosevelt National Recreation Area	LARO	WA	100,390	40,625	X	-	X
Minidoka Internment National Monument	MIIN	ID	73	30	X	-	-
Nez Perce National Historical Park	NEPE	ID	2,122	858	X	-	-
Whitman Mission National Historic Site	WHMI	WA	98	40	X	-	-

The Columbia Basin is in a transition-type climate zone and climate patterns are dominated by topographic features (Ferguson 1999; Quigley and Arbelbide 1997). Vegetation type and distribution varies depending on the soils, long-term precipitation patterns, and climate. Climate at park sites is influenced by three distinct air masses: 1) moist, marine air from the west that moderates seasonal temperatures; 2) continental air from the east and south, which is dry and cold in winter and hot with convective storms in summer; and 3) dry, arctic air from the north that brings cold air to the basin in winter and helps to cool the basin in summer (Ferguson 1999).

Winter precipitation (20-40 cm, 8-16 inches) accumulates as snowpack in much of the central Columbia and Snake River Plateaus. The mountain snowpack acts as a natural reservoir, supplies the basin with most of its useable water, and stream hydrographs are dominated by peaks in snowmelt run-off with much lower base flows occurring in late summer, fall, and winter. Summer precipitation through the basin ranges from 20 cm to 50 cm (8-20 inches). Trends in precipitation over the last 50 to 100 years indicate a general decrease in winter precipitation and an increase in summer precipitation (Davey et.al. 2006; Ferguson 1999; Mote et al. 2005).

Temperatures are generally mild in the basin because of the periodic influxes of moderating Pacific moisture. Winter mean monthly temperatures range from -10 to -3°C (-14 to 27°F) and mean

monthly summer temperatures ranges from 10 to 15°C (50 to 59°F). Temperature trends in the last 50 to 100 years indicate a slight increase in winter temperatures and slight decrease in summer temperatures (Ferguson 1999). Climate change scenarios identified by the US Global Change Research Program (USGCRP) for the Rocky Mountain/Great Basin region, which includes the UCBN area, are complex but include a reduction in snowpack and an overall aridification of the region, with increased evapotranspiration negating the effects of potential increased summer precipitation (Wagner et al. 2003).

Watershed land use/land cover (LULC) has strong effects on water resources (Allan 2004). Shrub-steppe habitat is the most extensive vegetation type in the Upper Columbia Basin Network parks (Table 2). However, forested vegetation is also widespread, especially in the northern portion of the network. Forest types present in the network include ponderosa pine forest, pinyon-juniper woodlands, lodgepole pine forest, aspen communities, isolated stands of Douglas-fir, and limber pine woodland. Small amounts of wetland and riparian vegetation are also present in most UCBN parks.

LULC of the watersheds that contain UCBN park units, but that are outside of park boundaries probably have strong effects on park water quality given the small areas of many park units relative to the watersheds which contain them (Allan 2004). Notably, in contrast to large parks that fully encompass one or more headwater watersheds, most UCBN parks are a small proportion of the watershed and are situated well downstream from headwaters. The small size of parks and their position within the watershed is illustrated by the example of BIHO (Figure 4). Consequently, LULC and other activities in upstream areas outside of park boundaries have the potential to affect water resources within UCBN parks. CRMO and CIRO are exceptions to this rule. For instance, the watersheds for Little Cottonwood Creek and several playas and pools are fully encompassed by CRMO. Similarly, all or most of the watersheds for streams of the main unit of CIRO (Figure 5) fall within NPS boundaries. The water quality standard operating procedure document (bound separately) includes maps of each park and USGS Hydrologic Unit Code (HUC) boundaries.

Water bodies in the UCBN fall into three general categories. Many water bodies within the UCBN are small streams or rivers, seeps, or ponds. Currently, there are few or no data on water quality or aquatic biota for these water bodies. A second class includes short sections of three large rivers: the John Day River in Oregon (JODA), the Clearwater River in northern Idaho (NEPE), and the Snake River in southern Idaho (HAFO) that have watersheds extending thousands of square kilometers upstream of park units, and have or have had substantial aquatic resource monitoring, though often outside UCBN park boundaries.

LARO is a third, unique combination of these two classes because the recreation area includes Lake Roosevelt, a large reservoir of the Columbia River, with most of the watershed located in Canada. LARO also has several smaller tributaries that empty into Lake Roosevelt. Impairments of LARO aquatic resources by upstream inputs have had cascading effects on lake sediments and potential effects on human health are now being investigated by multiple agencies including the Environmental Protection Agency (EPA). A lead-zinc smelter on the Columbia River in Trail, British Columbia operated by Teck Cominco, Inc. and past and current mining activities in the Coeur d'Alene drainage basin are the two largest sources of toxins. Lake Roosevelt is currently being

considered for listing as an EPA “Superfund” site. Lake Roosevelt also has an intensely managed fish community composed primarily of exotic species. Due to the large amount of on-going monitoring in Lake Roosevelt (e.g., Lee et al. 2006) and very limited UCBN resources for network-wide water resource monitoring, sampling at LARO is not included in this monitoring protocol.

Table 2. Percentage of UCBN park area in each land cover type as determined with the National Land Cover Dataset and the National Park Service digital park unit layer (NPS boundary).

Land Cover	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
Open Water	1%	-	-	1%	1%	75%	-	1%	6%
Urban	-	-	<1%	-	-	1%	-	<1%	-
Bare Rock/Sand/Clay	-	-	81%	<1%	1%	<1%	-	-	-
Transitional	18%	-	-	-	-	<1%	-	4%	<1%
Deciduous Forest	<1%	<1%	-	-	<1%	<1%	-	4%	2%
Evergreen Forest	23%	4%	-	<1%	21%	11%	-	7%	-
Mixed Forest	-	-	-	-	-	<1%	-	<1%	-
Shrubland	3%	71%	18%	53%	68%	6%	45%	17%	3%
Orchards/Vineyards/Other	-	-	-	-	-	<1%	-	-	5%
Grasslands/Herbaceous	32%	23%	1%	41%	5%	4%	29%	51%	83%
Agriculture	-	3%	<1%	5%	5%	1%	26%	16%	-
Woody Wetlands	21%	<1%	<1%	<1%	-	<1%	<1%	<1%	-
Emergent Herbaceous Wetlands	2%	-	-	-	<1%	<1%	-	<1%	-



Hydrologic Unit Code Boundaries

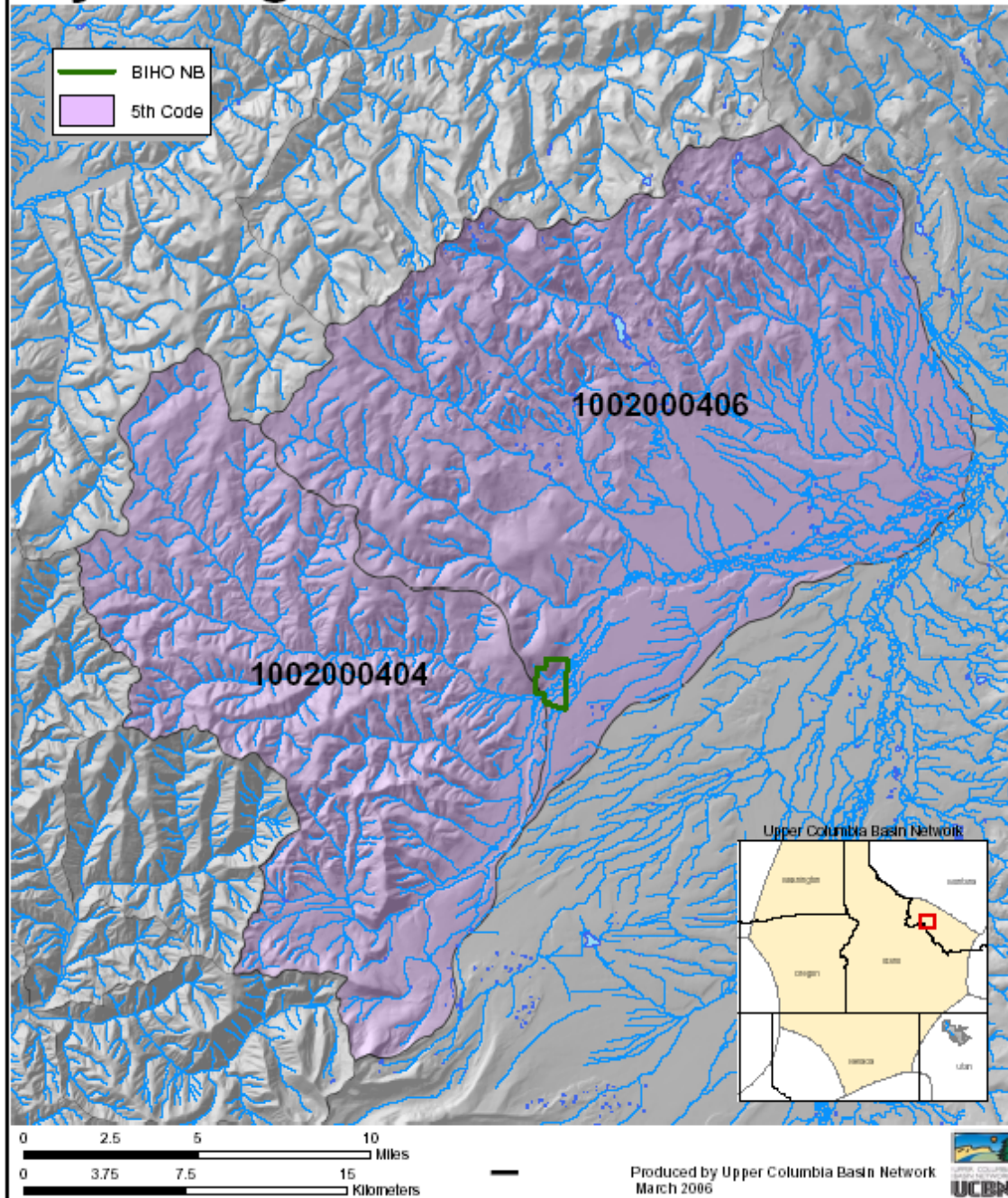


Figure 4. Stream network in Big Hole National Battlefield and associated HUCs illustrating the large watershed area and total stream length outside of the park in comparison to area and stream length within the park.



Hydrologic Unit Code Boundaries

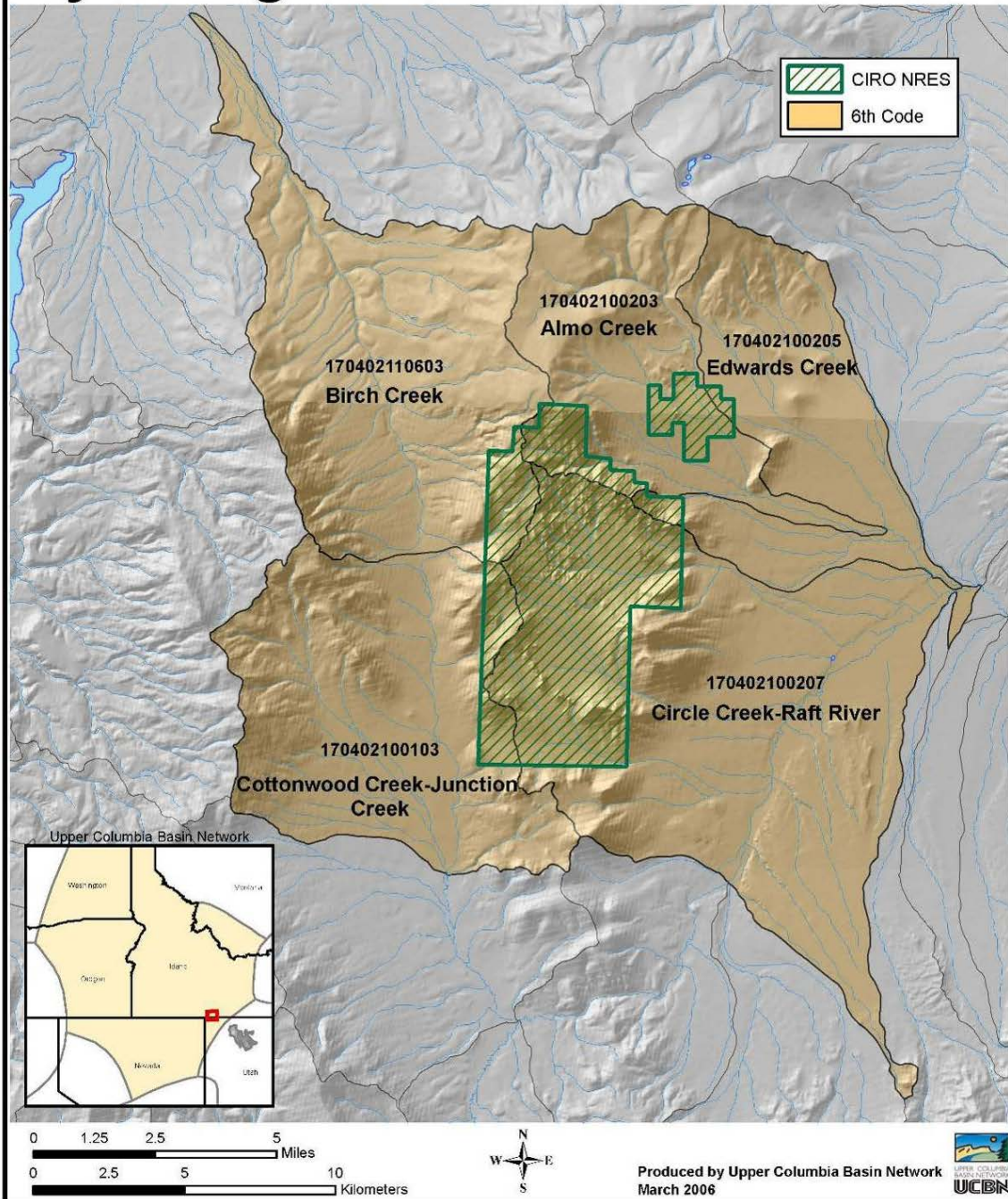


Figure 5. City of Rocks (CIRO) stream network and HUCs. The main unit of the park includes the entire watersheds for the streams flowing through it.

Within the boundaries of UCBN parks, aquatic resources represent a very small percentage of total land cover, with the exception of LARO. However, like riparian and wetland vegetation, aquatic environments are disproportionately important in terms of biodiversity, biological productivity, and many other ecosystem functions and values (Richardson 1994; Kauffman et al. 1997; McKinstry et al. 2004). Lotic (flowing water) environments in the UCBN include large rivers, perennial tributary creeks, irrigation ditches, and numerous seasonal and ephemeral streams, springs, and seeps. Lake Roosevelt, a large run-of-the-river reservoir in the Columbia River, and Lower Salmon Falls Reservoir in the Snake River adjacent to HAFO, function as lotic environments in the upper reaches of the reservoir and lentic (standing or still water) environments near the dams. Other lentic environments in the UCBN include small lakes and ponds, as well as floodplain and depressional wetlands. Table 3 presents the distribution of aquatic environments in the UCBN.

Table 3. Summary of water resources in UCBN parks.

Park	Large Rivers (no.)	Small Rivers & Streams (no.)	Intermittent Streams (no.)	Irrigation Ditches (no.)	Ponds (no.)	Reservoir (no.)	Mapped Springs / Seeps (no.)	Unmapped Springs / Seeps (no.)
BIHO	-	1	-	2	-	-	-	-
CIRO	-	5	numerous	-	-	-	5	1+
CRMO	-	-	1	-	1+	-	9	numerous
HAFO	1	-	1	1	-	1	1+	numerous
JODA	1	2	1	2	1	-	8	6
LARO	1	5+	1+	-	-	1	-	-
MIIN	-	-	-	-	-	-	-	-
NEPE	2	2	-	-	1	-	-	-
WHMI	-	2	-	1	1	-	-	-

Assessments of aquatic resources in the Columbia Basin have shown wide-spread habitat degradation. Habitat degradation, dams, excessive harvest, and introduced non-native gamefish have been implicated in the declining fisheries throughout the basin (National Research Council 1996; Quigley and Arbelbide 1997; Levin et al. 2002), particularly in anadromous (sea-run) fisheries. Extensive grazing caused removal of willow riparian vegetation in many parts of the region as early as 1860 (Elmore and Kauffman 1994). Floodplain irrigation and agriculture altered hydrology and many river and stream channels were straightened and cleaned of wood and other in-stream structures (Quigley and Arbelbide 1997). Beginning in the early 20th century, large dams were constructed along many rivers and streams in the basin for flood control, irrigation, and electricity, resulting in habitat loss, degradation, and altered hydrology. This legacy of habitat alteration is clearly evident in most UCBN aquatic environments. Lake Roosevelt, the Snake River adjacent to HAFO, the Walla Walla River and Mill Creek at WHMI, the Clearwater River adjacent to NEPE, the

North Fork Big Hole River at BIHO, and the John Day River at JODA have all experienced significant habitat loss, habitat degradation, and associated declines in native fish populations that have occurred throughout the Columbia Basin (National Research Council 1996; Quigley and Arbelbide 1997). Water quality impairment in the Columbia Basin is also widespread, primarily as a result of non-point source pollution (Quigley and Arbelbide 1997). Water temperature, turbidity and sedimentation, nutrients, and stream flow alteration have been identified as the most prevalent causes of impairment (Quigley and Arbelbide 1997). Numerous examples of point-source discharge of pollutants exist, including high levels of toxic industrial waste, from an upstream point-source, buried in Lake Roosevelt's sediments.

Information on water resources within the UCBN parks is limited. Previous assessments of water quality consist of historical data from surrounding sampling sites, and state 303(d) assessments. Additionally, in 2003, a water quality questionnaire was sent to resource managers in UCBN parks to assess manager's perceptions of the threats to water quality in their parks (Table 4). A baseline survey of water resources conducted in 1992-3 for CRMO generally revealed high water quality, with some evidence of local impairment from mining, grazing, and recreation (Falter and Freitag 1996). HAFO has completed a water resources management plan (Farmer and Riedel 2003) and LARO has completed a water resources scoping report (Riedel 1997). All of the parks have baseline water quality data reports ("Horizon" reports) summarizing water quality data in the EPA STORET database up to the time of the report (e.g., Riedel 1997). Currently, the majority of UCBN parks do not collect water quality monitoring data, although some parks have state DEQ monitoring or USGS sites located nearby. There are no designated Outstanding Natural Resource Waters (ONRW) or watersheds of exceptional quality identified in the UCBN. The Clearwater River (NEPE) is classified as a Special Resource Water by the state of Idaho, a classification that recognizes its exceptional value as a recreational and aesthetic resource, but the river has not been formally recognized as an Outstanding Resource Water by the state legislature (Idaho Administrative Code 58.01.02).

Table 4. List of threats to UCBN water resources.

Park	State	Data	Threats to Water Resources
Big Hole National Battlefield (BIHO)	MT	Park data - none Outside sources from 1975	Mining, agriculture, and stormwater runoff
City of Rocks National Reserve (CIRO)	ID	Park – no data since 1985	Ranching and grazing activities; residential development; gas, oil and mining operations; recreational use
Craters of the Moon National Monument (CRMO)	ID	1999-2003	Pesticide runoff and drift from agricultural lands, as well as weed management activities along state and county roads
Hagerman Fossil Beds National Monument (HAFO)	ID	2003	Irrigation and agricultural activities, altered subsurface hydrology, upstream agricultural and industrial effluent, altered flow regulation
John Day Fossil Beds National Monument (JODA)	OR	2003	Irrigation withdrawals and confined animal feeding upstream, untreated sewage effluent upstream
Lake Roosevelt National Recreation Area (LARO)	WA	2002-2003	Mining, permitted discharges from waste water treatment plants, residential development (septic tanks), and agriculture (grazing and farming), campsite sewage disposal, upstream industrial discharge, altered flow regulation
Minidoka Internment National Monument (MIIN)	ID	No Data	No water resources within the park boundaries
Nez Perce National Historical Park (NEPE)	ID	1975-1994	Point and non-point discharge from upstream sources – Dworshak dam, agriculture, logging, grazing, recreation, highway runoff and urbanization
Whitman Mission National Historic Site (WHMI)	WA	2000-2003	Agricultural chemical use, over allocation of irrigation water, private airfield 3 miles upstream

Current estimates, based on existing data sources, indicate that approximately 15-20 species of fish are present in network waters. One of the last strongholds of the arctic grayling south of Canada and Alaska is in the upper reaches of the Big Hole River near BIHO.

Status of UCBN Waterbodies (303d and State Beneficial Uses)

Under section 303(d) of the federal Clean Water Act, states must assess all waterbodies every two years to determine if they are supporting beneficial uses or if additional pollution control measures are required. Reports must be approved by the EPA before the document can be used by states for management decisions, resulting in considerable lags between assessment and finalization of reports. In past years, these assessments were published as “303(d) Reports” and in more recent years, states have prepared “Integrated Reports” that combine 303(d) and 305(b). The 303d report is the primary vehicle for informing Congress and the public about general water quality conditions in the United

States. In addition, it also serves as guidance documents for establishing Total Maximum Daily Load (TMDL) criteria.

All UCBN waters that have been assessed by state Division of Environmental Quality (DEQ) agencies for regulatory compliance are on 303(d) lists for impairment of at least one parameter. Table 5 lists the impairments for each UCBN park. Note that data for most regulatory assessments have been collected outside of park units (i.e. upstream or downstream of the park).

In the case of the North Fork Big Hole River, Montana DEQ identifies agricultural crop-related sources for impairment in its 2002 303(d) list. The 1997 Horizon report for BIHO lists anthropogenic sources of impairment as mining, agricultural, and storm water runoff (NPS 1997). In addition, flow impairment may be threatening the arctic grayling population in the Big Hole drainage.

Information for HAFO from both Idaho DEQ and Farmer and Riedel (2003) indicate significant water quality stressors originating from extensive agricultural irrigation. The fossil-bearing bluffs in HAFO have experienced a series of large landslides beginning in 1979 resulting from perched aquifers formed from irrigation to the crop fields above the escarpment. Although pesticides and industrial chemicals are not listed on the 303(d) list for Lower Salmon Falls Reservoir, sturgeon tissue samples collected immediately below the reservoir have shown organochlorine and PCB levels exceeding maximum contaminant levels set by the EPA (Farmer and Riedel 2003).

In the case of JODA, Oregon DEQ water quality index reports (<http://www.deq.state.or.us/lab/wqm/wqindex/johnday3.htm>) for the John Day Basin show fair to poor water quality both above and below the monument – one monitoring site near Dayville above the Sheep Rock Unit is showing improving water quality, and one at the confluence of the North Fork John Day River downstream from Sheep Rock shows declining quality. A water quality index score is a single number meant to reflect the overall quality of water. It is based on eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+ nitrate nitrogen, total phosphorus, total solids, and fecal coliform). Average water quality index scores are poor for the mainstem of the John Day River during summer due to low flow, increased concentrations of fecal coliform, elevated temperature, and reduced dissolved oxygen.

In the case of Lake Roosevelt, serious concerns have been raised about the high levels of sediment contamination resulting from over 70 years of industrial discharge originating in Canada. In NEPE, the reach of the Clearwater adjacent to the Spalding Unit of NEPE and Lapwai Creek, which flows through Spalding, show impacts from upstream agriculture, highway runoff, and other land use practices. The reach of Jim Ford Creek through Weippe Prairie has not been assessed by Idaho DEQ, but it has been severely degraded by historic channel straightening and intensive agricultural and grazing activities, and water quality is almost certainly impaired there as well.

Along Mill Creek and the Walla Walla River at WHMI, temperature, instream flow, and fish habitat are all impaired parameters. Impacts from agriculture throughout the Walla Walla Valley are of concern, and lower reaches of the Walla Walla River downstream of WHMI are on the Washington DEQ 303(d) list for chlordane, benzene, dieldrin, heptachlor, and total PCB's.

Table 5. 303(d) status of UCBN water resources.

Park	303(d) listed waters	Impairments	List Date
Big Hole National Battlefield (BIHO)	N. Fork Big Hole River	Flow Impairment, Dewatering	2002
City of Rocks National Reserve (CIRO)	Not Assessed	-	-
Craters of the Moon National Monument (CRMO)	Not Assessed	-	-
Hagerman Fossil Beds National Monument (HAFO)	Lower Salmon Falls Reservoir (Snake R.)	Dissolved Oxygen (DO), Flow Alteration, Sediment	2000
John Day Fossil Beds National Monument (JODA)	John Day River, Pine Creek, Bridge Creek, Rock Creek	Temperature, Dissolved Oxygen (DO), Fecal Coliform	2002
Lake Roosevelt National Recreation Area (LARO)	Lake Roosevelt, Colville River, Spokane River, Colville River	Sediments, Fecal Coliform, Total PCB's, Mercury, Lead, Zinc, Cadmium, Copper, Dioxin, Arsenic, AROCLOR 1254, DDT, Dieldrin, Total Dissolved Gas	2002
Minidoka Internment National Monument (MIIN)	Not Assessed	-	-
Nez Perce National Historical Park (NEPE)	Jim Ford Creek (Jim Ford Creek Waterfall)	Sediment	2002
Nez Perce National Historical Park (NEPE)	Lower Clearwater River, Lapwai Creek	Total Dissolved Gas, Nutrients, Bacteria, Dissolved O ₂ (DO), Flow Alteration, Habitat Alteration, Sediment, Temperature	2002
Whitman Mission National Historic Site (WHMI)	Doan Creek	Temperature	2004, 2004
Whitman Mission National Historic Site (WHMI)	Mill Creek	Temperature, pH, Dissolved O ₂ (DO), Instream Flow, Fish Habitat	2002,2004

Beyond the 303(d) listings, very few data are available to assess the status or trends of water quality within UCBN park boundaries. Few of the sampling sites compiled by the 1997 Baseline Water Quality Data Inventory and Analysis reports, also referred to as the Horizon reports, were within park boundaries (Table 6) and few data or no data were submitted to STORET between the 1997 Horizon reports and 2005 for most UCBN units (Garrett et al. 2007).

Table 6. Summary of sampling stations and sampling from the 1997 Baseline Water Quality Data Inventory and Analysis reports.

Park	Total Stations	Number in Park	%Stations in Park	% All Reported Observation that were in the Park
BIHO	18	0	0.0%	0.0%
CIRO	12	3	25.0%	21.9%
CRMO	23	10	43.5%	65.8%
HAFO	66	4	6.1%	0.3%
JODA	42	4	9.5%	2.3%
NEPE	238	0	0.0%	0.0%
WHMI	20	9	45.0%	35.3%

States are required to classify streams by beneficial uses under the Clean Water Act. For example, the State of Idaho defines beneficial uses as:

Any of the various uses which may be made of the water of Idaho, including, but not limited to, domestic water supplies, industrial water supplies, agricultural water supplies, navigation, recreation in and on the water, wildlife habitat, and aesthetics. The beneficial use is dependent upon actual use, the ability of the water to support a non-existing use either now or in the future, and its likelihood of being used in a given manner. The use of water for the purpose of wastewater dilution or as a receiving water for a waste treatment facility effluent is not a beneficial use.

(Idaho Administrative Code 58.01.02: Water Quality Standards

<http://adminrules.idaho.gov/rules/current/58/0102.pdf>)

The beneficial uses for each UCBN waterbody are determined by individual states and tribes during 303(d) assessments as mandated under the Clean Water Act. Beneficial uses are determined during an attainability analysis which determines actual use and potential future uses of a waterbody. Beneficial use status is reviewed every three years and the current status of UCBN waterbodies is given in Table 7. For waterbodies within the state of Idaho, “Prior to designation, undesignated waters shall be protected for beneficial uses, which includes all recreational use in and on the water and the protection and propagation of fish, shellfish, and wildlife, wherever attainable” and the State presumes that all undesignated waters are suitable for cold water aquatic life and all classes of recreation (IDAPA 58).

An example of how the state of Idaho recognizes beneficial uses and use subclasses (IDAPA 58) is given below:

Aquatic Life:

Bull Trout (Supports bull trout)

Cold Water (COLD, Supports cold water species)

Salmonid Spawning (SS, Provides or could provide self-propagating salmonid fish populations)

Seasonal Cold Water (SC, Seasonally supports cold water species)

Warm Water (WARM, Supports warm water species)

Modified (MOD, “Water quality appropriate for an aquatic life community that is limited due to one or more conditions that preclude attainment of reference streams or conditions”)

Recreation:

Primary Contact Recreation (PCR, High probability of ingesting water, e.g., swimming and water skiing)

Secondary Contact Recreation (SCR, Low probability of ingesting water, e.g., fishing, boating, wading)

Water Supply:

Domestic (DWS, Drinking water supply)

Agricultural (Irrigation, drinking water for livestock)

Industrial (Appropriate for industrial processes, all waters in state)

Wildlife Habitats: (All waters)

Aesthetics: (All waters)

Undesignated waters in Idaho are presumed to support COLD and PCR or SCR. Beneficial uses in the other states are very similar.

Oregon designates the following beneficial uses to the John Day River and all tributaries in the John Day Basin: Public Domestic Water Supply, Private Domestic Water Supply, Industrial Water Supply, Irrigation, Livestock Watering, Fish & Aquatic Life, Wildlife and Hunting, Fishing, Boating, Water Contact Recreation, Aesthetic Quality (i.e., all uses except Hydro Power and Commercial Navigation & Transportation [OR 340-41-0170]). All UCBN waters in the John Day Basin are designated

Salmon and Trout Rearing and Migration areas except the mainstem John Day River at the Sheep Rock unit which is designated a Salmon and Steelhead Migration Corridor.

Washington State classifies water bodies into Class AA, A, B, & C depending on which beneficial uses are supported. Class AA waters are pristine waters that may be fresh or marine water. While class AA waters are possible throughout Washington, most occur in areas less affected by civilization. Class A, B and C waters each support fewer beneficial uses, in order. Class B waters no longer support recreational uses such as swimming, or spawning of fish. Oregon and Washington also recognize anadromous fish migration as a beneficial use.

The most current designations and classifications will be described in annual monitoring reports published following each monitoring season in a given park.

Table 7. UCBN Waterbodies, encompassing HUCs, and designated state beneficial uses (2008).

Park	State	USGS HUC	Waterbodies	Designated Uses
CIRO	ID	17040210	Graham Creek and Tributaries	Idaho, Undesignated (UD)
CIRO	ID	17040210	Birch Creek and Tributaries	UD
CIRO	ID	17040210	Junction Creek and Tributaries	UD
CIRO	ID	17040210	Circle Creek and Tributaries	UD
CIRO	ID	17040210	Raft River Tributaries	UD
CIRO	ID	17040211	Walters Creek	UD
CRMO	ID	17040209	Numerous intermittent streams and perched/pothole waterholes, few springs.	UD
CRMO	ID	17040209	Little Cottonwood Creek	UD
CRMO	ID	17040221	Little Wood River at edge of Monument	COLD, SS, PCR
CRMO	ID	17040218	Few intermittent streams to edge of lava	UD
CRMO	ID	17040206	None	UD
HAFO	ID	17040212	Snake River	COLD, SS, PCR
HAFO	ID	17040212	Yahoo Creek and > 10 intermittent streams	UD
MIIN	ID	17040212	North Side Canal, some ditches	UD
NEPE-White Bird Battlefield	ID	17060209	Schwartz Pond	UD
NEPE-White Bird Battlefield	ID	17060209	White Bird Creek	COLD, SS, PCR, DWS (White Bird Creek from mouth to confluence of N. and S. Fork White Bird Creek--believe that the White Bird unit includes some of this stretch)
NEPE-Heart of the Monster	ID	17060305	Clearwater River	COLD, SS, PCR, SRW (ID Special Resource Water)
NEPE-Weippe Prairie	ID	17060306	Jim Ford Creek	COLD, PCR
NEPE-Spalding	ID	17060306	Clearwater River	COLD, SS, PCR, SRW (ID Special Resource Water)

* Oregon designates the following beneficial uses to the John Day River and all tributaries in the John Day Basin: Public Domestic Water Supply, Private Domestic Water Supply, Industrial Water Supply, Irrigation, Livestock Watering, Fish & Aquatic Life, Wildlife and Hunting, Fishing, Boating, Water Contact Recreation, Aesthetic Quality (i.e., all uses except Hydro Power and Commercial Navigation & Transportation [OR 340-41-0170]). All UCBN waters in the John Day Basin are designated Salmon and Trout Rearing and Migration areas except the main stem John Day River at the Painted Rocks unit which is designated a Salmon and Steelhead Migration Corridor.

Table 7 (continued). UCBN Waterbodies, encompassing HUCs, and designated state beneficial uses (2008).

Park	State	USGS HUC	Waterbodies	Designated Uses
NEPE-Spalding	ID	17060306	Lapwai Creek	COLD, PCR
NEPE-Buffalo Eddy	ID	17060103	Snake River	COLD, PCR, DWS
NEPE-Old Chief Joseph	ID	17060105	None	N/A
BIHO	MT	10020004	N. Fk Big Hole River and slough areas	Montana Class A-1 (CWF, PCR, IND, AQ, DWS, AQL; CWF = Cold Water Fishery, AQL = Aquatic Life)
JODA	OR	17070201 17070204	John Day River	*
JODA-Sheeprock	OR	17070201	Squaw Creek, Rock Creek, Rattlesnake Creek, >7 creeks w/o names in database, numerous springs	*
JODA-Painted Hills	OR	17070204	Bridge Creek and 4 unnamed streams	*
JODA-Painted Hills	OR	17070204	Indian Canyon, Hanncock Canyon and 1 unnamed stream	*
LARO	WA	17020001	Lake Roosevelt, numerous tribs	Class AA
LARO	WA	17020002	Kettle River arm, numerous tribs	Class A by default
LARO	WA	17020003	Colville River arm, numerous tribs	WA Class A
LARO	WA	17010307	Spokane River arm, numerous tribs	WA Class A
LARO	WA	17020004	Sanpoil River arm, numerous tribs	Class A by default
LARO	WA	17020005	Columbia River, numerous tribs	Class AA
WHMI	WA	17070102	Mill Creek	Class AA inside WHMI, Class B Below 13th Street Bridge in Walla Walla to mouth
WHMI	WA	17070102	Doan Creek	Class A by default
WHMI	WA	17070102	Mill Pond, Irrigation ditch	UD

* Oregon designates the following beneficial uses to the John Day River and all tributaries in the John Day Basin: Public Domestic Water Supply, Private Domestic Water Supply, Industrial Water Supply, Irrigation, Livestock Watering, Fish & Aquatic Life, Wildlife and Hunting, Fishing, Boating, Water Contact Recreation, Aesthetic Quality (i.e., all uses except Hydro Power and Commercial Navigation & Transportation [OR 340-41-0170]). All UCBN waters in the John Day Basin are designated Salmon and Trout Rearing and Migration areas except the main stem John Day River at the Painted Rocks unit which is designated a Salmon and Steelhead Migration Corridor.

Objectives

The overarching programmatic goal of the UCBN integrated water quality monitoring program is to obtain information that will aid in informed management decisions pertaining to improved water quality within UCBN parks. Park managers have committed to improving the water quality of impaired waters by adopting the NPS Government Performance Results Act (GPRA) goal, stating that 99.3% of streams and rivers managed by NPS will meet State and Federal water quality standards. Many UCBN waters do not meet standards and are listed on 303(d) lists. Park managers would also like to be able to demonstrate and maintain high water quality where it exists. The NPS should be leading the way in high water quality regardless of beneficial uses (i.e., consideration should be given to water resources for their intrinsic value alone).

Given the lack of available data on water quality in UCBN parks, the following fundamental questions drive much of the UCBN's inquiry into water quality:

- Are the core water quality parameters of streams in the UCBN with established TMDLs selected for sampling improving over time?
- What is the status and long-term trend of core water quality parameters (temperature, pH, conductivity, dissolved oxygen, and turbidity) in UCBN streams selected for sampling?
- What is the status and long term trend in aquatic macroinvertebrate abundance and assemblage composition in selected UCBN streams?
- Do aquatic macroinvertebrate assemblages sampled within UCBN streams indicate polluted or otherwise impaired water quality?
- Do aquatic macroinvertebrate assemblages sampled within UCBN streams indicate “pristine” or “reference” conditions according to regional criteria established by EPA and the states of Idaho, Oregon, Montana, and Washington?

In light of these questions and the broader goals outlined above, this protocol will address the following specific measurable monitoring objectives:

- Determine status and long term trend in key water quality parameters for selected streams within UCBN park units. **Justification:** *Water quality has strong effects on aquatic biota, but both vary through time as a result of natural and human-induced causes. Understanding the patterns of variability among years is critical to detecting long-term trends.*
- Determine status and trend in aquatic macroinvertebrate abundance, assemblage composition, and functional feeding group composition in wadeable streams within the UCBN. **Justification:** *Aquatic macroinvertebrates are good indicators of ecosystem condition because they occur in all waterbodies, integrate point, nonpoint, pulse, and press disturbances, are trophically diverse, and are less mobile than fishes. Macroinvertebrate communities are also affected both by conditions in local stream reaches and those within the watershed.*

The knowledge gained by answering these monitoring questions and measurable objectives will support the management of water resources within the UCBN.

The following sampling objectives have been developed for this protocol:

- Detect a 20% change over 10 years in the mean for the core water quality parameters temperature, pH, conductivity, dissolved oxygen, and turbidity in selected lotic waterbodies with 80% power and 5% acceptable false change error (α or type I error).
- Sampling objectives for macroinvertebrates will be developed after baseline indices have been established. It is anticipated that baseline indices can be established after species abundance and assemblage composition has been determined for each sampled stream following 5 years of data collection.

Sampling Design

Sampling Design Rationale

The objectives and sampling design were developed through a process that involved site reconnaissance, pilot data collection and analysis, and thoughtful consideration of budget and Network information requirements. The protocol team consisted of this document's authors, as well as park resource management staff.

We note that, while the aim of the sampling design is to provide optimal statistical robustness and scientific rigor, other considerations including personnel safety, fiscal and logistical constraints, and the ability to integrate data with other vital signs must be considered. In addition, the water bodies of most UCBN parks are diverse and the most efficient sampling design will differ among parks.

To achieve the measurable objectives, this protocol outlines two primary data collection approaches and the rationale for choosing each data source, as is illustrated in Figure 6:

1. Collection of core water quality parameters in selected UCBN wadeable streams. Continuous water quality monitors (multiprobes) will be deployed from June to November at index sites to determine the status, variability and long-term trends in core parameter values at diel, seasonal, annual, and eventually, decadal time scales. An index site is a location determined to be relatively representative of the stream segment falling within park boundaries, and is logistically feasible to sample water chemistry parameters. The core parameters to be measured are water temperature, dissolved oxygen, pH, conductivity, and turbidity. While a full census or spatially balanced probabilistic sampling design for all UCBN water bodies would be desirable, the number of water bodies and very limited sampling resources do not make such a design feasible. Specifically, the number of water bodies is too large to fully census with available resources, but not so large that probabilistic sampling is justified. Rather, a subset of wadeable streams will be sampled for core water quality parameters and/or macroinvertebrates (see Tables 8 & 9). Core water quality parameters will be determined using continuous water quality monitors (multiprobes) at the most downstream of the selected macroinvertebrate sample reach, and hence, will not be strictly probabilistic. Multiprobe location and sampling will follow guidelines recommended by USGS (Wagner et al. 2006). Core water quality parameters will be sampled hourly at individual index sites in each park. Multiprobes will be deployed after high water in the spring (approximately June) and will be removed from the streams in mid-November. Limiting sampling to the spring, summer, and early fall months will eliminate the need for permanent housings or possible damage due to high water or ice. Due to budgetary constraints, multiprobe sampling will be phased in over 2-4 years.
2. Macroinvertebrate biomonitoring: quantification of macroinvertebrate assemblage composition and structure in selected UCBN wadeable streams. Macroinvertebrate samples will be collected at targeted reaches to determine status and trends in assemblage species composition and structure composition from wadeable streams in the UCBN (Tables 8 & 9).

Sampling of benthic macroinvertebrates occurs during implementation of the UCBN stream channel characteristics protocol (Starkey et al. 2016). For this reason, sample design and field techniques have been removed from version 1.9 of the integrated water quality protocol and are outlined in Starkey et al. 2016.

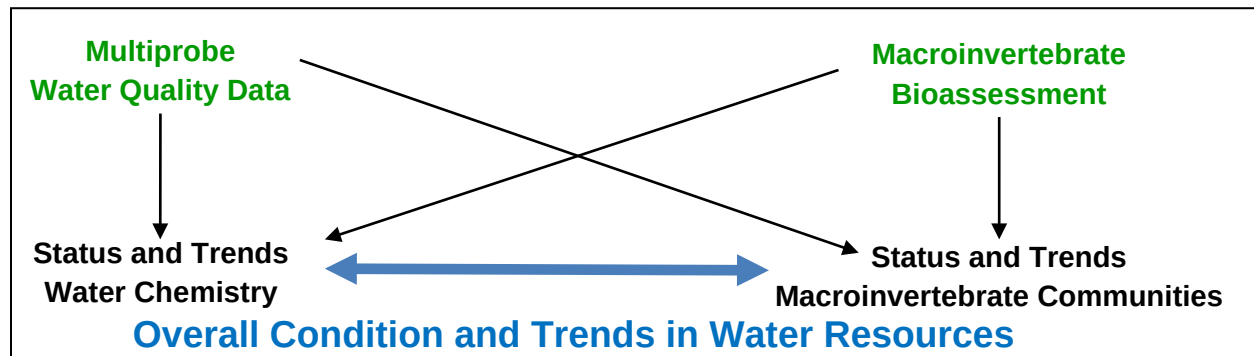


Figure 6. Overview of the relationships among data sources, measurable objectives, and the overall assessment of water resources in UCBN parks.

Overall, our approach to water quality monitoring will reflect the large differences between classes of water bodies in the UCBN. The protocol focuses monitoring resources on small streams within the network. In contrast to large river biota, the smaller streams and biological communities should respond more strongly to management and restoration action within the parks, and represent resources with little or no available status or trend data. The proposed sampling will also provide valuable monitoring sites for the detection of invasive aquatic species.

Selection of UCBN Waterbodies for Monitoring

In general, the UCBN integrated water quality monitoring locations represent the only or the largest water bodies present within each park. Prioritization and selection was based on:

- preference for wadeable, permanent streams
- preferences and perceived need from park resource managers
- known data gaps
- available monitoring resources

UCBN streams selected for monitoring are shown in Table 8. Table 9 includes a prioritization of remaining UCBN waterbodies for additional sampling in the future, should resources become available.

Target Population

The initial target population for the integrated water quality monitoring protocol was defined as representative UCBN waterbodies. Due to logistical constraints it is not possible to sample all UCBN waterbodies; as a result, the water quality monitoring sample population is defined as representative UCBN wadeable streams with permanent water sampled between the months of June and November.

Table 8. Selected wadeable streams and stream length within the boundaries of each park as identified using NAIP imagery. Actual or estimated number of water quality monitoring stations and macroinvertebrate sample reaches within each stream (updated 2016). Actual sample area may differ due to varying hydrologic conditions and changes to stream channel.

Park	Selected Streams	Maximum Length (m) Within Park	Number Of Water Quality Monitoring Stations	Number of Macroinvertebrate Reaches
BIHO	North Fork Big Hole River	3389	1 ¹	6 ¹
CIRO	Almo Creek	4545	1 ^{1, 2}	2 ¹
CIRO	Main Stem Circle Creek	1333	1 ^{1, 2}	2 ¹
CIRO	North Fork Circle Creek	1294	1 ^{1, 2}	2 ¹
CIRO	South Fork Circle Creek	1066	1 ^{1, 2}	2 ¹
CRMO	Little Cottonwood Creek	2762	1 ^{1, 2}	1 ¹
JODA	Bridge Creek	6033	1 ¹	2 ¹
JODA	John Day River	10694	1 ¹	6 ¹
JODA	Rock Creek	2370	1	2
NEPE	Jim Ford Creek	1258	1 ¹	3 ¹
NEPE	Lapwai Creek	374	1 ¹	1 ¹
WHMI	Doan Creek	529	1 ¹	1 ¹
WHMI	Mill Creek	151	1 ¹	1 ¹

¹ Indicates established water quality monitoring stations/ macroinvertebrate sample reaches.

² Due to the ephemeral nature of these streams, continuous water quality monitors will only be deployed for 24-48 hrs. in mid-June.

Table 9. Prioritization and identification of potential UCBN water quality monitoring sites.

Park	Potential Waterbodies	USGS HUCS	UCBN Priority¹	Water Quality²	Macro-invertebrates
BIHO	N. Fork Big Hole River and slough areas	10020004	1	Core parameters	Yes
CIRO	Almo Creek	17040210	1	Core parameters ³	Yes
CIRO	Birch Creek	17040210	2	-	-
CIRO	Graham Creek	17040210	2	-	-
CIRO	Junction Creek	17040210	2	-	-
CIRO	North, South, and Main Forks Circle Creek	17040210	1	Core parameters ³	Yes
CIRO	Raft River Tributaries	17040210	2	-	-
CIRO	Walters Creek	17040211	2	-	-
CRMO	Little Cottonwood Creek	17040209	1	Core parameters ³	Yes
CRMO	Numerous temporary pools	17040209	2	-	-
HAFO	Snake River	17040212	3	-	-
HAFO	Yahoo Creek	17040212	2	-	-
JODA-Painted Hills	Bridge Creek	17070204	1	Core parameters	Yes
JODA	John Day River	17070201 17070204	1	Core parameters	Yes
JODA-Clarno Unit	Pine Creek; runs adjacent to southern boundary of park unit	17070204	2	-	-
JODA-Sheeprock	Rock Creek	17070201	1	Core parameters	Yes

¹UCBN numerical priority rating:

1 – planned sampling at current funding levels.

2 – additional waterbodies to be sampled contingent on additional funding or partnerships

² Water quality core parameters to be determined using a continuous water quality monitor in lotic habitats only. Parameters to be measured include temperature, specific conductance, turbidity, pH, and dissolved oxygen.

³ Due to the ephemeral nature of these streams continuous water quality monitors will only be deployed for 24-48 hrs. in mid-June.

Table 9 (continued). Prioritization and identification of potential UCBN water quality monitoring sites.¹

Park	Potential Waterbodies	USGS HUCS	UCBN Priority¹	Water Quality²	Macro-invertebrates
LARO	Columbia River, numerous tribs	17020005	2	-	-
LARO	Colville River arm, numerous tribs	17020003	2	-	-
LARO	Kettle River arm, numerous tribs	17020002	2	-	-
LARO	Lake Roosevelt	17020001	3	-	-
LARO	Sanpoil River arm, numerous tribs	17020004	2	-	-
LARO	Spokane River arm, numerous tribs	17010307	2	-	-
NEPE-Weippe Prairie	Jim Ford Creek	17060306	1	Core parameters	Yes
NEPE-Spalding	Lapwai Creek	17060306	1	Core parameters	Yes
NEPE-White Bird Battlefield	Schwartz Pond	17060209	2	-	-
WHMI	Doan Creek	17070102	1	Core parameters	Yes
WHMI	Mill Creek	17070102	1	Core parameters	Yes
WHMI	Mill Pond	17070102	2	-	-

¹ UCBN numerical priority rating:

1 – planned sampling at current funding levels.

2 – additional waterbodies to be sampled contingent on additional funding or partnerships

² Water quality core parameters to be determined using a continuous water quality monitor in lotic habitats only. Parameters to be measured include temperature, specific conductance, turbidity, pH, and dissolved oxygen.

³ Due to the ephemeral nature of these streams continuous water quality monitors will only be deployed for 24-48 hrs. in mid-June.

Macroinvertebrate Measurements, Sampling Design, and Frequency

Sampling of benthic macroinvertebrates occurs during implementation of the UCBN stream channel characteristics protocol (Starkey et al. 2011a and Starkey et al. 2016). For this reason, sample design details have been removed from version 1.9 of the integrated water quality protocol and are outlined in Starkey et al. 2016.

Selection of Water Quality Monitoring Station

A continuous water quality monitor (multiprobe) will be located in close proximity to the downstream park boundary. This location is considered optimal to assess the quality of water flowing out of the park and will be used to determine water quality throughout a park's stream segment. In some parks this design will be modified to accommodate cultural resources and logistical concerns. One such example is the encampment at Big Hole National Battlefield (BIHO). If the multiprobe is placed at the downstream margin of the park it would be in or very near the culturally significant Nez Perce encampment. To avoid this location, the water quality monitoring station will be placed near the upstream park boundary.

The chemical and biological properties of aquatic habitats are variable in space and time (Allan 1995; Fausch et al. 2002). In particular, understanding variation in space is critical to ensuring representative samples and to make certain that sample locations are not biased and represent average conditions within a water body. This is particularly true when logistical constraints permit only a single sampling location within streams (Wagner et al. 2006). Consequently, periodic evaluation of small-scale (<1-10 m) spatial variability and longitudinal (upstream-downstream) trends in water quality within each stream will aid in initial site selection for the multiprobe and determine whether conditions at the monitoring station remain representative of average conditions in each stream. These spatial evaluations (cross section surveys) will be conducted twice a year using a modified version of the equal width incremental design developed by the USGS (Wagner et al. 2006) and is discussed in further detail in SOP #3.

Water Quality Measurements, Sampling Design, and Frequency

Continuous water quality monitors (multiprobes) are the preferred method of water chemistry data collection since they allow for the assessment of daily and seasonal stream conditions. While traditional "grab" samples are much less expensive and easier to obtain, they are discreet samples that do not accurately reflect the dynamic nature of stream systems. This is due to the fact that a single snapshot does not capture event-driven and daily fluctuations in the stream. UCBN multiprobes will include sensors to measure temperature, specific conductance, pH, dissolved oxygen, turbidity and depth. Currently, the UCBN has purchased two Hach MS-5 Hydrolab multiprobes and received a third purchased by WHMI in FY2008. Each year the UCBN will deploy two of the multiprobes in selected parks; these parks will be re-sampled every three years (Table 10). In years when both NEPE and WHMI streams will be sampled the third multiprobe will be deployed. When the third unit is not in use, it will serve as the field meter (SOP #5).

Multiprobes will be sited in close proximity to the downstream park boundary. Water quality monitoring station locations cannot be strictly random because of both logistical constraints and statistical considerations. Specifically, core water quality parameters vary in time and space (see SOP

3), and selecting a representative site for multiprobe deployment is critical to the collection of useful data. While multiprobes provide high temporal sampling resolution, in this protocol, they are restricted to sampling at a single location due to the logistical constraints of securing the multiprobe at multiple locations to prevent wash-out and vandalism. The multiprobes will be deployed after high water in the spring/early summer (June) and retrieved in late fall before ice forms (mid-November). Eliminating the winter sampling period will reduce the possibility of losing a multiprobe to a high water event and reduce staff time in the winter months for monthly calibration of the sensors.

Prior to selection of permanent water quality monitoring locations, a survey comparing the spatial variation in core parameters will be conducted to identify representative and non-representative sites within the study reach (SOP 3). Final site selection will be determined collaboratively by UCBN scientists and park resource managers using information collected during the surveys and following the recommendations of the USGS (Wagner et al. 2006). Bi-annual repetition of the spatial surveys (cross section survey) of core water quality parameters will continue to assess the representativeness of the selected sampling location through time (SOP 3). These spatial surveys will be repeated on the same three-year rotating panel design (Table 10).

The timing of benthic sampling for macroinvertebrates will be carefully noted to account for any effects of benthic sampling on core parameters measured by the multiprobe (e.g., turbidity). Given the short duration and low intensity of disturbance, macroinvertebrate sampling will likely have a minimal effect on most water chemistry parameters. Turbidity will be most affected but will accurately reflect stream conditions during macroinvertebrate sampling.

Sampling frequency will be determined by multiprobe capability, consideration of the benefits of high temporal resolution versus costs of data management, and factors such as electrical power requirements affecting battery replacement interval. A sampling frequency of approximately one hour should provide adequate resolution to characterize variability in diel patterns of core water quality parameters while providing adequate battery life and minimizing long-term data storage needs. As sensor technology and battery configurations change, it may be possible to increase sample frequency.

In 2008, the UCBN used a multiprobe equipped with dissolved oxygen, pH, self-cleaning turbidity, specific conductance, and temperature sensors. This multiprobe was operated by 8 AA batteries. The self-cleaning turbidity sensor significantly decreased battery life due to the rotating wiper. When using the sensors and internal batteries listed above with a one hour sample interval, battery life was approximately 28 days and the memory accommodated 2 and a half months' worth of data.

In order to reduce operational costs, increase data quality, and extend deployment lengths; in 2009 the UCBN began powering multiprobes via an external power source (12V deep cycle battery trickle charged by a solar panel (SOP1)). With the same sensors listed above and a one hour sample interval battery life was nearly unlimited. As such, sensor fouling is now the driver for calibration/maintenance revisits rather than loss of power. Fouling conditions vary from site to site, but the maximum deployment period between revisits should be no more than ~35 days.

Monitoring station revisits will occur approximately every 30-days (June-November). These visits will allow for data download, multiprobe calibration and routine maintenance.

Table 10. Rotating panel design for water quality monitoring in selected UCBN streams. Sampling year and macroinvertebrate index period indicated for each stream.

Park	Stream	Index Period (1)	Index Period (2)	Index Period (3)
NEPE	Jim Ford Creek	July 1 – October 15, 2014	July 1 – October 15, 2017	July 1 – October 15, 2020
NEPE	Lapwai Creek	July 1 – October 15, 2014	July 1 – October 15, 2017	July 1 – October 15, 2020
WHMI	Mill Creek	July 1 – October 15, 2014	July 1 – October 15, 2017	July 1 – October 15, 2020
WHMI	Doan Creek	July 1 – October 15, 2014	July 1 – October 15, 2017	July 1 – October 15, 2020
BIHO	NF Big Hole River	June 21 - September 21, 2015	June 21 - September 21, 2018	June 21 - September 21, 2021
CIRO	Circle Creek	July 1 – October 15, 2015	July 1 – October 15, 2018	July 1 – October 15, 2021
CIRO	Almo Creek	July 1 – October 15, 2015	July 1 – October 15, 2018	July 1 – October 15, 2021
JODA	John Day River	July 1 – October 15, 2016	July 1 – October 15, 2019	July 1 – October 15, 2022
JODA	Rock Creek	July 1 – October 15, 2016	July 1 – October 15, 2019	July 1 – October 15, 2022
JODA	Bridge Creek	July 1 – October 15, 2016	July 1 – October 15, 2019	July 1 – October 15, 2022
CRMO	Little Cottonwood Cr.	July 1 – October 15, 2016	July 1 – October 15, 2019	July 1 – October 15, 2022

Power Analysis for Continuous Water Quality Data

Statistical power analyses require information on sample size, effect size, and sample variance (Sokal and Rohlf 1995). The latter is currently unavailable for most parameters and locations, and preliminary power analyses were based on available data for a few locations (see below and SOP 9). Power analyses for all parameters shall be revised in five-year reports as estimates of intra- and interannual variability become available and improve with increasing sample size.

Preliminary power analysis using multiprobe data from Lapwai Creek for two seasons (April and September) are given in SOP #9. The results suggest that power ($1-\beta$) to detect a 20% change over 10 years in core water quality parameters will be adequate for most parameters (pH = 99%; mean temperature = 90%; minimum temperature = 74%; specific conductivity = 99%; dissolved oxygen = 99%) SOP # 9 provides additional power analysis details. Higher variability in maximum temperature, and very high variability in turbidity resulted in lower power for these two parameters (maximum temperature = 49%; turbidity = 6%). While the power to detect the desired minimum effect size in turbidity was poor, the importance of sedimentation as an impairment in some UCBN streams (Table 5) justifies continuing to estimate this parameter for both status and trend.

Strengths and Limitations of the Sampling Design

The selected approach provides several benefits to the UCBN, park resource managers, and regional stakeholders. The design will provide long term data on status and trends in core water quality parameters and will describe mean trends and variability at multiple time scales (daily, weekly, seasonal, interannual, and decadal). The data will assist in the assessment of the effectiveness of management actions aimed at improving water quality within UCBN park and watershed boundaries. The collection of macroinvertebrate assemblage samples over long periods will provide a valuable record of biotic responses to changes in water quality, human impacts, and changing climatic conditions using standardized and accepted protocols. The macroinvertebrate samples will also inventory an important biological resource for which no data are currently available. The design will provide a representative picture of status and trend in the small and medium sized streams and rivers within the UCBN.

The sampling frequency will provide excellent baseline information on summer base flow water quality trends within selected park water bodies. However, many infrequent, but potentially important, short-term events such as large floods in the spring may not be captured.

The primary limitation is that the sample design is not spatially comprehensive and as a result, the scope of inference will be restricted to the sampled sites (e.g., water quality) within selected streams. In addition, no directed monitoring will be conducted at LARO. Importantly, selected core parameters reflect available sampling resources and many other important water quality parameters will not be estimated (nutrients, chlorophyll, bacteria, etc.).

Overall, the UCBN integrated water quality monitoring protocol should provide a well-documented baseline of background conditions given the modest level of funding available to conduct water quality monitoring. Detection of concerning trends will provide the direction for the Network and

affected parks to pursue additional funding and resources to address these emerging problems through targeted research.

Field and Laboratory Methods

Note that sampling of benthic macroinvertebrates occurs during implementation of the UCBN stream channel characteristics protocol (Starkey et al. 2011a, Starkey et al. 2016). For this reason, macroinvertebrate methods have been removed from version 1.9 of the integrated water quality protocol and are outlined in Starkey et al. 2016..

Field Season Preparations for Water Quality Sampling

In preparation for each new field season the first step will be to revise procedures based on the experiences and results from the previous year. After any revisions are completed, preparation will involve determining annual stream locations, gathering together water quality sampling equipment, and fulfilling permitting and compliance requirements. All study sites are NPS units, and permits will be provided through the NPS research permit and reporting system (<https://irma.nps.gov/rprs/>). A pre-season check of all multiprobes and water quality sensors is required prior to deployment and is required monthly thereafter (Figure 7). This is a critical step to ensure quality data collection. Pre-season checks are discussed in more detail in SOP # 1 and monthly checks in SOP #5. GPS devices will be loaded with all the sampling locations before the start of sampling. Tablet PCs will be loaded with the most current version of the water quality database. Batteries and spare batteries must be charged for all GPS units and tablets. Paper sample forms will also be updated and photocopied, and will serve as a backup to the tablet PC and database. SOPs should be thoroughly reviewed by directing staff well in advance of training and field work. Because of this program's reliance on seasonal field crews, hiring and scheduling should begin as early as possible, and no later than January proceeding a spring sampling occasion. Equipment needs are relatively costly at the start of implementation but once sufficient equipment is constructed or purchased, replacement will be infrequent. An equipment list is included in SOP #1 and under the operational requirements section of this narrative. Field vehicles for this protocol should have sufficient capacity to safely transport two UCBN staff and all equipment required for the setup of 3 monitoring stations. In addition, the vehicle should be available for monthly site visits.

Locating and Establishing Water Quality Monitoring Stations

Detailed information on how to locate and establish a water quality monitoring station for deployment of the multiprobe is described in SOP #1 and #5. Driving directions to each of the target streams (Table 10.) are available from each park's website or map/driving direction websites such as Google Maps. Once on site, access to most sampling areas is straightforward on relatively flat, open terrain. Dense riparian vegetation and incised stream banks in some locations can make access difficult. Sample location waypoints are provided in the SOPs Appendix C.

The main factors that will be considered in locating and establishing water quality monitoring stations are:

- Potential for water quality measurements at the station to be representative of the stream segment being monitored.
- Degree of cross-section variation and vertical stratification.

- A channel configuration that may pose unique constraints.
- Range of stream stage (from low flow to flood) that can be expected.
- Water velocity.
- Presence of turbulence that will affect water quality measurements.
- Conditions that may enhance the rate of fouling, such as excessive fine sediments, algae, or invertebrates.
- Range of values for water quality field parameters.
- Need for protection from high-water debris damage.
- Need for protection from vandalism.

For UCBN streams, cross-section surveys will be conducted to help determine the most representative location for multiprobe placement. Data from cross-section surveys will also help the UCBN determine if a stream is poorly mixed and if there is a need to move the monitoring station to a more representative location. However, this cross-section information will not be used to correct data due to the inherent variability in stream parameters. Corrections of this type are not recommended by the USGS (Wagner 2008, personal comm.) The primary parameter for evaluation of cross-section surveys will be specific conductance. Specific conductance is less variable than other core parameters and should accurately reflect stream mixing. Secondary parameters such as pH and dissolved oxygen are important, but due to their inherent variability, will not be the primary means of evaluating the cross-section survey. A minimum of two cross-section surveys are recommended per sampling year to verify or revise results from previous surveys (Figure 7). If it is determined that there are temporal changes in cross-section variability, more frequent surveys will be done.

Continuous Water Quality Data Collection

After the initial setup of the monitoring station and deployment of the multiprobe, data will be downloaded to a laptop computer or handheld PDA approximately every 30 days. Data may need to be downloaded and the multiprobe serviced more often if an internal power source is used. An initial data evaluation will be conducted to verify the accurate transfer of raw field data (multiprobe readings) to the PDA and to evaluate and identify erroneous data. After downloading data, drift and fouling error checks will be conducted to aid in the interpretation, correction and grading of data (SOP 5). Continuous water quality data will be processed and plotted in Aquarius Time-Series software immediately after the service visit to verify data quality and to detect instrument or sensor error. Calibration and maintenance data recorded during site visits will be entered directly into the UCBN water quality database.

After the Field Season

Following field work, all equipment will be sterilized with disinfectant (10 % Sparquat 256 Solution) and stored in the UCBN headquarters. Non-electrical equipment, including nets, stakes, buckets, etc. should be stored in well-marked plastic bins. Some of this equipment may be used by other UCBN protocols, so thorough organization and documentation of equipment will be important. Electronic

equipment, including GPS units, should have the batteries removed from them during the winter months to prevent corrosion and leaking, and will be stored in plastic bins in the UCBN office.

Multiprobes will require post deployment maintenance and error checks. Post-deployment error checks will follow the same procedure outlined for pre-mobilization. General maintenance will include; o-ring lubrication, communication cable cleaning, sensor cleaning, re-calibration and evaluation of damaged components. New sensors/parts should be ordered and replaced prior to the next field season. In some cases this may take several weeks to receive and install sensors or other parts. After maintenance, the sensors should be placed in the calibration/storage cup with one ½ inch of clear pH 4 buffer solution. This buffer solution will prevent desiccation, biological growth and damage to the pH sensor. It is important to note that the sensors should never be stored in de-ionized water or dyed (red) pH buffer solution. The multiprobes will be stored in a hard plastic case, such as a Pelican case, to prevent any damage.

<u>Water Quality Field Season Tasks</u>	<u>Month</u>
<u>Field Season Prep</u> Gather/Prepare Equipment Calibration/Maintenance QA/QC Measurements	Early June
<u>Beginning of Season Site Visit</u> Monitoring Station Establishment Cross Section Survey Deployment of Continuous Monitor	June
<u>Monthly Revisit</u> Download Data Calibration/Maintenance Re-deployment of Continuous Monitor Process Data in Aquarius	July August September October
<u>End of Season Site Visit</u> Download Data Calibration/Maintenance Cross Section Survey Removal of WQ Monitoring Station Process Data in Aquarius	November
<u>After Field Season</u> Disinfect and Store Equipment	November

Figure 7. Core water quality field season tasks (June-November).

Data Management, Analysis, and Reporting

The following section outlines specific procedures for water quality monitoring and related data management, analysis, and reporting processes. For additional information on general UCBN wide data management process and practice see the UCBN Data Management Plan (Dicus and Garrett 2007).

Overview of Data Management Work Flow

The Water quality monitoring process results in the collection of three distinct datasets: 1) continuous water quality monitoring time series data, 2) monitoring station cross section surveys, and 3) multiprobe calibration and maintenance metadata. While being distinct the datasets are inter-related and are created from monitoring efforts with concurrent workflows (Figure 8). Continuous water quality data is transferred from multiprobe collection devices to comma separated value (.csv) tabular data which is then imported into Aquarius Time-Series software. Cross section survey and multiprobe calibration and maintenance metadata are entered and stored in the water quality monitoring station and instrumentation Access database.

Water quality data (continuous) is collected using multiprobes which are installed at sampling locations (Continuous Water Quality Site Selection – Cross Section Survey SOP 3) at the beginning of the field season. At the initial site or second site visit and the season closeout visit (2 total per season) site cross sectional data is entered into the water quality monitoring station and instrumentation database (see SOP 3 for cross section survey data entry details).

For revisits and season closeout site visits water quality monitoring data is downloaded from the multiprobe devices and stored in tabular format (see SOP 5 for details on multiprobe site revisits). Additionally at revisit and season closeout visits multiprobe calibration and maintenance data is collected and entered to the water quality monitoring station and instrumentation database (see SOPs 4 & 5). Post field visit, continuous water quality data (tabular format) is uploaded to the Aquarius Time-Series platform following processing steps defined in the Continuous Water Quality Record Processing SOP 7. Quality assurance and quality control processes are subsequently performed on the continuous data within the Aquarius platform as explained in SOP 7 and the QA/QC SOP 10.

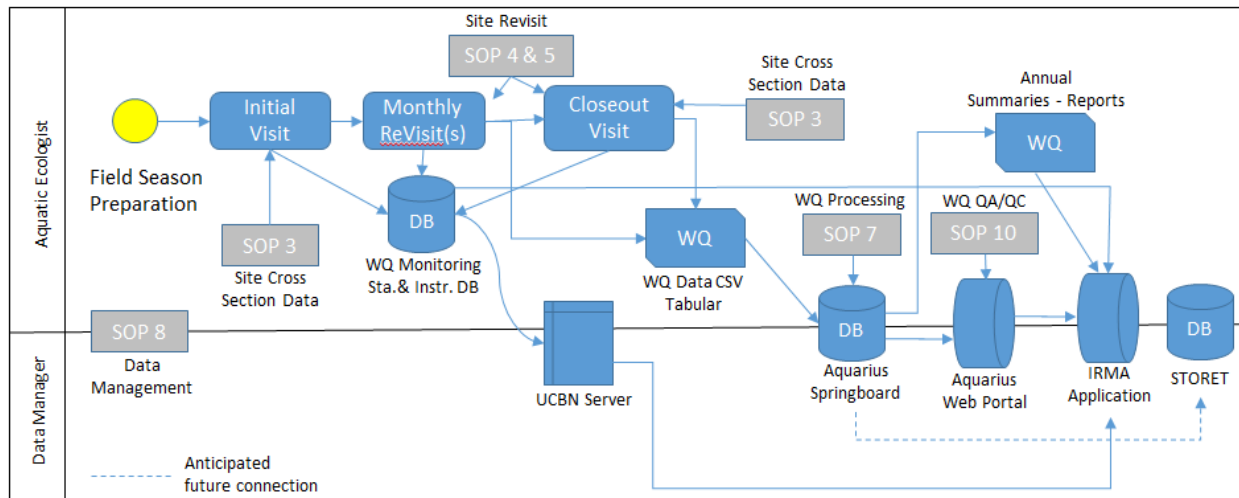


Figure 8. Generalized data management annual work flow for water quality monitoring, cross section data and calibration and maintenance metadata collection.

Database(s) Overview

1. The water quality monitoring station and instrumentation database has a user interface Access front-end (Figure 9) that links to a back-end Access database containing the cross section and instrumentation data entry and value lookup tables. A field going copy of the backend database will be used for field data entry, QA/QC error-checking and data certification procedures. When data has been certified as complete for the season a copy of the working database will be made to represent the certified database for the season (by year). The certified database will contain all of the calibration and maintenance metadata across all monitoring years. Detailed water quality monitoring station and instrumentation database information is available in SOP 8.

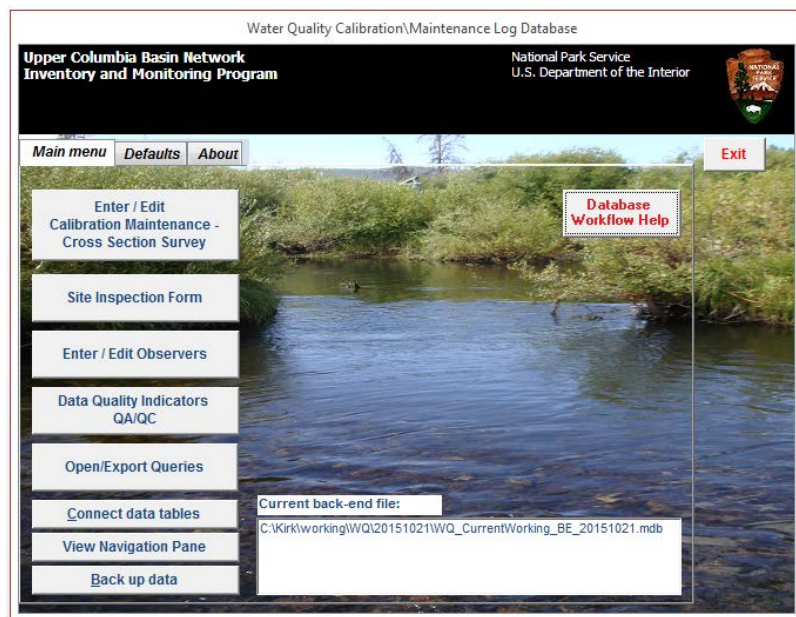


Figure 9. Water quality monitoring station and instrumentation database user interface Access front-end.

2. Raw continuous water quality monitoring data (.csv) is imported to the Aquarius platform via Aquarius Springboard. A screen shot of Aquarius Springboard interface which is located on the NRSS server is shown in Figure 10. For additional continuous data import information see Continuous Water Quality Record Processing SOP 7.

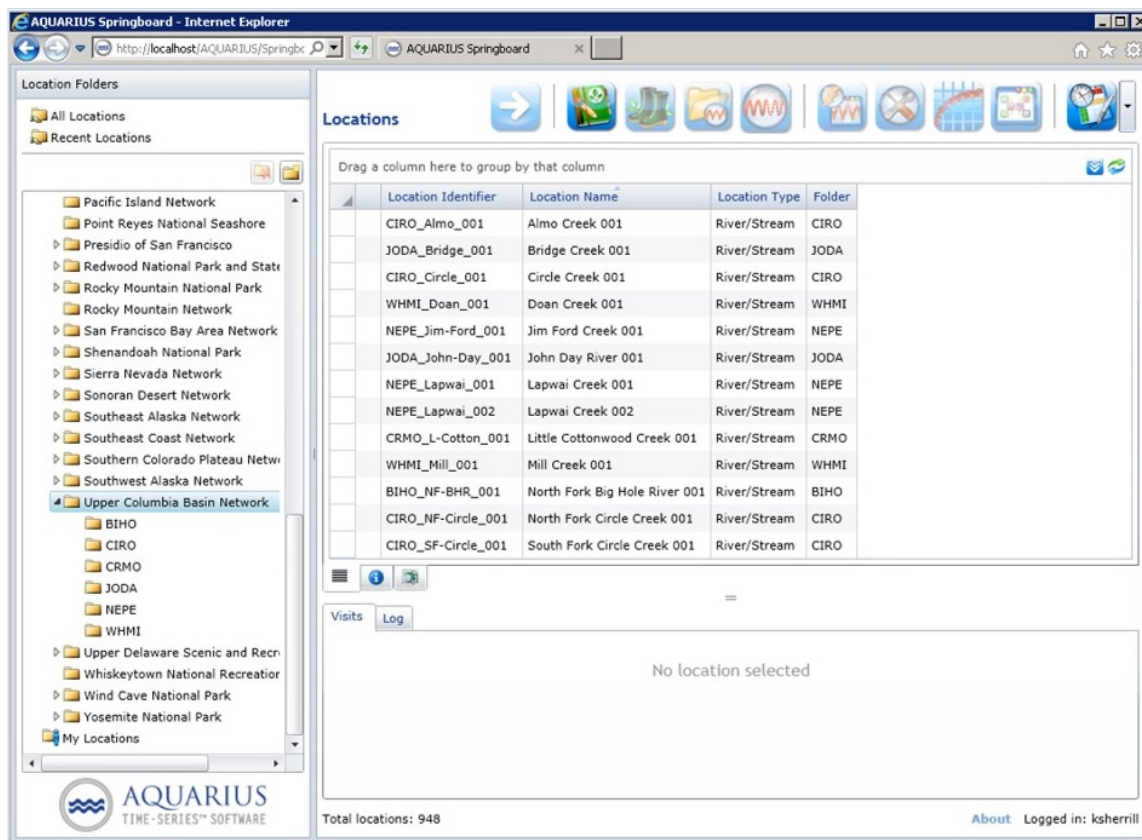


Figure 10. Aquarius Springboard interface, used to transfer raw tabular .csv continuous water quality data to the Aquarius.

Quality Assurance and Quality Control Overview

After monitoring data (site cross section data, instrumentation metadata, and continuous water quality data) have been entered and processed, they need to be reviewed by the Project Lead for quality, completeness, and logical consistency. The QA/QC reviewer will then address problems and document any applied corrections. Documentation of corrections occurs within the Site Inspection Form found in the Water Quality Monitoring Station and Instrumentation Database and in Aquarius. If all errors and inconsistencies cannot be addressed, these errors will be documented and included in the metadata and season certification report.

The UCBN Water Quality Monitoring Station and Instrumentation database facilitates QA/QC review for cross section surveys and multiprobe maintenance data via queries that define method detection limits, minimum levels of quantitation, measurement sensitivity, and precision (see QA/QC SOP #10) (Figure 11). Data integrity, data outliers, missing values, and illogical values are generally identified during processing of water quality data in Aquarius Time-Series software.



Figure 11. Water Quality Monitoring Station and Instrumentation Database queries to be used for quality review

Metadata Procedures

Detailed metadata for monitoring sites and instrumentation used during monitoring is explicitly collected throughout the annual workflow cycle. This information is entered during initial, revisit and closeout visits to the Water Quality Monitoring Station and Instrumentation database as described in the water quality site selection and revisit SOPs 3 & 5. Metadata for all UCBN monitoring data will conform to Federal Geographic Data Committee (FGDC) and NPS guidelines and will contain supporting information so data may be confidently manipulated, analyzed, and synthesized. After initial metadata creation for the project, metadata info will remain largely static with updates being necessary for only a smaller subset of the metadata record. Updates may be necessary for information such as collection date, contact information, changes to instrument/sensor serial numbers, etc.

As protocols are revised over time, changes should be tracked using the protocol tracking form so changes are explicitly defined and available for use when updating XML metadata files. At the conclusion of the field season, the Project Lead will be responsible for providing a completed, up-to-date season closeout form to the data manager. The Data Manager will facilitate metadata development by creating updated metadata records that will accompany the monitoring data. Additional procedures for metadata development are outlined in the UCBN Data Management Plan. The Project Lead and Data Manager will work together to create and update the FGDC- and NPS-compliant metadata records in XML format. The Project Lead will update the metadata content as changes to the protocol are made, and each year as additional data is collected.

Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information, which includes specific locations of rare, threatened, or endangered species. Prior to completing metadata, the Project Lead and Park Resource Managers should identify any anticipated sensitive information resulting from monitoring efforts. To date we have not collected sensitive data and don't anticipate the collection of sensitive information from water quality monitoring.

Data Certification and Delivery Overview

Data certification is a benchmark in the project information management process that indicates that 1) the data are complete for the period of record; 2) they have undergone and passed the QA/QC checks; and 3) that they are appropriately documented and in a condition for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies which may not have been detected during QA/QC reviews. To ensure that only data of high quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is responsible for completing certification and is assisted by the Data Manager in this process. Completed data certification forms, certified data, and updated metadata should be delivered to the Data Manager according to the timelines defined in Table 17 of the protocol narrative. More explicit details on the data certification and delivery processes are defined in Data Management SOP 8 in the Data Certification and Delivery section.

Continuous Water Quality Data Analysis

Continuous water quality data will be used to examine patterns of status, variability, and trend in core water quality parameters with respect to established water quality criteria (Table 11). Once data have been acquired, quality checked, and submitted to the UCBN Data Manager, the Project Leader will generate report tables with descriptive statistics using automated scripts that will ensure quality control of the analysis. Basic summary analyses will be performed using Microsoft Access and/or Aquarius Time-Series software, and additional analyses will be conducted in other stand-alone environments such as the R statistical language and environment (<http://www.r-project.org/>).

Table 11. Regulatory thresholds for UCBN streams. Thresholds are set by state DEQs and consequently differ considerably among parks.

Park	Waterbody	Temperature	pH	Dissolved Oxygen	Conductivity/TDS	Turbidity
BIHO ¹	Big Hole River	"A 1°F (0.56°C) maximum increase above naturally occurring water temperature is allowed"	6.0-8.5; < 0.5 unit human induced change; Maintain >7.0 if naturally > 7.0	Daily minimum > 8.0 mg/L; 7-d mean > 9.5 mg/L (Early life stage- applicable 16 July to 30 Sept.) 1-day minimum >4.0 mg/L; 7-d mean minimum > 5.0 mg/L; 30 day mean >6.5 mg/L (Other life stages applicable to data collected 20 June to 15 July and 1 Oct. to 17 Oct.)	Not designated	"No increase above natural turbidity is allowed"
CIRO ²	Circle Creek/Almo Creek	MDMT<22 °C ⁷ MDAT<19 °C ⁷	6.5-9.0	> 6.0 mg/L	Not designated	< 50 NTU (instantaneous); < 25 for 10 consecutive days
CRMO ²	Little Cottonwood Creek	MDMT<22 °C ⁷ MDAT<19 °C ⁷	6.5-9.0	> 6.0 mg/L	Not designated	< 50 NTU over background (instantaneous) < 25 for 10 consecutive days
JODA ³	Bridge Creek, John Day River	7 day average of the daily max. < 18 °C (salmon/trout rearing/migration)	6.5-9.0	> 6.5 mg/L instantaneous (cool water, non-spawning)	TDS < 500 mg/L	< 10% cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity

¹ MT DEQ water quality standards for North Fork Big Hole River planning area and Montana numerical water quality standards (MT DEQ 2009 and MT DEQ 2012).

² ID Criteria for cold water life designation (ID Admin Code 2015, 58.01.02.101.01a [through 4/5/00]).

³ John Day River basin total maximum daily load (TMDL) and water quality management plan (OR DEQ 2010) and Admin. Rules of OR 2013, 340-041-001 [through 12/15/2013].

⁴ Criteria established for Salmonid Rearing and Migration (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁵ Criteria established for Salmonid Rearing and Migration Only (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁶ Special designation for Mill Creek mouth to 13th St. Bridge (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁷ MDMT – Maximum Daily Maximum Temperature, MDAT – Maximum Daily Average Temperature, 7-DADMax: 7-Day Average Daily Maximum

Table 11 (continued). Regulatory thresholds for UCBN streams. Thresholds are set by state DEQs and consequently differ considerably among parks.

Park	Waterbody	Temperature	pH	Dissolved Oxygen	Conductivity/TDS	Turbidity
NEPE ²	Jim Ford Creek, Lapwai Creek	MDMT<22 °C ⁷ MDAT<19 °C ⁷	6.5-9.0	> 6.0 mg/L	Not designated	< 50 NTU over background (instantaneous) < 25 for 10 consecutive days
WHMI	Doan Creek ⁴	7-DADMax <17.5 °C ⁷	6.5-8.5 with < 0.5 unit human caused variation	>8.0 mg/l Minimum Daily Minimum	Not designated	< 5 NTU increase above background when background NTU < 50, < 10% increase when background NTU > 50
WHMI	Mill Creek ⁵	7-DADMax <17.5 °C ⁷	6.5-8.5 with < 0.5 unit human caused variation	>5.0 mg/l Minimum Daily Minimum ⁶	Not designated	< 10 NTU increase above background when background NTU < 50, < 20% increase when background NTU > 50

¹ MT DEQ water quality standards for North Fork Big Hole River planning area and Montana numerical water quality standards (MT DEQ 2009 and MT DEQ 2012).

² ID Criteria for cold water life designation (ID Admin Code 2015, 58.01.02.101.01a [through 4/5/00].

³ John Day River basin total maximum daily load (TMDL) and water quality management plan (OR DEQ 2010) and Admin. Rules of OR 2013, 340-041-001 [through 12/15/2013].

⁴ Criteria established for Salmonid Rearing and Migration (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁵ Criteria established for Salmonid Rearing and Migration Only (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁶ Special designation for Mill Creek mouth to 13th St. Bridge (WA Admin. Code 2011, 173-201A-602 [through 8/1/03])

⁷ MDMT – Maximum Daily Maximum Temperature, MDAT – Maximum Daily Average Temperature, 7-DADMax: 7-Day Average Daily Maximum

Status of Core Water Quality Parameters

Seasonal and annual patterns in the mean and variability of core water quality parameters will be reported in a tabular form similar to the formats in Tables 12 and 13. Estimates of the proportion of observations exceeding state DEQ regulatory thresholds from Table 11 will be routinely performed.

In addition to tabular summaries, plots of time series and exceedance conditions for each parameter will quickly convey status. Figures 12 and 13 provide examples plots for core water quality parameters in Lapwai Creek (NEPE), 2008-2014. To convey data quality, data grades/ratings for each deployment period will be regularly published alongside tabular and summary data plots (Table 14). Generation of data grades/ratings is discussed in SOP #7 Continuous Water Quality Record Processing.

Table 12. Summary of descriptive statistics for core water quality parameters for a spring and late summer sampling period at Lapwai Creek, 2007 (NEPE).

Season	Descriptive Statistic	Temp (°C)	pH	Conduct.	Turbidity (NTU)	DO (mg L ⁻¹)
Spring (4/16-4/24)	N	390	390	390	390	390
	Mean	9.528	7.988	151.056	32.167	10.690
	Standard Dev	1.909	0.179	7.824	143.163	0.552
	Median	9.42	7.9	151	0	10.68
	Minimum	5.64	7.79	136	0	9.41
	Maximum	14.21	8.46	171	1530	11.92
	C.V.	0.200	0.022	0.052	4.451	0.052
	% exceedance	0	0	0	10%	0
Late Summer (9/18-9/30)	N of cases	1138	1138	1138	1138	1138
	Mean	13.756	8.579	255.002	2.976	10.871
	Standard Dev	2.371	0.492	40.415	89.134	1.900
	Median	13.66	8.79	259	0	11.53
	Minimum	8.61	5.98	0	0	7.2
	Maximum	15.51	9.19	276	3000	15.52
	C.V.	0.172	0.057	0.158	29.953	0.175
	% exceedance	0	0	0	0.20%	0

Table 13. Lapwai Creek Water Chemistry Summary 2014. Vital sign summary table for water chemistry in Lapwai Creek, June-November, 2014.

Measure	Current Condition (June-November, 2014)	State DEQ Thresholds a	% Exceedance b
Temperature (*MDMT, **MDAT)	* MDMT= 26.59 °C ** MDAT= 22.81 °C	<22 °C ^d **MDAT<19 °C	13% ^{d, 2}
			32% ³
Specific conductance (mean)	214.39 µS/cm	N/A	N/A ¹
Dissolved oxygen (mean daily min)	8.13 mg/L	> 6.0 mg/L	0% ¹
pH (mean daily max)	8.6 pH Units	9.0 pH Units, Max	2% ²
pH (mean daily min)	7.7 pH Units	6.5 pH Units, Min	0% ¹
Turbidity (mean daily max)	22.5 NTU ^c	< 50 NTU over background (instantaneous) < 25 for 10 consecutive days	Insufficient data

¹ Good exceedance (0-5%) (also highlighted in green).

² Moderate exceedance (5-55%) (also highlighted in yellow).

³ Poor exceedance (>25%) (also highlighted in red).

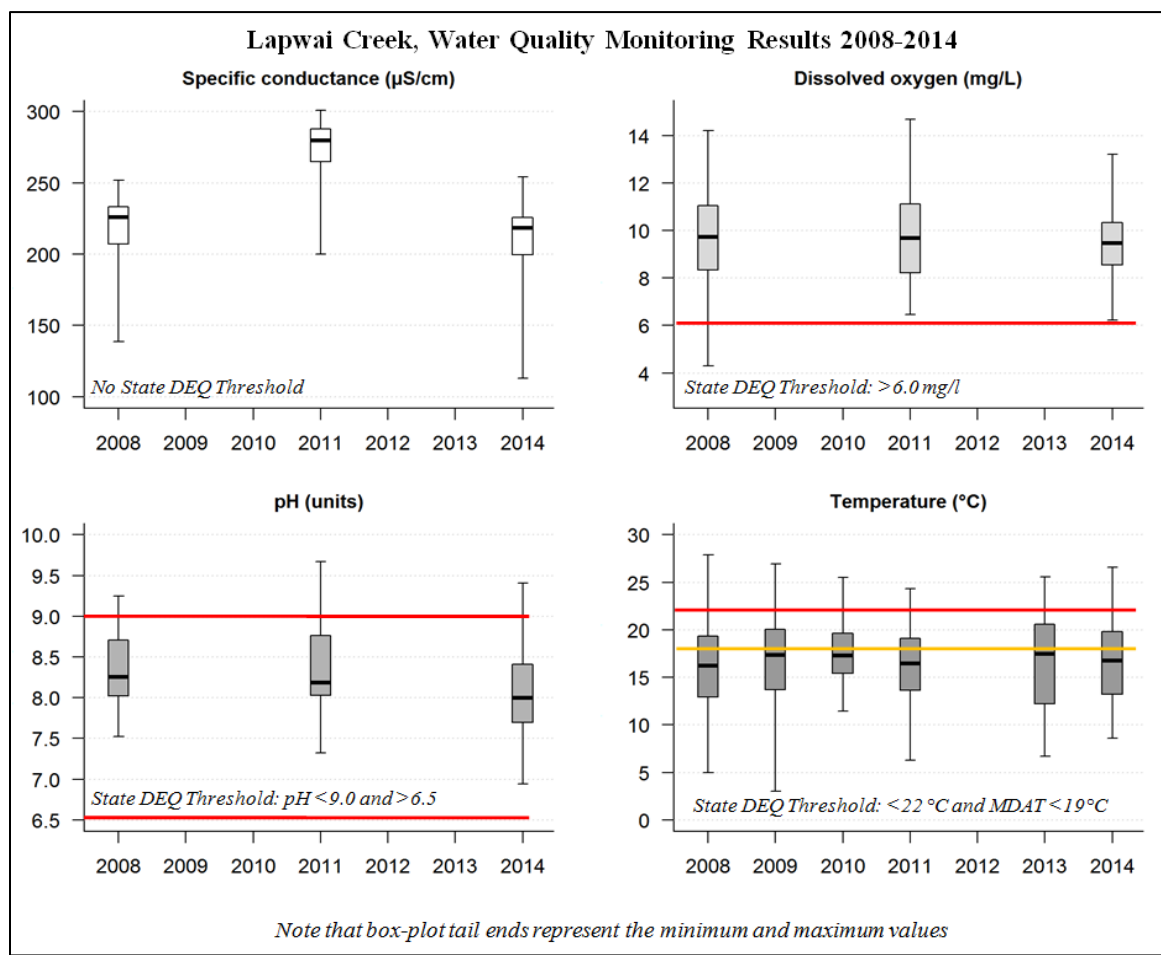


Figure 12. Lapwai Creek, water quality monitoring results box-plot 2008-2014.

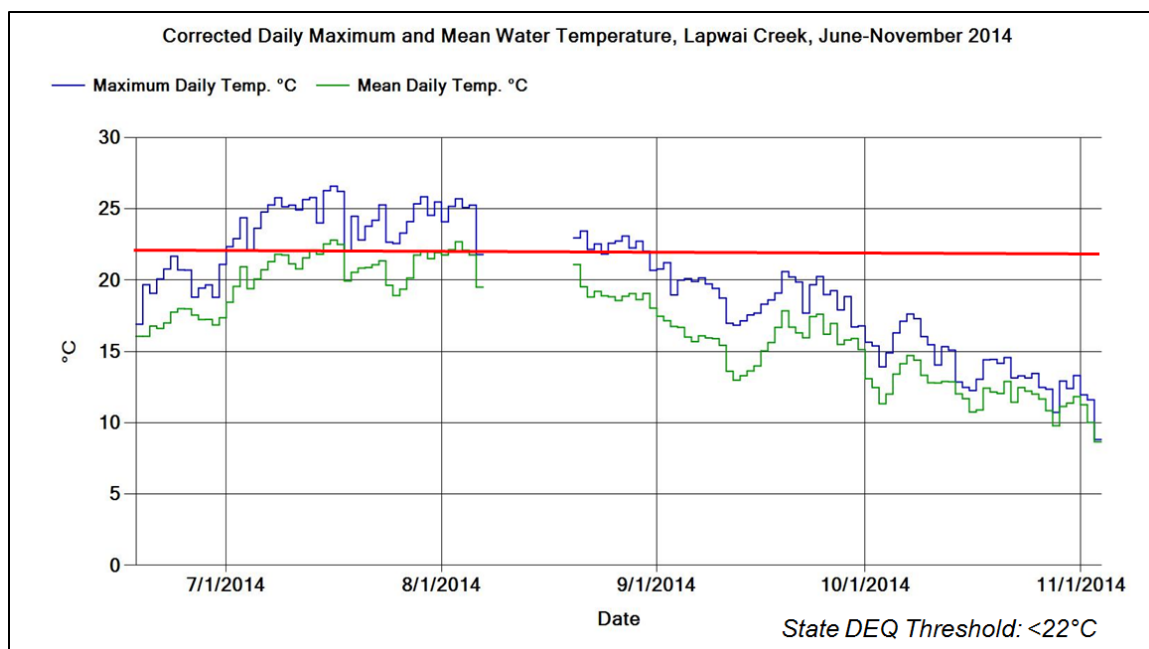


Figure 13. Daily maximum and mean water temperature in Lapwai Creek, NEPE, 2014.

Table 14. Data grade/rating for specific conductance each deployment period June-November 2014 in Lapwai Creek, NEPE.

Specific Conductance Data Grade/Rating	From UTC-07:00	To UTC-07:00
EXCELLENT	06/18/2014 15:00	07/09/2014 09:00
GOOD	07/09/2014 13:00	08/06/2014 08:00
EXCELLENT	08/20/2014 15:00	09/04/2014 08:00
GOOD	09/04/2014 13:00	10/01/2014 08:00
FAIR	10/01/2014 18:00	11/03/2014 09:00

Trend in Core Water Quality Parameters

Long-term trend is measured on a scale of years and may be blocked by months. Trend analysis will use a repeated measures analysis with months as the sampling units (blocks) and years as the repeated measures (treatments). Each year we will obtain one replicate reading for each month (June thru November). For example, at Lapwai Creek we will obtain six observations per year. The long-term monitoring data table consists of readings arranged in years and months. The parametric analysis of simple repeated measures of monthly data over years is equivalent to a randomized complete block ANOVA (van Belle and Hughes 1984). One can also use the seasonal Mann-Kendall test (Helsel and Hirsch 2002). If the UCBN considers only the first and last years of data, it can test for a step trend using the Wilcoxon signed rank test. Tests for linear trend in each core water quality parameter will be conducted once every five years.

The means table will resemble the table below, where μ is the mean and subscripts represent year and month, respectively.

Table 15. Means table, where μ is the mean and subscripts represent year and month, respectively

YR/Month	Month 1	Month 2	...	Month s
Year 1	μ_{11}	μ_{12}	...	μ_{1s}
Year 2	μ_{21}	-	...	μ_{2s}
:	:	:	-	:
Year t	μ_{t1}	-	...	μ_{ts}

Data Analysis of Macroinvertebrate Data

While collection of benthic macroinvertebrate data is done concurrently with stream channel characteristics monitoring; analysis, interpretation and reporting of data will occur in conjunction with continuous water quality data. This co-analysis of vital signs will facilitate better interpretation of results generated from both data sets.

Annual Macroinvertebrate Status Summary

Each year, a multimetric approach will be used to determine and summarize the status of macroinvertebrate assemblages and water quality relative to reference sites. The UCBN will follow the general procedures for multimetric index development established by Jessup et al. (2006) and Barbour et al. (1999). Figure 14 illustrates the UCBN conceptual model for determining stream status from macroinvertebrate samples.

Multimetric indices include attributes of the assemblage thought to reflect biodiversity (taxon richness; number of Ephemeroptera, Plecoptera, Trichoptera taxa [EPT taxa, mayfly, stonefly, caddisfly taxa]), sensitivity to organic pollution (Hilsenhoff Biotic Index [HBI]), community evenness (% dominant taxon), trophic structure (% predators, % shredders), or other functional groupings (e.g., % burrowers) (Barbour et al. 1999; Karr and Chu 1999). The observed multimetric value for each index is compared to threshold or benchmark values for regional streams, when available. An overall composite index estimates overall water quality. Examination of individual metrics or indices can provide clues to the causes of assemblage shifts. For instance, shifts in HBI values could indicate changes in pollutant sources because this metric includes tolerance values for organic pollutants, while a shift in the percent predators could indicate a shift in the food web resulting from changing land use surrounding a stream. SOP #9 lists the metrics that are currently used by state and federal agencies within the UCBN region. Metrics for the integrated water quality protocol will be selected after consultation with the USFS, state DEQ, and macroinvertebrate taxonomists based on utility, robustness and comparability.

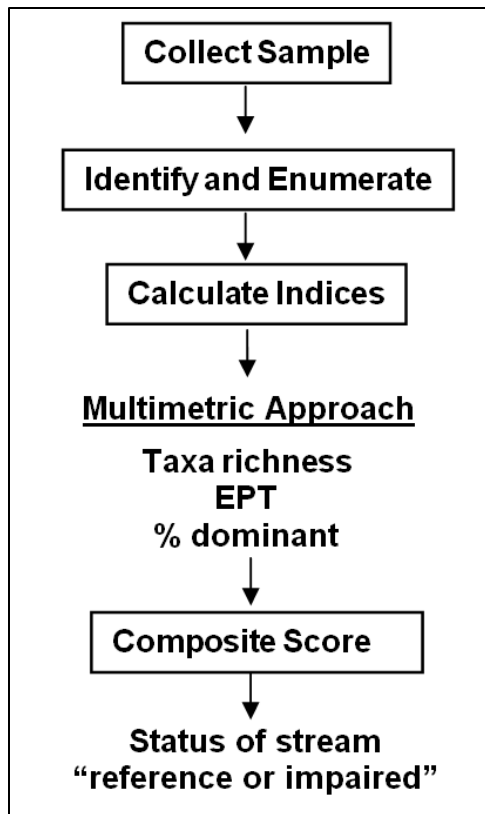


Figure 14. Conceptual model for determining stream status used in the analysis of macroinvertebrates data to infer water quality.

As indicated by Barbour et al. (1999) metrics should have a high degree of utility, in that they are ecologically relevant to the community of interest, are sensitive to stressors, and provide a response that can be separated from natural variation. The metrics that are chosen should also be robust and respond in a relatively predictive manner to stressors such that a suite of metrics become a reliable diagnostic tool. Having metrics that are similar to those used by state and federal agencies will allow our data to be easily integrated with other monitoring activities. Furthermore, by selecting similar metrics we will be able to use established reference sites for comparison to UCBN monitoring locations. After calculating individual metrics a composite score is calculated. This composite score is compared to those for streams identified prior to analysis as “reference or impacted” based on watershed condition and impairments to water quality. Reference and impacted sites will be determined based on information provided by state and federal agencies in the UCBN region. As reference sites are developed and become available for UCBN streams, comparisons will be made with reference sites at the end of each collection season.

Figure 15 illustrates a hypothetical example of macroinvertebrate data analysis using a multimetric approach. Sample data (blue circles) are compared to a distribution of values observed for many samples (box plots) taken from reference and impacted streams in the same region (mountainous streams in western Montana). The individual scores for replicate samples are shown adjacent to the mean and a confidence interval to the right. These hypothetical data indicate that the stream was in a

reference or unimpacted condition. Each year a similar graph will be constructed for each park, in addition to tables that list individual metric scores. A more detailed description of the multimetric approach is detailed in SOP #9.

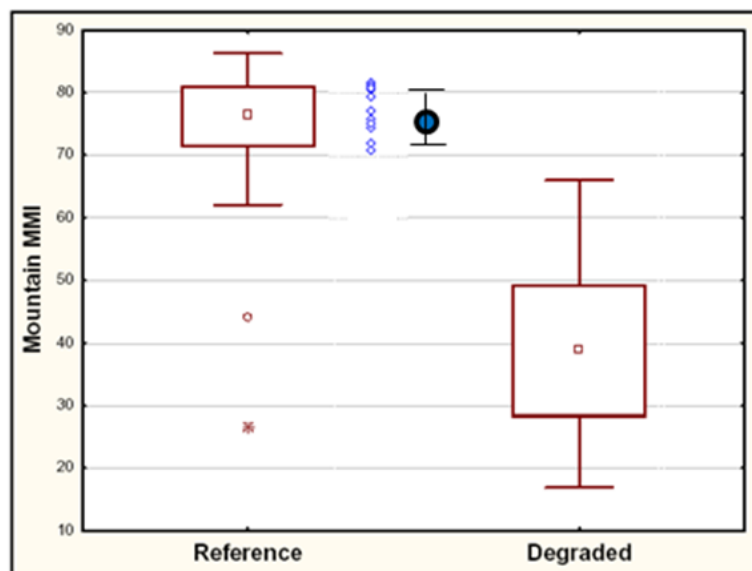


Figure 15. Hypothetical examples of macroinvertebrate data analysis using a multimetric approach. Sample data (blue circles) are compared to a distribution of values observed for many samples (box plots) taken from reference and impacted streams in the same region (mountainous streams in western Montana). Figures modified from Jessup et al. (2006).

Macroinvertebrate Trend Analysis

Trend in macroinvertebrate assemblage structure will be evaluated after a minimum of 3 sampling rotations and after each rotation thereafter. Two-sample tests (step trend *sensu*, Helsel and Hirsch 2002) such as the *t*-test and Wilcoxon rank-sum test may be used to detect statistically significant changes between any two sampling periods. However, given up to 6 replicates per sampling period, power will be restricted to detect only large changes. Once several years of sample data become available, linear trends in measures such as % EPT as a function of time can also be evaluated (Helsel and Hirsch 2002). Repeated measures ANOVA and nonparametric trend tests (van Belle and Hughes 1984) can also be applied. Simple graphical tools to display biologically important changes in macroinvertebrate indicators over time will also be very powerful.

Reporting

A summary will be produced annually, with a more detailed status and trend report produced every five years. The annual summary will:

- List project personnel and their roles.
- List locations sampled during the current year.
- Provide a summary history of the samples taken during each year of monitoring and mean monthly calculations for core water chemistry parameters by location and park.

- Provide descriptive summaries for each core water quality parameter at each sampling location relative to DEQ regulatory threshold.
- Provide trend estimates for each core water quality parameter after five years.
- Evaluate data quality and identify any data quality concerns and/or deviations from protocols that affect data quality and interpretability.
- Evaluate and identify suggested or required changes to the protocol.

The annual summary report should be reviewed by UCBN and park natural resource staff, and published in the NPS Natural Resource Report series (NRR). In addition, a 1-2 page resource brief will be prepared for public consumption, and will be provided to park interpretive staff for distribution to interested visitors. A template for the resource brief is included in SOP #9. A NPS template for producing maps with ESRI ArcGIS or ArcView software is available at http://www.nps.gov/gis/data_info/standards.html. The proportion of observations above or below the DEQ regulatory threshold will be reported annually in the resource brief along with any unusual observations (e.g., new taxa, high flow events, invasive species, etc.).

A more in-depth analysis and report will be produced approximately every five years, or as the importance of emerging information warrants. This report will provide greater analytical and interpretive detail, and will evaluate the relevance of findings to long-term management and restoration goals. The report should also evaluate operational aspects of the monitoring program, such as whether the sampling period remains appropriate.

The 5-year status and trend report should use the NPS Natural Resource Publications Natural Resource Report (NRR) template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. This template, guidelines for its use and documentation of the NPS publication standards are available at the following address: <http://www.nature.nps.gov/publications/NRPM/index.cfm>.

Data Archival Procedures

The final data management step in the annual water quality workflow is to insure long-term accessibility and permanence of certified monitoring products via data archival. The certified Water Quality Monitoring Station and Instrumentation Database will be uploaded to the NPS IRMA system, while certified continuous water quality monitoring data is currently being archived in the Aquarius software platform. The future archival location for continuous water quality data is anticipated to be the Environmental Protection Agency's STORET water monitoring repository (Figure 8) pending additional development of STORET functionality. Other water quality annual products such as annual summaries and reports will be archived in the NPS IRMA application.

Protocol Testing and Revision

Version 1.0 (draft) of this protocol was the first version and was submitted for formal peer review in January 2008. The protocol was accepted pending minor revisions in June 2008. Pilot testing in summer 2008 resulted in several changes, which, along with reviewer comments, have been incorporated into Version 1.0 published in January, 2008.

Version 1.9 of this protocol was developed in 2016 and incorporates minor revisions to sampling methods and data management processes. These changes were a result of experience gained during 7 years of protocol implementation. Subsequent protocol testing will occur during each field season and evaluation of existing methods and recommended revisions will be documented in annual reports and during season close-out.

Revisions to this protocol and the SOPs are expected. Sampling sites should be revised only if management priorities shift significantly, and should be done only in consultation with park management and careful consideration of statistical consequences. All revisions will be carefully documented using the protocol development and revision log in SOP #13 and the change history log at the front of each SOP and this narrative.

Personnel Requirements and Training

Personnel Requirements

This protocol requires at a minimum an aquatic biologist to collaborate with the UCBN I&M Network Program Manager, Data Manager, and park resource managers in the implementation of the protocol (Figure 16).

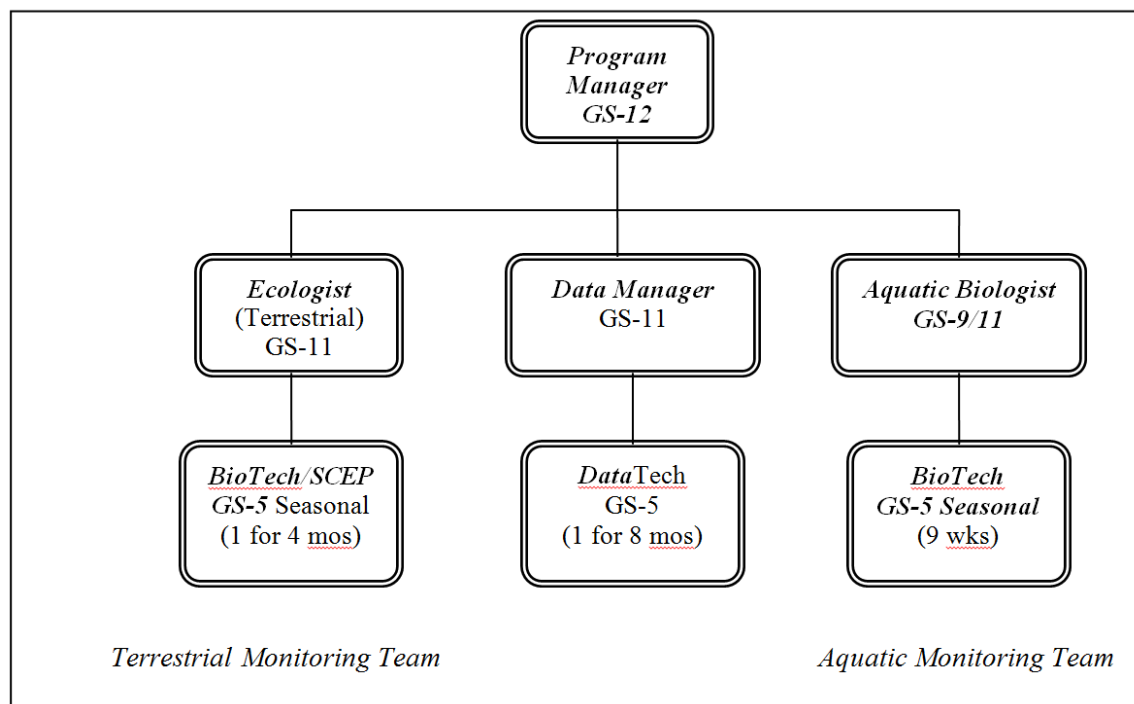


Figure 16. Staff structure for UCBN I&M program (modified from Garrett et al. 2007).

The aquatic biologist is responsible for obtaining water quality samples, training seasonal staff in sample collection and multiprobe operations, overseeing macroinvertebrate sample processing (when not handled under IAA with USFS), upload of data to Aquarius-Time Series Software, coordinating archival of data, and performing data analysis and reporting. One skilled technician will be required seasonally to assist with monthly site visits for multiprobe calibration and maintenance. Participation of park resource managers may supplant the need for a seasonal technician. Involvement from the UCBN Data Manager will be necessary to develop and maintain database(s) for calibration and maintenance data generated by this protocol and for ensuring upload of continuous water quality data to Aquarius-Time Series Software and or NPSTORET. The roles and responsibilities are summarized in Table 16.

Roles and Responsibilities

Table 16. Roles and responsibilities for implementing the water resource monitoring program in the UCBN.

Role	Responsibilities	Position
Project Lead	- Project oversight and administration - Collaborate with Network Coordinator on tracking project objectives, budget, personnel requirements, and progress toward meeting monitoring objectives - Facilitate communications between NPS resource managers and field crew - Coordinate and ratify changes to protocol - Training field staff/crew - Provide training to resource managers on multiprobe operation - Supervise or conducts field work - Supervise macroinvertebrate sample processing - Perform data summaries and analyses - Maintain and archive project records - Project operations and implementation - Certify each season's data for quality and completeness - Complete reports, metadata, and other products according to schedule	UCBN Aquatic Biologist
Field Assistance	- Collaborate with project lead in multiprobe site selection - Calibrate and maintain multiprobes including data downloads - Assist with cross-section surveys	Park resource managers
Technicians	- Field assistance responsibilities listed above - Assist with data compilation/data entry	Seasonal employees
Data Manager	- Consultant on data management activities - Facilitate check-in, review, and posting of data, metadata, reports and other products to national databases according to schedule - Maintain and update database application - Provide database training as needed - Consultant on GPS use - Work with Project Lead to analyze spatial data and develop metadata for spatial data products - Primary steward of Access database and GIS data and products	UCBN Data Manager
Network Program Manager	- Project leader oversight - Administration and budget - Consultant on all phases of protocol review and implementation - Review of annual and 5-year reports	UCBN Program Manager

Training

The Project Leader will be in charge of training for multiprobe data download, calibration, maintenance, and continuous water quality record processing. Multiprobe training and calibration techniques will be based on the HACH MS-5 user manual (HACH 2006) and Wagner et al. 2006.

Continuous water quality record processing training will be based on USGS procedures outlined in Wagner et al. 2006. Resource managers and other personnel will be trained each spring to help ensure consistent calibration and data download techniques. If personnel changes are made within the sample year, new personnel should be trained by the UCBN project lead before they attempt to calibrate or download data. A more detailed description of training techniques and resources is given in SOP #2.

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) processes for data collection are covered in SOP #8 and 10. Basic procedures will adhere to the guidelines established in part B Lite (Irwin 2008) the National Coastal Assessment Quality Assurance Project Plan 2001-2004 (EPA 2001); the Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses (EPA 1995); and Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999).

For detailed water quality multiprobe QA/QC documentation see SOP #5 and 10

General QA/QC methods for water quality multiprobe calibration and data downloads include:

- Representative multiprobe sample locations will be determined by using a cross-section and stream segment survey. This site will be re-assessed for representativeness at the start and end each sample year.
- UCBN will follow pre-established maximum acceptable differences for field instrument calibration and QC checks (See SOP #5). If the multiprobe has readings outside of the maximum acceptable differences the multiprobe will likely need to be removed for non-routine maintenance.
- When calibrating the multiprobe, values of known standard solutions will be determined pre and post calibration, to help determine if the instruments measurements have “drifted.” In addition, repeated measures of these solutions will help determine the repeatability of multiprobe measures.
- Calibration, maintenance, and site visit data will be entered into a field going Access database. This database will include built in QC checks. Paper datasheets will be provided as a back up to the database.
- All multiprobe data will be visual checked for outliers and QC issues immediately following the download of data.

Operational Requirements

Annual Workload and Schedule

The annual workload of this monitoring protocol is outlined in Table 16 of the preceding section on Roles and Responsibilities. Table 16 provides a thorough overview of the general roles and tasks (responsibilities) required to complete all aspects of this monitoring protocol following rigorous and comprehensive data management practices as outlined in the UCBN Data Management Plan (Dicus and Garrett 2007). The budget table (Table 18) demonstrates that adequate resources have been allocated to data management, analysis, and reporting activities. The SOPs provide a comprehensive step-by-step description of the annual workload and tasks required for completion, including data management tasks and report delivery. The annual start-up for water quality monitoring begins in January with the recruitment of seasonal personnel and final reporting, review and close-out activities for the previous year. An evaluation of the protocol and any necessary changes must be made by February. Multiprobes are deployed in June after spring runoff subsides and will be serviced monthly until November. Table 17 provides additional details of the annual schedule.

Table 17. Annual implementation schedule for water quality monitoring.

Month	Administration	Water Quality Monitoring	Data Management/Reporting
January	UCBN annual report and workplan complete, begin recruiting and hiring UCBN seasonal personnel		Analysis, reporting and close-out of previous year's data. Submission of final report for review.
February	Administer and modify existing agreements, if necessary. Supervise macroinvertebrate sample processing if not being conducted under IAA with USFS-PIBO.	Identify sites for multiprobe installation	-
March	Apply for new NPS research permit. Complete reporting requirements for previous years NPS research permit.	-	-
April	-	-	Update protocol SOPs
May	-	Order new calibration standards. Perform QA/QC checks on multiprobes.	-
June	-	Install multiprobes/ train resource managers to service multiprobes, if necessary. Conduct cross section survey.	-
July	-	Monthly site visit for data download, calibration, and maintenance.	Upload continuous data to Aquarius Time-Series software, QA/QC data, apply data quality ratings and approve data.
August	-	Monthly site visit for data download, calibration, and maintenance.	Upload continuous data to Aquarius Time-Series software, QA/QC data, apply data quality ratings and approve data.
September	UCBN annual report and work plan drafted, Budget preparation for new fiscal year	Monthly site visit for data download, calibration, and maintenance.	Upload continuous data to Aquarius Time-Series software, QA/QC data, apply data quality ratings and approve data.
October	Supervise MI sample processing	Monthly site visit for data download, calibration, and maintenance.	Upload continuous data to Aquarius Time-Series software, QA/QC data, apply data quality ratings and approve data.
November	-	Monthly site visit for data download, calibration, and maintenance.	Upload continuous data to Aquarius Time-Series software, QA/QC data, apply data quality ratings and approve data.
December	-	Clean and store equipment for the following field season. Inventory calibration standards.	Preliminary analysis of current year's results, data certification complete, data archival and posting, and preparation of annual report and resource brief drafts.

Water Quality Equipment Needs

Equipment needs for this protocol are fairly extensive and represent a considerable amount of capital expense initially to implement the protocol. Recurring expenses over time include replacement of aged continuous water quality monitors, routine repair costs, and purchase of calibration solutions. The list of equipment for water quality monitoring are shown below. The continuous water quality monitors (MS-5 Hyrdolabs) are purchased from HACH, Inc. GPS units need to be maintained and replaced, if necessary, during the late winter/early spring well in advance of the field season. Field vehicles for this protocol should have sufficient capacity to safely transport two UCBN staff and all equipment required for the setup of 3 monitoring stations. In addition, the vehicle should be available for monthly site visits.

Capital expenses:

- Continuous water quality monitor, e.g., MS-5 HydroLab purchased from HACH, Inc.
- Communication/power cable and proprietary water quality monitor software
- Continuous water quality monitor housing and security cable
- External power supply (optional, may use AA batteries)
- Handheld barometer
- PVC pipe (see SOP#1)

Expendable supplies:

- AA Batteries
- Laptop/PDA for data download
- Rugged PC capable of running MS Access
- SD Memory card or similar for data transfer and back-up
- Calibration/maintenance supplies (pH, DO, standards, copper scrub pads, etc.)
- Digital camera for documentation

Budget

Below is the annual operational budget for the integrated water quality monitoring protocol (Table 18). In FY 2016, total available water quality monitoring funds from NPS Water Resource Division are \$45,700 with the difference being made up from vital signs monitoring funds .

Table 18. The detailed 2016 annual budget for integrated water quality monitoring in the UCBN.

Expenditures	Time Allotted	% of time spent on DM ¹	Cost in dollars DM ¹	Cost in dollars (2016)
Permanent Personnel	-	-	-	-
Project leader (Aquatic Biologist)	5 months	-	-	\$27,700
Benefits 39%	-	50%	\$19,250	\$10,800
Data Manager	6 weeks	-	-	\$7,750
Benefits 39%	-	100%	\$10,773	\$3,023
Seasonal Personnel	-	-	-	-
Biotech	9 weeks	-	-	\$4,320
Benefits 8%	-	50%	\$2,332	\$345
Park Personnel	-	-	-	-
Resource management staff	1 week	-	-	In-Kind support
Travel (Field personnel)	-	-	-	\$3,000
Operations/Equipment	-	-	-	-
Calibration solutions (estimated yearly supply)	-	-	-	\$1,500
MS-5 Hydrolab service agreement—3 units @ \$709 ea.	-	-	-	\$2,127
Software Annual Updates (Aquarius)	-	-	-	\$2,248
TOTAL	-	-	\$32,355 ²	\$62,813

¹ DM = data management

² More than 30% of the water quality budget is dedicated to data management, analysis, and reporting activities

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Glossary of Terms

Definitions from HACH Environmental (2006) and EPA (2006)

Benthic macroinvertebrates: Aquatic larval stages of insects such as dragonflies, aquatic insects such as aquatic beetles, crustaceans such as crayfish, worms, and mollusks. These small creatures live throughout the stream bed attached to rocks, vegetation, and logs and sticks or burrowed into stream bottoms.

Biological assemblages: Key groups of animals and plants—such as benthic macroinvertebrates, fish, or algae—that are studied to learn more about the condition of water resources.

Biological integrity: State of being capable of supporting and maintaining a balanced community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

Conductivity: Conductivity is inversely related to the resistance of a solution. Conductivity is the ratio of the electric current density to the electric field in a material, also known as electrical conductivity. In limnology, conductivity is a measure of the ability of water to pass an electrical current. Compensation of this measurement to 25 °C constitutes specific conductance. This parameter indicates the amount of dissolved substances (salts). Salts and their concentration dictate osmoregulatory (salt-balancing) functions in plants and animals. The ionic strength of water also regulates the toxicity of many substances.

Dissolved oxygen (or DO): A measure of the amount of oxygen present in water and available for respiration. The concentration of DO is controlled by many factors including: consumption by aerobic (requiring DO.) organisms (bacteria, fish, amphibians, and invertebrates), consumption by plants (algae, vascular plants, particularly during dark hours), and water temperature, water flow, and depth. While water plant respiration during daylight hours typically leads to an increase of DO in the water column during the day, DO will decline at night in the diurnal cycle and after the growing season, upon plant death, the biodegradation of this plant biomass can significantly lower or deplete a stagnant water body of DO.

Ecoregions: Ecological regions that are similar in climate, vegetation, soil type, and geology; water resources within a particular ecoregion have similar natural characteristics and similar responses to stressors.

Index period: The index period is the period of time that macroinvertebrate samples should be collected to minimize seasonal variation.

Index site: A location determined to be relatively representative of the stream segment falling within park boundaries, and is logistically feasible to sample water chemistry parameters. Representativeness of the index site is evaluated with a cross-section survey.

Instream fish habitat: Areas fish need for concealment and feeding. These areas include large wood within the stream banks, boulders, undercut banks, and tree roots.

Intermittent (ephemeral) streams: Streams that flow only during part of the year, such as in the spring and early summer after snowmelt.

Macroinvertebrate Index of Biotic Condition: The sum of a number of individual measures of biological condition, such as the number of taxa in a sample, the number of taxa with different habits and feeding strategies, etc.

Metric: A metric is a characteristic of the biota that changes in some predictable way with increased human influence.

Multiprobe: The combination of several sensors, electrodes, or probe assemblies into a complete, stand-alone piece of equipment which simultaneously measures several parameters for profiling, spot-checking, or logging readings and data. A multiprobe is a multi-parameter instrument typically with built-in algorithms that may automatically compensate measurements (e.g., DO, pH, specific conductance, turbidity) for other parameters measured simultaneously such as temperature and conductivity (salinity). Multiprobes may also be called sondes or continuous water quality monitors.

National Hydrography Dataset: Comprehensive set of digital spatial data - based on U.S. Geological Survey 1:100,000 scale topographic maps - that contains information on surface water features such as streams, rivers, lakes, and ponds.

Nutrients: Substances such as nitrogen and phosphorus that are essential to life but can overstimulate the growth of algae and other plants in water. Excess nutrients in streams and lakes can come from agricultural and urban runoff, leaking septic systems, sewage discharges, and similar sources.

O/E (Observed/Expected) Ratio of Taxa Loss: A ratio comparing the number of taxa expected (E) to exist at a site to the number that are actually observed (O). The taxa expected at individual sites are based on models developed from data collected at reference sites.

Parameter: A quantity (water quality variable) which is constant under a given set of conditions, but may be different under other conditions.

pH: Describes the hydrogen-ion activity of a system: pH 0–7: acid solution, pH 7: neutral, pH 7–14: alkaline (or basic) solution. The "p" in pH stands for power (puissance) of the hydrogen ion (H⁺) activity. pH is a major factor affecting the availability of nutrients to plants and animals. It controls in part the concentration of many biochemically active substances dissolved in water, and it affects the efficiency of hemoglobin in the blood of vertebrates (e.g., fish) and invertebrates (e.g., shrimp), as well as the toxicity of pollutants.

Perennial streams: Streams that flow continuously throughout the year.

Physical habitat: For streams and rivers, the area in and around the stream or river, including its bed, banks, instream and overhanging vegetation, and riparian zone.

Power analysis: The power of a statistical test is the probability that the test will reject a false null hypothesis, or in other words that it will not make a Type II error. As power increases, the chances of a Type II error decrease, and vice versa. The probability of a Type II error is referred to as β . Therefore power is equal to $1 - \beta$. Power is a function of effect size or minimum detectable change, variance of the parameter (e.g., standard error of the mean), and sample size. A power analysis determines the probability of correctly rejecting a false null hypothesis given fixed values of effect size, variance, and sample size.

Probability-based design: A type of random sampling technique in which every element of the population has a known probability of being selected for sampling.

Probe: A small tube containing the sensing elements of electronic equipment. The probe is an essential part of the water quality monitoring system, since it obtains measurements and data which can be stored, analyzed, and eventually transferred to a computer. The probe may also be referred to as a sensor.

Reach: A discrete segment of a stream.

Reference condition: The least disturbed condition available in an ecological region; determined based on specific criteria and used as a benchmark for comparison with other sample sites in the region.⁹

Riparian: Pertaining to a stream or river and its adjacent area.

Riparian disturbance: A measure of the evidence of human activities in and alongside streams, such as dams, roadways, pastureland, and trash.

Riparian vegetative cover: Vegetation corridor alongside streams and rivers. Intact riparian vegetative cover reduces pollution runoff, prevents streambank erosion, and provides shade, lower temperatures, food, and habitat for fish and other aquatic organisms.

Sample Reach: Refers to the area from which one composite macroinvertebrate sample is collected. The UCBN macroinvertebrate sample reach is equivalent to the USFS PIBO stream channel monitoring reach, which is defined relative to stream width.

Sensor: The generic name for a device that senses either the absolute value or a change in a physical quantity such as temperature, pressure, flow rate, or pH, and converts that change into a useful input signal for an information-gathering system.

Stream order: Stream size, based on the confluence of one stream with another. Firstorder streams are the origin or headwaters. The confluence or joining of two 1st order streams forms a 2nd order stream, the confluence of two 2nd order streams forms a 3rd order stream, and so on.

Streambed sediments: Fine sediments and silt on the streambed. In excess quantities, they can fill in the habitat spaces between stream pebbles, cobbles, and boulders and suffocate macroinvertebrates and fish eggs.

Stressors: Factors that adversely affect—and therefore degrade—aquatic ecosystems. Stressors may be chemical (e.g., excess nutrients), physical (e.g., excess sediments on the streambed), or biological (e.g., competing invasive species).

Station: The monitoring location selected for deployment of the continuous water quality monitor. The monitoring station has been deemed relatively representative of stream conditions within the park based on evaluation of water chemistry up or downstream of the station.

Taxa: Plural of taxon; groupings of living organisms, such as phylum, class, order, family, genus, or species. Scientists organize organisms into taxa in order to better identify and understand them.

Temperature: A measure of heat present in water. Aside from dissolved oxygen, temperature is considered the single most important parameter. Knowledge of water temperature is essential to the measurement of dissolved oxygen, conductivity (salinity), pH, alkalinity, biological/biochemical oxygen (needed to meet the metabolic needs of aerobic - requiring DO - organisms) and virtually every other water quality parameter. Temperature controls metabolism (utilization of inorganic and organic matter for life processes) of aquatic animals and plants. Temperature is largely responsible for biochemical reactions and is one of the most important cues for beginning and ending of spawning, migration, and many other phenomena.

Transect: A path or line along which one counts and studies various aspects of a stream, river, or other study area.

Turbidity: The measure of the clarity of a liquid by using colorimetric scales. It is also the expression of the optical property that causes a light to be scattered and absorbed rather than transmitted in straight lines through a sample. Turbidity is the opposite of clarity (ITM) A measure of the opacity or translucence of water. The main objective is to determine the scattering of light by particles of a body of water and report that scattering in some unit of measurement, usually nephelometric turbidity units (or NTU) based on a primary turbidity standard called formazin. Turbidity is caused by plankton (both animal and plant), clay, suspended clay, silt, etc. Although these substances impart color, color resulting from turbidity is referred to as "apparent color" and should not be confused with true color (resulting from dissolved substances). Apparent color can also result from overshadowing by vegetation or substrate (bottom material) color. Note, that turbidity may be correlated to suspended sediment concentration but this correlation is often temporary and water body specific. This is due to the type of suspended sediment and grain size composition during a particular turbidity event.

Wadeable streams: Streams that are small and shallow enough to adequately sample by wading, without a boat.

Waterbody: Any lotic or lentic water occurring within the Upper Columbia Basin Network.

Appendix A. Index of Standard Operating Procedures

Note that SOPs are bound and published as a separate document

- SOP 1: Preparations and Equipment Set-up Prior to the Field Season
- SOP 2: Training Field Personnel
- SOP 3: Continuous Water Quality Site Selection and Cross Section Survey
- SOP 4: Initial Water Quality Site Visit
- SOP 5: Water Quality Site Revisit- Calibration and Maintenance
- SOP 6: Decontamination of Equipment for Aquatic Invasive Species
- SOP 7: Continuous Water Quality Record Processing
- SOP 8: Data Management
- SOP 9: Data Analysis and Reporting
- SOP 10: Quality Assurance/Quality Control
- SOP 11: Field Safety for Water Quality Sampling
- SOP 12: Final Site Visit and Post Field Season Activities
- SOP 13: Administrative Record/Protocol Revision

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/132998, July 2016

National Park Service
U.S. Department of the Interior



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